

## Conference Paper

# Implementation of Re-used Shipping Containers for Green Architecture (Case Study: ITSB Creative Hub-Cikarang)

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### Abstract

The largest of CO<sub>2</sub> emissions on earth derives from construction activities. It is necessary to solve the problem to reduce the impact of CO<sub>2</sub> emissions. One of the solution to reduce the impact of CO<sub>2</sub> emission because of construction activity is using re-used material for building construction, such as re-used shipping container because the re-used material has low embodied energy. This paper has three purposes, and there are: explaining the application of re-used containers as building materials in the context of green architecture, explaining the application of building design using re-used containers as material, and explaining the advantages and disadvantages of used containers as building materials. Creative Hub ITSB as a case study owned by the campus of ITSB. The building construction consists of 20 units of a re-used container (20 feet size). The prefabrication construction uses for each steel material. Each component of the building assembled in the workshop, then it delivered to site by truck. The main issues that need to be solved are a matter of the delivery system, the structure, and joints, and the component assembly. Cross-ventilation system and insulating material also crucial because it can reduce building temperature.

**Keywords:** Green Architecture, Re-used material, Shipping Containers.

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## 1. Introduction

Global warming caused by CO<sub>2</sub> emissions has created a fatal environmental damage today. CO<sub>2</sub> emissions caused by construction activities have high percentages (about 45% in the atmosphere) [1]. And, CO<sub>2</sub> emissions contained in building materials (embodied CO<sub>2</sub>) that are made and burned with fossil fuels which is the most significant cause of greenhouse effect (about 50%) [1]. Therefore, we need to reduce impact CO<sub>2</sub> emissions in building construction; one of the ways is using re-used and environmentally friendly material. It is because the re-used material has low embodied energy.

One example of the use of environmentally friendly materials is using re-used shipping containers. Shipping containers, or more commonly known as re-used containers,

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can be an innovation [1], especially in the application of appropriate technology in architecture. Re-used containers are not a waste, but if they accumulate in the harbor, the containers will become a burden for the harbor and will become unused waste. The use of re-used containers as building materials or building component also helps harbors reduce the load so that used containers can be re-used and not wasted. In addition to assisting in reducing the amount of waste available, the use of used containers as building materials has other advantages that are easy to transport, have modular systems that fit the concept of green buildings, and have easy construction systems that use steel construction or prefabricated construction. The material or component processing can be done in the workshop and then can be transported to the site easily by truck. The image of the container is described in the below figure:



**Figure 1:** containers in harbor (source[3]).

There are many examples of buildings using re-used containers for various functions: residential functions, library, office, etc. In Indonesia, the use of re-used containers as building materials requiring a treatment, especially in interior wall finishing. Interior finishing on a need to be added insulation wall in able to absorb the solar heat so that the interior space will remain comfortable. It must be done because Indonesia is a tropical country, so solar heat is a problem to be solved. The frequently used insulation walls are usually [4]:

1. Inorganic / Mineral: This product is made from silicon and calcium (glass and stone) which is generally seen in fiberboard. The insulator fiber sheets are similar to glass-wool, made from sedimentation rocks that are processed into fibers. The works of this sheet are also identical to aluminum sheets.

2. Synthetic Organics: Materials made from organic raw materials which are saturated from polymers.
3. Organic nature: Material made from natural such as hemp or a kind of wool that must be treated to avoid animal attacks and decay.

The application of re-used containers in many functions described in this below figure:



**Figure 2:** The application of re-used containers in many function. Interior wall reinforces with insulation (source[3]).

ITSB Creative Hub Building is located in Cikarang, West Java. In the case of ITSB Creative Hub building, re-used containers were chosen as a step forward of the campus vision that the campus of ITSB is an eco-friendly industrial campus. The main building of ITSB Campus has been certified Gold from Green Building Council Indonesia (GBCI). Another reason to choose used containers as materials is to pursue the speed of construction so that buildings can be used as soon as possible at the beginning of the new semester. Besides, the use of re-used containers with rustic and industrial ambient reinforces the ITSB image as a campus that focuses on eco-industry.

