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Interlocking compressed earth bricks as low carbon footprint building material

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Abstract. The building construction significantly contributes to the carbon growth due to the high carbon emissions produced by buildings and their effects on climate change. Malaysia has devoted to reduce the carbon dioxide emission by the year of 2020. Therefore, the Interlocking Compressed Earth Bricks (ICEB) has been introduced as an alternative for low carbon building material. This paper studies the carbon footprint of Interlocking Compressed Earth Bricks as a walling structure in buildings or residential houses. The Interlocking Compressed Earth Bricks system is an improvement from the conventional brick production where the brick is fabricated by compressed method (not fired), thus reducing the carbon emissions. This paper presents a cradle-to-gate carbon emission study of a multi-story residential building in a Community house in Tawau, Sabah by using the life cycle assessment (LCA) methodology. The total carbon of the buildings using conventional FCB and ICEB construction are 405.75 kgCO₂/m² and 264.50 kgCO₂/m², respectively, which are comparable with the results of similar studies found in the literature. In order to achieve low-carbon buildings for the residential houses in Sabah, the use of ICEB as alternative materials with low carbon intensities and sustainable construction practices are suitable and recommended. The result shows that the implementation of Interlocking Compressed Earth Bricks contributes to carbon footprint reduction of 35% from the conventional and suitable to be used as a low carbon footprint building material.

1. Introduction

The construction sector can be categorised as one of the largest global consumers of materials, and the building sector is having the most significant single energy use worldwide [1]. According to IPCC (2014) [2], buildings are responsible for 19% of global greenhouse gas (GHG) emissions and suggest that buildings offer enormous abatement opportunities for reducing GHG emissions in the short-term. The greenhouse gases emission that caused global warming are having 72% of carbon dioxide (CO₂), 18% Methane and 9% Nitrous oxide. Therefore, carbon dioxide emission is focused in this paper since it has the most contributory to global warming. Wasim and Nine (2016) [1] on his research, mentioned that CO₂ emission is increasing by almost 3% each year for the past 50 years. In contributing to a sustainable environment, our country Malaysia has devoted to reduce the carbon dioxide emission by the year of 2020.

As mentioned by Asman et al. (2019) [3], the construction field nowadays is designed and constructed without the considerations on the environmental impacts. In order to solve these issues, environmentally friendly materials can be used as a replacement for conventional construction materials to achieve the implementation of sustainability in Malaysia. In this study, the interlocking



compressed earth brick (ICEB) was introduced replacing the conventional brick where the brick is not fired, thus contribute to carbon emissions reduction and in line with environmental issues regarding air pollution and global warming. According to Mirasa and Chong (2020) [4], interlocking brick is a recently developed product that can be acted as a load-bearing system and the utilization of interlocking brick system can significantly reduce the usage of cement and constructs the green building. The interlocking brick is different from conventional bricks because the brick does not require mortar during bricklaying work [5]. In addition for the environmental impact, the adoption of the ICEB in green building construction can lower energy consumption and reduce the overall environmental impact and has the potential in carbon footprint reduction [3].

This paper analysed the carbon emission of residential houses projects using ICEB as a walling material and compared with the conventional construction using the fire clay brick (FCB) with a reinforced concrete (RC) structure.

2. Methodology

Life cycle assessment (LCA) approach are used in this study. According to ISO 14040 [6], there are four stages of LCA methodological framework, which include goal and scope definition, inventory analysis, impact assessment and interpretation. LCA method used was process-based or process analysis where the input data in the form of materials (extracted from BQ) were utilised in terms of embodied carbon. The newly constructed community houses, a residential building project by Universiti Malaysia Sabah in Tawau Sabah, was selected as a case study and considered for cradle-to-gate life cycle assessment (LCA). Figure 1 shows the ground floor plan of the building using ICEB construction having a total floor area of 65 m². Then the conventional construction using Fire clay brick (FCB) are used as a control to compare the carbon footprint reduction. The carbon emission are classified into selected major construction materials where only the main materials used for building structure, envelope and finishes are considered. However, temporary works, building services, furnishing and transportation are excluded. LCA Framework for the residential buildings used in this study shown in Figure 2.

