

Floating houses “*lanting*” in Sintang: Assessment on sustainable building materials

D Susanto, M S Lubis

Department of Architecture, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia

E-mail: dalhar3001@yahoo.com, miralubis@gmail.com

Abstract. One important element in the concept of sustainable building is the use of materials. The higher the use of sustainable material in building, the more sustained the building. *Lanting* is one type of floating construction, usually made from wood, that can be found in settlement along the river, such as in the city of Sintang, West Kalimantan. *Lanting* is still survive today because it is still used by community whose lives are tied to the river, and also because of its flexible nature that is able to function as a 'water building' as well as 'land building', and it is also movable, in addition for land limitation in some places. However, the existence of *lanting* settlements in the city of Sintang faces insistence because it is considered slum, polluting the environment, the scarcity of wooden materials, disturbing the beauty of the city, and threatened by the concretized river banks by local government. This paper discussed the sustainability of waterfront buildings in the city of Sintang in terms of material uses, through the assessment of 'green-features' of the main materials used. Assessment results show that wood is the most green building material and *lanting* is considered at the highest sustainability level for its use of wooden materials.

Keywords: *lanting*, floating house, sustainable material.

1. Introduction

Lanting is a local term for floating houses located in major rivers in Kalimantan, such as Kapuas, Barito and Mahakam rivers. It is a building that stands on a raft construction consisting of floating logs moving up and down following changes of water surface, and can be moved to a different locations. Most constructions are made of local wood that is resistant to weather conditions, such as bentawang, kayu belian or ulin. In Sintang, *lanting* is still survive because of the existence of community whose life is still bound to the river, utilizing the river for various purposes of daily living. For *lanting* residents, river is a living space, source of water, fish, forest products, as well as inter-city and inter-village transportation trade routes [1]. River is the lifeblood of the community in the upstream to downstream. *Lanting* is divided into several types, such as *lanting* for toilets, *lanting* as dwelling houses, as docks for sampans and boats, and *lanting* shops for commercial activities [1]. However, the existence of *lanting* has increasingly threatened by riverbank normalization activities and wave disruptions caused by large boat passers. In some floating settlements are regarded as slums so the local government tries to remove the *lanting* because it is considered polluting the environment and disturb the visual qualities of the city. Therefore, we argued that *lanting* and other waterfront buildings in Sintang need to be assessed in a sustainability perspective especially in terms of materials use.

Buildings tend to carry enormous threats to environmental sustainability. According to Graham (2002) the building and construction sector takes the largest share of natural resources, both for land use and for materials extraction; and buildings use 50 percent of the world's raw materials – many of which are non renewable resources – and they responsible for 36 percent of all waste generated worldwide [2].



Buildings also contribute to one-third of greenhouse gas emissions (GHG) worldwide, which increase sharply as construction increases. Estimated at 8.6 billion tons in 2004, building related GHG emission could almost double by 2030 to reach 15.6 billion tons under high-growth construction, according to the Intergovernmental Panel on Climate Change (IPCC) 2007 [2]. One of the factors in the building that threatens environmental sustainability is the use of materials that are destructive to nature in the whole cycle of its use.

According to Umar, Khamidi, and Tukur (2012), sustainable building materials by definition are materials which are domestically created and sourced which reduce transportation costs and CO₂ emissions [3]. They could consist of reused materials, possess a lower environmental effect, thermally effective, need less energy than conventional materials, make use of renewable resources, lower in harmful emissions and economically sustainable. A sustainable building material needs to be used properly and contextually in every community development. The application of sustainable building materials not just minimizes transport costs, carbon emissions, and in most cases materials costs, it also offers employment and skills development opportunities for community members. Jin Kim Jong (1998) added that sustainable material should be exist at each step of the material manufacturing process, from gathering raw materials, manufacturing, distribution, and installation, to ultimate reuse or disposal. Jong (1998) also stated that there are fifteen criteria that must be met by sustainable material applicable in all phases of building life cycle [4].