## 2. Purpose of the Paper

This paper explained the design process and construction of re-used container for building that is being held. Purposes of this paper are:

1. To illustrate the application of re-used containers as building materials in the context of green architecture
2. To explain the application of building design using re-used containers as material
3. To describe the advantages and disadvantages of used containers as building materials

### 3. Methods

The method that used is observation and descriptive explanation about the design and construction process that is being held. The observed results are described as follows:

1. Comparison of design results with green architecture principles
2. System construction and application of used materials
3. The advantages and disadvantages of using a used container as a material

### 4. Discussion

#### 4.1. Re-used containers as part of the green architecture concept

Many experts have determined green building or green architecture criteria. In world-wide, green building assessment criteria such as LEED in the United States, GREEN STAR in Australia, GREEN MARK in Singapore, and so on. In Indonesia, known as GBCI (Green Building Council Indonesia) which concerned in the criteria of green building assessment or better known as GREENSHIP. There are five aspects of assessment that are assessed in the GREENSHIP standard that implemented in the container building of ITSB, namely [5]:

1. Source and material cycle
2. Land using
3. Energy efficiency and conservation
4. Water Conservation
5. Indoor health and comfort

In the term of describing the building of ITSB Creative HUB using re-used materials as a green building, the author using the principle which has been stated in GREENSHIP

by GBCI (Green Building Council Indonesia) which is a green building policy-making institution in Indonesia which has been recognized nationally. The main ITSB campus building has also received the Green Building certificate from GBCI.

The application of the principle of the use of containers is in line with the green building criteria [6], especially on the source and material cycles aspects. Besides, the design implementation of ITSB Creative HUB building also apply some aspects of green building. The following **table 1** describes the green building aspects and their application in ITSB Creative HUB building design:

TABLE 1: Some aspects of green building implemented in container building of ITSB.

Aspects	Sub aspects	Implementation
Source and material cycle	Use of buildings and used materials, environmentally friendly materials, prefabricated materials, and regional materials	Use of re-used container material; use of steel material for main structure; use of prefabricated concrete floor panel material; use of gypsum panel wall, use of aluminum window and door
Land using	Green-based area	Minimum exploited and intervention the green area; not cutting the existing tree and using it to make shade surrounding building environment
Energy efficiency and conservation	Natural lighting and cross ventilation	Implementation of cross ventilation system in lobby area and amphitheater to create cool air flow around the building; make door and window in the wall of containers so that natural light can come to the building easily.
Water Conservation	Rainwater catchment and landscape water efficiency	The building is constructed with a stilts building system, so rainwater can be conserved and absorbed easily down into the soil; the use of clean water in toilets using a centralized system where water is drawn from the center of the main building of ITSB campus.
Indoor health and comfort	Visual comfort, thermal comfort, outdoor viewing, and noise levels.	Interior wall insulation materials using glass wool and gypsum; environmentally friendly and energy efficient of air conditioner; the use of a wide window in order to see the vast view out the window; attractive and attractive exterior paint finish.

The elaboration of aspects of green building and design and also the construction process that has been executed is described in the **table 2** below:

#### 4.2. Implementation of re-used container for ITSB creative hub building

TABLE 2: The elaboration of implementation.