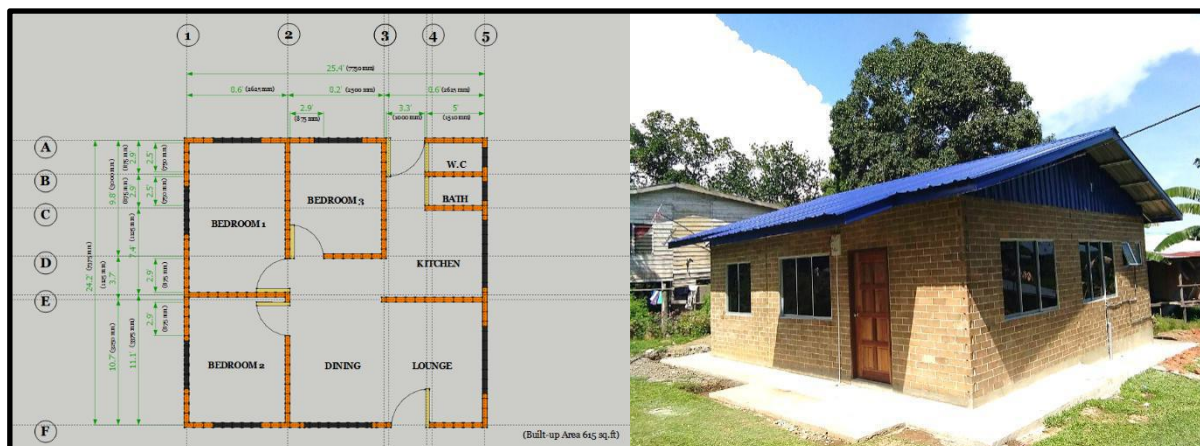


Figure 1. Ground floor plan and the photo of Tawau residential building using ICEB construction.