2. Methods

The evaluation of sustainability of building materials was done using the 'green-features' chart developed by Jin Kim Jong (1998), consisting of 15 features divided into the three stages of building life cycle: Pre-Building Phase, Building Phase and Post-Building Phase. This chart helps comparing the sustainable qualities of different materials used for the same purpose. The presence of one or more of these "green features" in a building material can be assured in determining its relative sustainability. [4]. An assessment was made of the main material used by various types of waterfront buildings in Sintang city. The research data was collected through direct field observation and interviews around January to May 2017.

Table 1. Key to the green features of sustainable building materials. [1:25]

Manufacturing Process (MP)	Building Operations (BO)	Waste Management(WM)
Waste Reduction (WR)	Construction Waste Reduction (CWR)	Biodegradable(B)
Pollution Prevention (P2)	Energy Efficiency (EE)	Recyclable(R)
Recycled (RC)	Water Treatment & Conservation (WTC)	Reusable (RU)
Embodied Energy Reduction (EER)	Nontoxic (NT)	Others (O)
Natural Materials (NM)	Renewable Energy Source (RES)	
	Longer Life (LL)	

There are five green-features in Pre-Building Phase (production stage or material manufacturing process): (1) Waste Reduction: material with minimum waste production process; (2) Pollution Prevention: materials with minimum pollution production; (3) Recycled Content: recycled element content in a material; (4) Reduction of Embodiment Energy: low energy content in a material; and (5) The use of Natural Materials: the content of natural ingredients in a material.


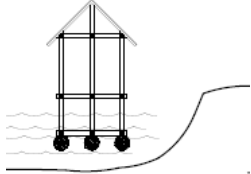

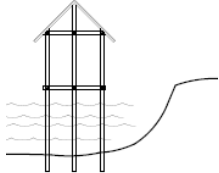

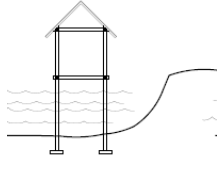

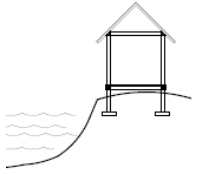
There are six green-features in Building Phase (the stage of material use and building operations): (1) Reduction in Construction Waste: materials with efficient assembly processes thereby reducing

construction waste; (2) Energy Efficiency: materials that contribute to energy savings; (3) Water Treatment/Conservation: assembling material that does not disturb the quality and quantity of water around the building site; (4) Use of Non-Toxic or Less-Toxic Materials; (5) Renewable Energy Systems: materials that support natural energy-based building systems; (6) Longer Life: material with long or durable life time.

There are four green features in the Post-Building Phase (the stage when the material passes through its lifetime and must be discarded): (1) Reusability: the ability of the material to be reused to other buildings. (2) Recyclability: the ability of the material to be recycled into new material; (3) Biodegradability: the ability of the material to decompose naturally and not to be poisonous when disposed of; (4) Other capabilities in any form which can support the sustainability performance of a material.

3. Results

Table 2. Four types of riverfront buildings in Sintang and main material used

Riverfront building types	Construction	Sub structure	Wall	Roof
 Wooden floating house		Wood	Wood	Zinc Metal sheet
 Wooden stilt house		Wood	GRC board	Zinc Metal sheet
 Concrete stilt house		Reinforced Concrete	Brick w/ mortar	Clay tile
 Brick house		Stone w/ mortar	Brick w/ mortar	Clay tile

In general, there are four types of waterfront buildings in Sintang river settlement: (a) *lanting*: floating building with wooden construction, (b) Wooden stilt house (c) Concrete house, and (d) Brick house (see figure-1). There are seven main materials used by the buildings: (1) wood, (2) concrete, (3) brick &

mortar, (4) stone & mortar, (5) cement board, (6) Zinc metal sheet , And (7) clay tile. The results of assessing the sustainability of the seven materials using the green-features chart are explained below:

a. Wood.

Wood is used as the main construction material of *lanting* for reasons of its buoyancy and durability. Wood is usually taken from meranti, bangkirai, ulin and belian, used in almost all of building components, such as foundations, structural frameworks, floorboards and walls as well as roofs. Overall, this material has a very high sustainability level because it has fourteen 'green features'.