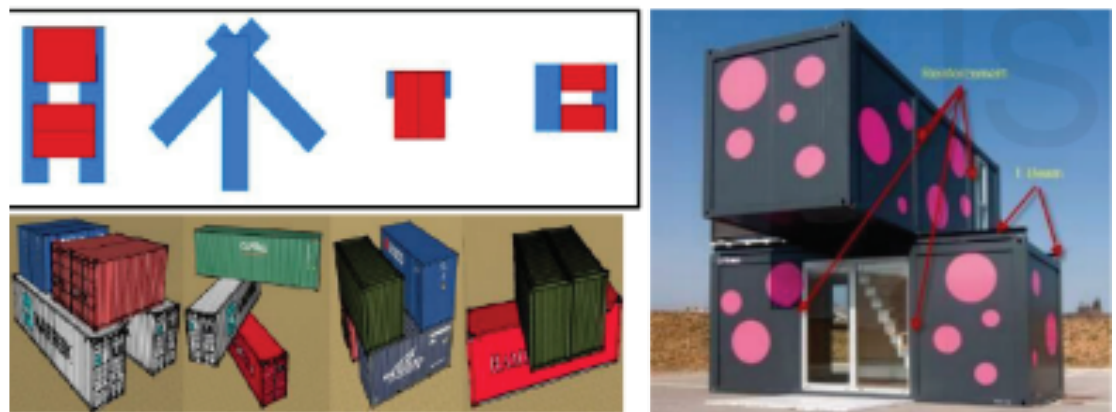
Implementation	Design and photo in construction site
<p>Use of re-used container material; use of steel material for main structure; use of prefabricated concrete floor panel material; use of gypsum panel wall, use of aluminum window and door</p>	
<p>Minimum exploited and intervention the green area; not cutting the existing tree and using it to make shade surrounding building environment</p>	
<p>Implementation of cross ventilation system in lobby area and amphitheater to create cool air flow around the building; make door and window in the wall of containers so that natural light can come to the building easily.</p>	
<p>The building is constructed with a stilts building system, so rainwater can be conserved and absorbed easily down into the soil; the use of clean water in toilets using a centralized system where water is drawn from the center of the main building of ITSB campus.</p>	
<p>Interior wall insulation materials using glass wool and gypsum; environmentally friendly and energy efficient of air conditioner; the use of a wide window in order to see the vast view out the window; attractive and attractive exterior paint finish.</p>	

#### 4.2.1. Structure and construction system application

Containers are usually used to transport goods or material from one area to another through the ship by the sea. In addition to having the ability to store items to be distributed, containers can now be used as a component to create space in architecture. Re-used container for building construction usually has a length of 6-12 meters with a width and height of 2.5 meters or better known as a container with a size of 20 feet. The container box can be stacked up to 12 arrangements and has high strength (attached to the image below):



The stacked container mass design can be done in various ways, can be stacked parallel, perpendicular, or crossed. Containers should be supported each other at the grid of the column and the beam so that the structural system can work properly. Besides, the connection between the container components must be in good condition (using a bolt or weld joint). Here is an example of a building created from a container with a stacked system:



**Figure 5:** Implementation of stacked construction system (Source: left [2], right [3]).

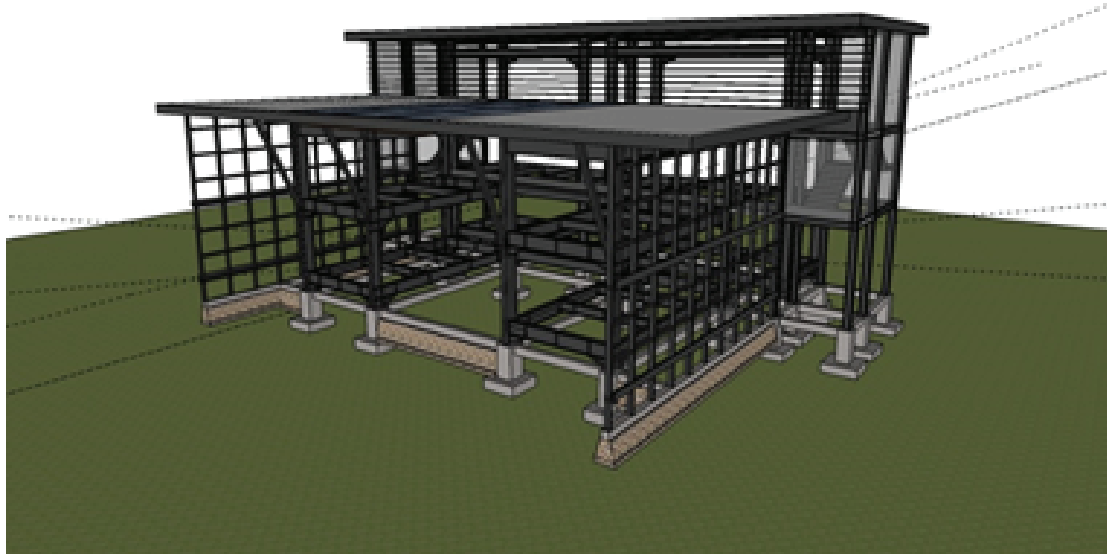
## 2. Using columns and steel beams reinforcement for additional structures