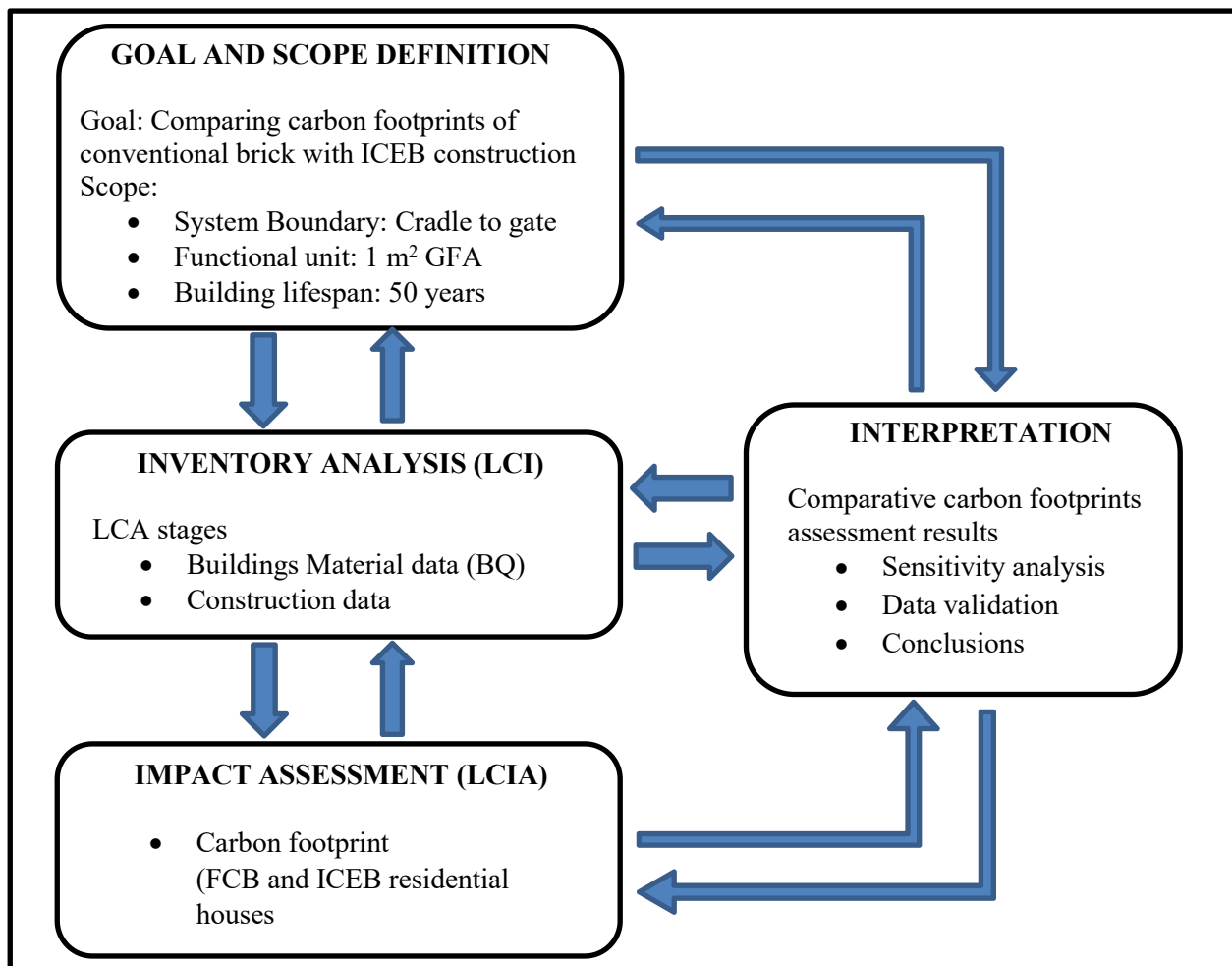


Figure 2. LCA Framework for the residential buildings.

3. Result and discussion

The summary of materials used and embodied carbon for conventional construction and ICEB construction are presented in Table 1 and Table 2, respectively. The total embodied carbon for conventional construction are 2,6373.86 kgCO₂; then carbon is reduced by 17192.31 kgCO₂ when ICEB construction were used. Among the materials used for conventional construction, concrete and steel combination (13,664.71 kgCO₂) are having the highest value of carbon emission. Differ from the FCB construction; bricks using ICEB contribute the highest total material mass (9495 kgCO₂).

Table 1. Summary of material used and embodied carbon for conventional construction.

Material	Amount from BQ	Unit	Mass conversion (kg/m ³)	Mass (kg)	EC coefficient ^a (kgCO ₂ /kg)	Embodied Carbon (kgCO ₂)
Concrete	28.49	m ³	2200	62667.00	0.20	12533.4
Steel	625.04	kg	8000	625.04	1.81	1131.32
Cement Mortar	5.65	m ³	2200	12430.00	0.21	2610.30
Cement plaster	400.00	m ²	2200	8800.00	0.21	1848.00
Brick (FCB)	12000.00	Nos.	2400	41254.20	0.20	8250.84
Total				125776.24	-	26373.86

^a Value of carbon coefficient taken from Klufallah, Nuruddin, Khamidi, & Jamaludin (2014)[7].

Table 2. Summary of material used and embodied carbon for ICEB construction

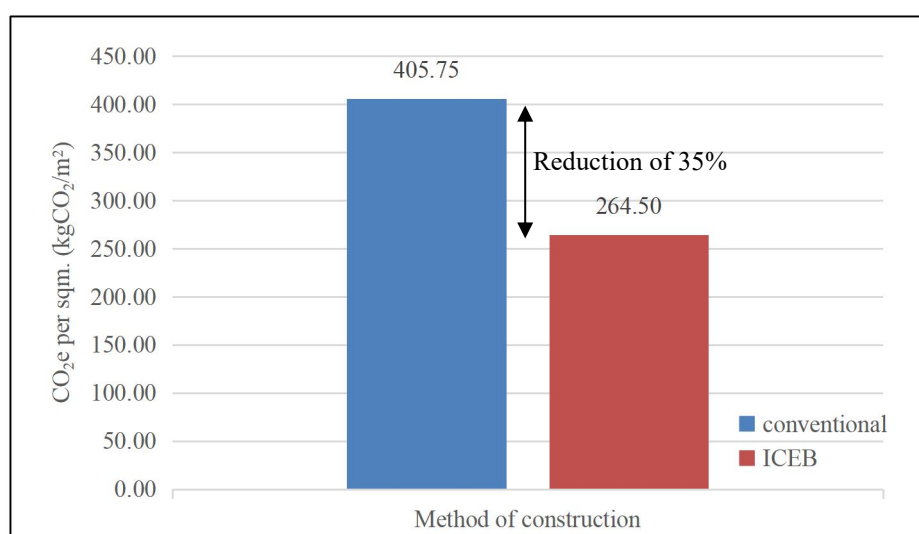
Material	Amount from BQ	Unit	Mass conversion (kg/m ³)	Mass (kg)	EC coefficient ^a (kgCO ₂ /kg)	Embodied Carbon (kgCO ₂)
Concrete	12.00	m ³	2200	26400.00	0.20	5280.00
Steel	437.69	kg	8000	437.69	1.81	792.22
Cement	3.52	m ³	2200	7738.50	0.21	1625.09
Mortar	0.00	m ²	2200	0.00	0.21	0.00
Cement plaster	8000.00	Nos	1899	47475.00	0.20	9495.00
Brick (ICEB)		.				
Total				82051.19		17192.31