Table 3 Green features of wood

Manufacturing Process	Building Operations	Waste Management
WR	CWR	B
P2	EE	R
-	WTC	RU
EER	NT	O
NM	RES	
	LL	
Total: 14 features		

In 'Pre-Building Phase' wood has four out of five existing green features. (WR +): During the process of harvesting raw materials and manufacture, wood produce relatively little waste because the process is short and simple, and almost all the waste generated can be utilized for various purposes. (PP +): Cutting and processing of wood are done manually or mechanically by industrial/timber companies, without much pollution. (RC-) Wood is a material that is 'renawable' that does not have recycled content. (EER +): Energy for wood processing is relatively small as only required for cutting. The distribution of timber is usually done by drifting logs along the river. (NM +): The material content in wood is one hundred percent natural.

In 'Building Phase', wood has all six 'green features' that exist. (CWR +): Wood wastes assembled during construction can be recovered for various purposes. (EE +): Timber assembly does not require much energy, since only a small proportion of devices require electrical energy. (WTC +): Wood processing and assembly during construction does not use too much water so as not to affect the water quality around the site. (NT +): Wood is a natural material that does not contain toxins. (RES +): Wood is a material that meets the passive cooling principle, since it has low heat conductivity. (LL +): Specific types of wood species such as “ulin” and “bangkirai” have very long life time.

In Post Building Stage, wood has all the three 'green-features'. (RU +): Wood can be reused for various needs as new building components, furniture, or other products. (R +): Although wood can not be recycled but wood powder and flakes can be processed into other processed materials. (B +): As the natural material, wood can decompose naturally when disposed in the soil. (O +): Wood is categorized as a local material from Borneo forests which is close from the *lanting* site, and is also renewable.

b. Reinforced Concrete

Concrete is a composite material, consisting of cement-base material, sand and split stones, which hardened when mixed into water without having to go through the combustion process first. In waterfront buildings, concrete or reinforced concrete is used as the foundation and other structural elements especially for stilt houses. Overall, reinforced concrete materials have very low sustainability levels because they only have five of the total fifteen green features available.

Table 4. Green features of concrete

Manufacturing Process	Building Operations	Waste Management
-	-	-
-	EE	-
RC	-	-
-	NT	-
-	RES	
	LL	
Total: 5 features		

In 'Pre-Building Phase', reinforced concrete has only one of five green features available. (WR-): The process of making cement is very long and complex, coupled with the concrete mixing process in 'batching-plant', make all produce considerable waste. (PP-): The process of making cement, concrete mixing and reinforcing steel produces extremely high air, water and soil pollutants. (RC +): Although the concrete is difficult to reuse, the production of steel used as reinforcement often reinstates used iron/steel as 'recycled content'. (EER-): Cement and steel have very high embodied energy. (NM-): Reinforced concrete is classified as a non-natural material because it contains lots of cement and steel. In 'Building Phase' reinforced concrete has four of the six existing green-features. (CWR-): The process of mixing and casting during the construction period generates considerable waste. (EE +): Concrete assembly during construction does not require much energy because usually it is done manually. (WTC-): Concrete assembly during construction involves a lot of water as a medium for mixing cement and sand, affecting the water quality around the site. (NT +): Concrete is classified as non-toxic building material (RES +): Concrete contains substances with low heat conductivity, which is enough to help the performance of passive-cooling mechanisms. (LL +): Concrete is a material with a very high durability, very durable, and has a very long 'life time'.

In 'Post-Building Phase', concrete does not have any existing 'green-features'. (RU-): Used concrete cannot be reused in other buildings. (R-): Concrete cannot be recycled. (B-): Concrete does not readily decompose naturally when disposed of in the soil. (O-): Concrete is categorized as non-local and non-renewable material.

c. Brick w/ Mortar

The plaster brick is bonded to each other by mortar and coated on both surfaces by plastering, usually used as wall construction in landed-type buildings. The basic material of brick is clay, while mortar or plastering consists of mixture of sand, cement and water media. However, plaster bricks have a sustainability level that is quite high because it has 9 out of total fifteen 'green features' that exist.

Table 5. Green features of brick with mortar

Manufacturing Process	Building Operations	Waste Management
-	-	B
-	EE	R
-	-	RU
-	NT	O
NM	RES	
	LL	
Total: 9 features		

In the 'Pre-Building Phase' plaster brick has only one of five features available. (WR-): The production process of brick and cement, as the main material of plaster masonry forming, is a complex and long process (for the extraction of raw materials, combustion and transport etc.) generates waste.