The second way in structural and construction container building is with the support of IWF steel beam and column structure. The container component clamped and inserted into the IWF steel portal structure. Building ITSB Creative Hub as cases in this paper using this structure system. For the foundation system using footplate foundation with a concrete sloof and continuous foundation as reinforcement. The application of this concept of structure also anticipates if the physical condition of the container structure is not correctly (deformed and corrosive) so it needs additional structural strengthening. Mass composition of container buildings that have been reinforced with the IWF steel portal structure and its foundation system are as follows images below:

At the site, construction of container structure and transport is done gradually. The first step is to build the first-floor structure (up to the beam), then the container unloads to the portal and connected by using the bolt and welding system. After the first step is completed, then proceed to the second-floor construction and so on until the 3rd floor and roof construction completed. Here is a picture of the construction work at site:

The exploded axonometric of components of the ITSB Creative HUB building structure are described in the **Figure 8** below:





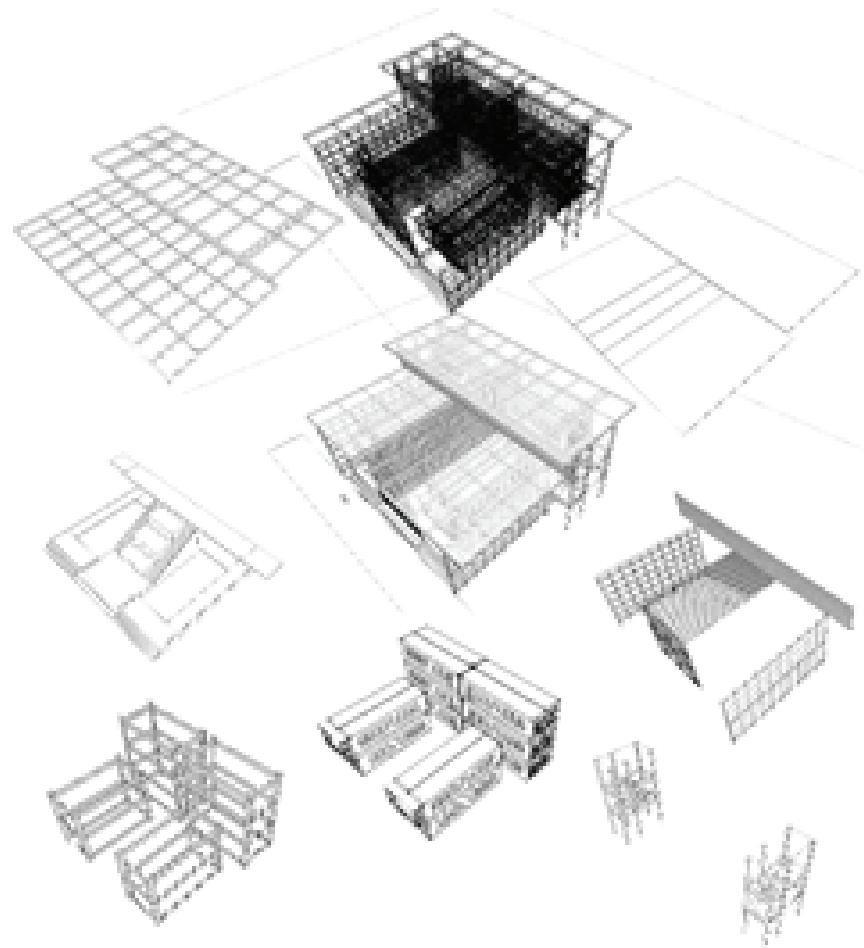
**Figure 6:** structural system of IWF steel reinforcement.