^a Value of carbon coefficient taken from Klufallah, Nuruddin, Khamidi, & Jamaludin (2014) [7].

Table 3 presents the total carbon emission equivalent of each project per meter square. The GFA of both houses are 65 m². Figure 3 shows the carbon emission equivalent per square meter for conventional and ICEB construction projects. Figure 3 shows the carbon emission equivalent per square meter of the residential houses using conventional and ICEB as a method of construction. The value obtained for conventional FCB is 405.75 kgCO₂/m², whereas the ICEB construction gives value of 264.50 kgCO₂/m². It is found that the ICEB construction has a lower carbon footprint than the conventional RC construction using FCB with 35% of carbon reduction. Technically, ICEB buildings emit less carbon footprint due to the efficiency in using building materials in construction activities where in this case, the ICEB system eliminates the formwork, beam and column during construction and reduce the usage of cement and mortar.

Table 3. The carbon emission equivalent (kgCO₂e) per square meter of the residential houses.

Method of construction	CO ₂ emission (CO ₂ e) (kg)	Gross floor area (GFA) (m ²)	CO ₂ e per sqm. (kgCO ₂ /m ²)
Conventional FCB	26373.86	65	405.75
ICEB	17192.31	65	264.50

**Figure 3.** Carbon emission per square meter of residential house projects.

As given in Table 4, the carbon emission of reinforced concrete structure with the conventional method and ICEB method of construction were found to be in the ranges of 326.00 – 733.70 kgCO₂/m² and 244.54 – 698.01 kgCO₂/m² respectively, which is quite comparable with the results of the current study. It illustrates the effect of materials along with the method of construction such as IBS and sustainable materials are having the lower carbon emission that contributing to carbon footprint reduction.

Table 4. Comparison results of carbon emission studies.

No.	Building type	Location	Type of structure	Embodied carbon (kgCO ₂ /m ²)	Reference
1	Residential	Malaysia	IBS	244.54	[8]
			Cast-in-situ concrete	276.93	
2	Housing project	Malaysia	Conventional House	733.70	[7]
			Sustainable house	698.01	
3	Office building	Malaysia	Conventional office	363.36	[7]
			Sustainable office	304.60	
4	Residential	South Korea	Reinforced concrete	459.93	[9]
5	Commercial	China	Reinforced concrete frame and bricks	715.40	[10]
6	Residential	China	Concrete and bricks	326.00	[11]
7	Residential	Malaysia	Conventional (FCB)	405.75	Current study
			ICEB system	264.50	

4. Conclusion

The cradle-to-gate life cycle carbon emission of the residential house using interlocking compressed earth brick system in Tawau, Sabah was assessed in this study. Carbon emission of reinforced concrete (RC) structure with conventional construction is 405.75 kgCO₂/m² and 264.50 kgCO₂/m² for ICEB construction. The value obtained for the carbon emission of ICEB as a walling material in building construction is less compared to the conventional FCB of RC structure by 35% reduction in comparison. Choosing environmentally-friendly materials and sustainable practices would help in minimizing the carbon emission where in this case, ICEB can be considered as green and sustainable materials as the brick are not fired, and the process of construction also contributing to green building construction. The result shows that the implementation of interlocking compressed earth bricks contributes to carbon footprint reduction and suitable to be used as a low carbon footprint building material.

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