(PP-): The process of making masonry plaster also produces pollutant. (RC +): Bricks and cement (as the main material of plaster masonry) do not have recycled content. (EER-): Due to the complex and lengthy production and distribution processes, plaster bricks have a high enough embodied energy. (NM +): Plaster bricks are classified as natural materials because most of the material compositions consist of clay that is processed in a simple way.

In 'Building Phase' plaster bricks have four of the six existing features. (CWR-): The process of assembling masonry (including the making of mortar and plastering applications) which is done in-situ generates considerable waste. (EE+): Nevertheless, the assembly of plaster masonry during the construction process does not require much energy because it is mostly done manually. (WTC-): The making of plaster bricks during construction usually involves a lot of water as a cement and sand mixer, which can affect the water quality around the site. (NT+): Plaster brick are classified as non-toxic building materials. (RES +): Bricks and cement are substances with low heat conductivity and porous brick structures make plaster masonry a material that satisfies the passive-cooling mechanism. (LL +): Plaster bricks are materials with very long 'life time' because of their high durability.

In the Post Building stage, plaster bricks show three of the four existing 'green-features'. (RU +): Bricks can be reused in new construction. (R-): Used brick materials cannot be recycled into new materials. (B +): Brick can decompose naturally in the ground even though it takes a long time. (O +): Plaster bricks are categorized as local materials as they are made up of materials and produced locally but are non-renewable materials.

d. Crushed Stone with Mortar

Crushed stone is used as the foundation of building type tread. The cement mix consists of a mixture of sand, cement and water. The stone masonry has a sustainability level which is quite high because it has eleven of the total fifteen features available.

Table 6. Green features of stone with mortar

Manufacturing Process	Building Operations	Waste Management
WR	-	-
P2	EE	R
RC	-	RU
EER	NT	O
NM	-	
	LL	
Total: 11 features		

In the 'Pre-Building Phase', the crushed stone has all five green-features available. (WR +): Processing stone into building materials is a simple and short in process so as not to generate large waste. (PP +): The stone processing process is also relatively not generating pollutants into the air, water and soil. (RC +): Crushed stone can utilize used stone materials, because the stone has a very high durability. (EER +): Crushed stones contain low embodied energy because they do not require too much processing and transport energy. (NM +): Crushed stones can be classified as natural materials because the main material is natural stone.

In the 'Building Phase' the crushed stone has three of the six existing green-features. (CWR-): The process of making crushed stone involving cement mortar is usually done in-situ and generates waste. (EE +): The making of crushed stone during the construction process does not require much energy because more is done manually. (WTC-): crushed stone-making always use a lot of water as a medium of mortar, that can affect the water quality around the site. (NT +): Crushed stone are classified as non-toxic building materials. (RES-): Stone masonry is usually used for the foundation which is not relevant

to the passive-cooling mechanism of a building. (LL +): Crushed stone consist of materials that have a very long 'life time' and even tend to 'long lasting'.

In 'Post-Building Phase' the crushed stone shows three of the four existing 'green-features'. (RU +): Used old stone can be reused in new construction. (R +): Used stone can also be recycled, for example by crushing it into split or into stone powder. (B-): Although as a natural stone material is not easy to decompose naturally when dumped into the soil. (O +): crushed stone can be categorized locally as the basic ingredients are from nearby locations even though they are not 'renewable'.

e. GRC-Board

GRC-board is widely used in waterfront buildings as wall coverings, especially on wooden stage building types, because of its practical uses. GRC-board (Glassfiber Reinforced Cement) is a precast / concrete board mixed with glass fiber / fiberglass as a bone and molded by cold, pressure-shaped pressing system 5mm-8mm thick and 120x240 cm2 size. All GRC-boards are materials with very low sustainability levels because they only have 4 features out of a total of 15 green / green features.