**Figure 7:** implementation of structure system at construction site.

#### 4.2.2. Container building architectural component

Re-used container already have some building components such as columns, beams, walls, floors, and ceilings that can be used directly. However, the re-used container material transported directly from the harbor is usually not entirely in good condition there are some parts that have been damaged or corrosive so it required reinforcement or replaced with other materials. The components of the container are described in the **Figure 9** below:



**Figure 8:** Exploded axonometric of structural component of ITSB Creative Hub Building.

In this case of ITSB Creative Hub Building, most components of the container are reused. Only part of the wall is cut and not used an example of the wall on one side of the container. Besides, the door part of the container is used to create a balcony wall. The door then is joined parallel to make 1 class unit or studio to make the room more prominent so that the part of the coincide wall must be discarded to create a bigger space (picture below). Other components such as interior walls, ceilings, floors, and window/doors are added components. The existing floor of container which is wooden floors have been replaced with concrete panel floors and finished with vinyl flooring. Interior walls and ceiling using gypsum panel with previously coated glass-wool insulation. Doors and windows are installed on the part of the container wall that is removed or cut. Some of the building components are made in the workshop; some are made at the construction site.

Components of buildings in detail are described in the **table 3** below:

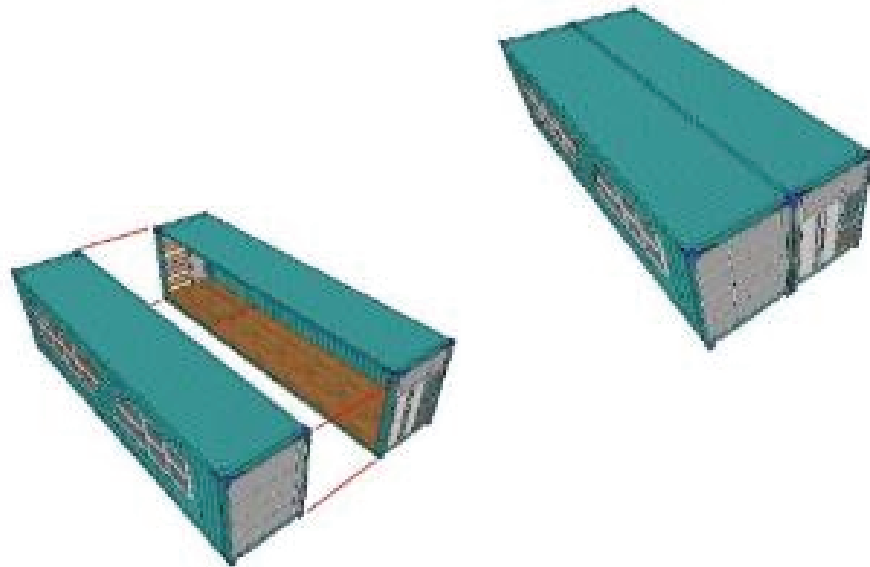


Figure 9: Container's component (Source: [3]).