Table 7. Green features of GRC-board

Manufacturing Process	Building Operations	Waste Management
-	CWR	-
-	EE	-
-	WTC	-
-	NT	-
-	-	-
Total: 4 features		

In 'Pre-Building Phase' GRC-board does not have any green-features. (WR-): The production of cement, as the main ingredient of GRC-board, is a complex and long process, resulting in considerable waste of production. (PP-): During the GRC-board manufacturing process, especially when the cement is produced, there is also a considerable amount of pollutant to air, water and soil. (RC-): GRC-board does not contain recycling elements. (EER-): GRC-board contains high embodied energy, due to a long manufacturing process including transport. (NM-): GRC board is classified as an inorganic material because most of its content is cement produced through a process that is not simple.

In 'Building Phase' GRC-board has four of the six existing green-features. (CWR +): GRC-boards are made in standard-modular sizes so that their applications on construction do not produce too much waste. (EE +): GRC-board assembly during the construction process does not require too much energy because it is mostly done manually. (WTC +): GRC-board assembly does not involve water, therefore it does not affect the water quality around the construction site. (NT +): GRC-board is not classified as a toxic building material. (RES-): With high cement material and material structure, GRC-board is not a material that satisfies passive-cooling rules. (LL-) GRC-board is classified as a material with short 'life time' because it has low durability, especially GRC-board with thin thickness (less than 6 mm).

At the Post Building stage, GRC-board does not show any 'green-features'. (RU-): Used GRC-boards are less reusable since they are easily damaged and destroyed. (R-): The used GRC-board cannot be recycled back into new material. (B-): Because it contains cement material and GRC-board plastic fiber does not readily decompose naturally in the soil. (O-): GRC-board is categorized as non-local material and contains non-renewable base material.

f. Corrugated zinc metal sheet

Corrugated zinc metal sheet are commonly used as roof coverings of almost any type of waterfront building because of its light weight and low cost. Corrugated zinc metal sheets are made of thin steel sheet material coated with zinc through electrolysis process. Overall metal sheets are materials with very low sustainability levels because they only have five of the total fifteen features available.

Table 8. Green features of corrugated zinc metal sheet

Waste Management	Waste Management	Waste Management
-	CWR	-
-	EE	-
RC	WTC	-
-	NT	-
-	-	-
Total: 5 features		

In 'Pre-Building Phase', corrugated zinc metal sheet only has one of five green-features available. (WR-): With a steel base material the manufacture of corrugated zinc metal sheet consumes a complex and long process that generates considerable waste. (PP-): During the manufacturing process they also produce high enough pollutants into the air, water and soil. (RC +): Some types of steel materials have recycled content. (EER-): Considering a complex and very long production process, corrugated zinc metal sheet contain large energy embodied, including energy for transport. (NM-): They are classified as inorganic materials because the processing is long and complicated.

In 'Building Phase' corrugated zinc metal sheet shows four of the six existing green-features. (CWR +): It is marketed in standard-modular sizes so that the assembly in the field does not produce too much waste. (EE +): During the construction process, its assembly does not require too much energy because it is mostly done manually. (WTC +): The assembly is carried out with a dry system involving no water at all so it does not impact the water quality around the site. (NT +): Corrugated zinc metal sheet are classified as non-toxic building materials. (RES-): With steel base material which has high heat conductivity then Corrugated zinc metal sheet is not suitable material for passive-cooling strategy. (LL-): Corrugated zinc metal sheet is a material with a relatively short 'life time' (according to the manufacturer can reach up to about 30 years) due to its low durability and easy to rust.

In 'Post-Building Phase', corrugated zinc metal sheet does not show any 'green-features'. (RU-): The used sheet is less useful for new uses, because it is easily rusted, damaged and destroyed. (R-): Used material is also relatively difficult to recycle because the steel material it contains has been mixed with the zinc layer. (B-): Because of this steel content, corrugated zinc metal sheet do not readily decompose naturally in the soil. (O-): It can be categorized as non-local materials and contain non-renewable base materials.

g. Clay roof tile

In waterfront buildings, clay roof tiles are used as roof coverings, especially in stilt houses, because of its light weight. The roof is made of clay material produced through the process of printing and burning. Overall the roof is a building material with a good sustainability level because it has ten of the total fifteen features available.

Table 9. Green features of clay roof tile

Manufacturing Process	Building Operations	Waste Management
-	CWR	B
-	EE	-
-	WTC	RU
-	NT	O
NM	RES	
	LL	
Total: 10 features		

In 'Pre-Building Phase' clay tile has only one green-features. (WR-): The process of making clay tiles produces liquid and solid wastes in considerable quantities especially in the form of residual clay processing and residual burning. (PP-): During the clay processing, baking of tiles also produce considerable pollutants. (RC-): To meet the good combustion quality, the tile content usually consists of a homogeneous clay mixture that rarely involves scrap or recycled materials. (EER-): Embodied energy of large enough tile is especially required for the combustion process, the extension of clay material and the transport. (NM +): Because it is made from clay so tile is classified as material that is organic or natural.

In 'Building Phase' clay tile has a total of six green-features. (CWR +): Clay tile is made in standard-modular sizes so that the assembly and installation do not produce too much waste (EE +): Clay tile is an energy-efficient material because the assembly is done manually. (WTC +): The assembly of clay tile at the construction site is done by dry system so as not to affect the quality of the surrounding water. (NT +): Clay tile is classified as non-toxic building material. (RES +): With its clay-based material, tile is suitable for passive-cooling strategy in buildings, ie through low heat conductivity and connection system leaving a gap for airflow. (LL +): Its 'life time' is quite good because it is supported with adequate 'durability'.

In 'Post-Building Phase' clay tile shows three of the four existing 'green-features'. (RU +): Due to the high durability of used tile can still be re-utilized for new buildings. (R-): Nevertheless, used clay tile can not be recycled. (B +): Because organic matter contains, clay tile is relatively easy to decompose in nature in the soil although it takes a while. (O +): The tile is categorized as local but non-renewable material.

Table 10. Comparison of assessment results on green-features

Material	Green Features			Total
	Manufacturing Process	Building Operations	Waste Management	
Wood	4	6	4	14 features
Concrete	1	4	0	5 features
Brick w/ mortar	1	4	4	9 features
Stone w/ mortar	5	3	3	11 features
GRC Board	0	4	0	4 features
Zinc metal sheet	1	4	0	5 features
Clay roof tile	1	6	3	10 features

Table 10 shows that amongst the seven main materials of the waterfront building, there are four high sustainability materials with 14 green-features, followed by stone masonry with 11 features, clay roof with 10 features and plaster masonry with 9 features. These four materials are natural materials because

their main contents are natural materials with a simple manufacturing process, ie wood, stone and clay. Meanwhile, there are three materials with low sustainability performance: concrete and corrugated zinc metal sheer with 5 features, as well as GRC board with 4 features . These three materials are non-natural materials with the main content of artificial materials such as cement and metal. The greater the natural content of a material, the more green features it has.

4. Discussion

There are various forms of floating houses that have different systems of construction technology and material usage.

In Siem Reap Province, Cambodia, floating villages are scattered in Tonle Sap Lake and River, survived for centuries. They are inhabited by local fishermen [5]. Their houses look similar with *lanting* in Kalimantan: wooden based, and built using traditional knowledge skills. In Aberdeen, southern Hong Kong, there is also floating village that has been existed since a thousand years ago, which inhabited by Tanka ethnic community. Today, the village activities merge with port activities, and still inhabited by thousands community [6]. Their houses look more like boathouses, different from *lanting* in Kalimantan and those in Cambodia. In Peru, South America, there is one of the world's oldest floating settlement in Lake Titicaca, inhabited by Uros ethnic community for centuries long. They live in houses over a large raft made of reeds leaves. Since many centuries ago, the Uros people make their own raft that almost like the island, to prevent attacks from the Incas and the Collas, their aggressive neighbors. To maintain the continuity of this raft island, once every three months they replace the reeds with the new ones because the reeds at the bottom are rapidly decay. This artificial island can last up to thirty years [7]. In some places in Vietnam, there are several floating villages inhabited by fishermen. The houses are wooden based and use jerry cans for their floating construction [8]. From the technological perspective of material use, the above precedents shows that most of floating building types are made using natural components, constructed with traditional methods, which resembles *lanting* construction in Kalimantan.



Figure 1. Floating village on Lake Tonle Sap, Siem Reap, Cambodia



Figure 2. Aberdeen fishing village Hongkong



Figure 3. Floating house of Uros People Peru - South America



Figure 4. Floating house in Vietnam



Figure 5. Floating house 'IJburg on IJmeer' Amsterdam



Figure 6. Floating House 'Canoe Pass Village' Canada

In Amsterdam there are floating settlements since the seventeenth century which then grew rapidly in the late nineteenth century when wooden cargo ships were replaced by iron / steel vessels, thus the old wooden ships were being converted to shelter. Their number were increased during the 1930 economic crisis and when there was a scarcity of houses due to the second world war. Floating houses in the Netherlands are estimated to reach 10,000 units by the end of the 20th century, declining thereafter, and have been re-embraced in recent decades with the support of modern technology, in particular to address the flood and sea level rise, and the scarcity of land for housing. One example of a floating settlement in Amsterdam is 'IJburg on IJmeer'. The building is a floating house built with modern technological methods with under construction in the form of a floating concrete tub and the top construction consists of mild steel. While in Canada, floating settlement is a result of modern technological experiments by residential developers. In the early 1980s floating home technology experienced a very important development when International Marine Floatation Systems Inc., developed a new technology build on water by using Expanded Polystyrene (EPS), which is a composite material that can float on water, which can shorten the development process and can be applied to relatively shallow waters [9]. One example of floating settlements in Canada is the 'Canoe Pass Village'. From the technological perspective of material use, the two precedents are floating buildings of which most of the components are non-natural, built with modern technological methods, which therefore, very different from the construction of *lanting* in Kalimantan.

5. Conclusion

The sustainability value of a material is determined by the number of green features it holds which applicable to all stages of 'life cycle building', i.e. 'pre-building', 'building' and 'post-building phase'. Materials with natural ingredients have more green features, and exhibit higher sustainability values, such as wood materials, stone masonry couples and masonry pairs. Conversely, materials with a non-natural material content will have fewer green-features, and exhibit lower sustainability values, like in concrete materials, corrugated zinc metal sheets and GRC boards.

The use of materials that have more green-features or has a high sustainability value of a material in a building will automatically increase the sustainability of the building. In terms of material use, the *lanting* building has the highest sustainability value compared to the other three types of waterfront buildings in the city of Sintang (wooden stage houses, concrete stilt houses and masonry landed-house) since most of the construction is made of natural materials i.e. wood.

References

- [1] Rizal Mustansyir, "Kearifan dan Kendala Lokal Warga Lanting sebagai Penghuni Pinggiran Sungai Sambas di Kalimantan Barat," in *The 5th International Conference on Indonesian Studies (ICSSIS) Vol. 2*, 2013.

- [2] Osman Attman, *Green Architecture: Advances Technologies and Materials*. Mc Graw-Hill, 2010.
- [3] Aminu Usman Umar, M F Khamidi, and Hassan Tukur, "Sustainable Building Material for Green Building Construction, Conservation and Refurbishing," in *Management in Construction Research Association (MiCRA) Postgraduate Conference*, 2012.
- [4] Jin Kim Jong and Brenda Rigdon, *Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials*, Jonathan Graves, Ed. Michigan: National Pollution Prevention Center for Higher Education, 1998.
- [5] Marko Keskinen, "The Lake with Floating Villages: Socioeconomic Analysis of the Tonle Sap Lake," *Water Resources Development*, vol. XXII, no. 3, pp. 463-480, September 2006.
- [6] Maarten Koekoek, "Connecting Modular Floating Structures," TU Delft, 2010.
- [7] S Prompayuk and P Chairattananon, "Preservation of Cultural Heritage Community: Cases of Thailand and Developed Countries," in *Procedia - Social and Behavioral Sciences* 234, 2016, pp. 239-243.
- [8] S Silapacharanan, "The Identity of Water-based Communities in Thailand," in *Procedia-Social and Behavioral Sciences* 85, 2013, pp. 27-32.
- [9] C Denpaiboon, M Tohiguchi, H Matsuda, and S Hashimoto, "Typology and Lifestyle Analysis of The Raft House (Ruan Pae) in Riverine Settlements in Thailand," *Journal of Architectural Research and Studies*, vol. 1, 2002.
- [10] Kloos Maarten and Y de Korte, *Mooring Site Amsterdam: Living on Water*, Kloos Maarten and Y de Korte, Eds. Amsterdam: ARCAM/Architecture & Natura Press, 2007.