#### 4.2.3. Advantages and disadvantages in usage of used containers

There are several advantages of using re-used containers as building materials:

1. Participate in preserving the environment especially in the re-use of material. As mentioned earlier, the use of containers can contribute to preserving the environment and reducing container waste at harbor.
2. Use of re-used container material can reduce cost and construction time. The comparison of construction cost of container building in the case of ITSB Creative Hub building when compared with conventional construction cost is explained in the following **table 4**:



**Figure 10:** configuration of container unit.

Buildings with used container materials can reduce costs up to 50%. The construction schedule is relatively fast (up to 6 months) because the construction system is mostly with bolt and welding system.

3. The system construction is easy and does not require difficult technology. Construction systems using re-used containers are not difficult to implement. Containers already have their own structural systems that can be directly used or can also be reinforced with columns and steel beams. The container wall is easy to drill with the machine. Cutting the container wall has a function to place the door and window components. Doors and windows material are usually iron or aluminum so it can be easily to connect to the main structure of the container.

In another hand, the used of re-used container for building material have some drawbacks such as:

1. Requires a good infrastructure path to be crossed by container transport trucks. Container transport trucks usually have large dimensions with a width of about 3-6 meters. So that container trucks cannot reach remote areas with a road width of fewer than 6 meters. The following are container transport truck specifications:
2. It will cause the hot temperature in the interior space. Container components are made of metal material. If the material is not reinforced with additional insulation which is has a good design system, the interior space will become uncomfortable. Therefore, a suitable design method is required in designing the building using

TABLE 3: list of container building material.




Architectural component	Material	Photograph
Exterior walls	Container Existing wall finished by exterior painting	
Interior walls	Glass wool and gypsum board	
Floors	Concrete Panel and finished by vinyl flooring	
Ceilings	Gypsum board	

TABLE 4: The construction price comparison per m2 between container building and conventional construction.

Area	Containers	Conventional
Corridor	443.44	443.44
Container floor area	576	576
Total	1019.44	1019.44
Cost estimated per m2	3,700,000	6,000,000
Cost Total	3,771,928,000	6,116,640,000

re-used container material. Some of the insulation material has a higher price if compared with other material.

3. In several times, containers will be decayed quickly if it is not treated correctly. Container materials such as steel and metal materials are generally corrosive. Because of that, it must take periodic maintenance so that the container building



**Figure 11:** unloading re-used containers (source: [7]).



*6m Til Tray Clearance Requirements:*  
 Height – 4.8m (16')  
 Width – 3m (10')  
 Length – 12m (40')

**Figure 12:** Container truck specification (Source: [8]).

can have excellent durability. Besides, the steel joints are also susceptible connections, as well as regular maintenance of the steel joints to keep the load well tolerated

- (a) It will cause the hot temperature in the interior space. Container components are made of metal material. If the material is not reinforced with additional insulation which is has a good design system, the interior space will become uncomfortable. Therefore, a suitable design method is required in designing the building using re-used container material. Some of the insulation material has a higher price if it compared with other material.
- (b) In several times, containers will be decayed quickly if it is not treated correctly. Container materials such as steel and metal materials are generally corrosive. Because of that, it must take periodic maintenance so that the container building can have excellent durability. Besides, the steel joints are also susceptible connections, as well as regular maintenance of the steel joints to keep the load well tolerated.

## 5. Conclusion

The use of re-used containers as building materials is one aspect in green building criteria which is material source and recycling. It contributes to the reduction of harbor waste amount. In addition, using re-used container material, indirectly other green architectural principles are also applied to decrease air temperature in interior space. It makes users can feel comfortable, for example, the application of cross ventilation and natural lighting, the use of environmentally friendly insulation materials, the application of stilts building to prevent moisture and heat, and also landscape conservation by not cutting trees so that it becomes sun-shading for buildings.

Container structure and construction system in ITSB Creative Hub building using IWF Steel portal structure as reinforcement structure. This method is to make the structure becomes stronger because the container material is modified, the wall component is drilled in some area to place the doors and windows so that it will impact the structural weakness. Besides, the container material is also not in such good condition because of corrosive and material deformation especially on the wall so that structural reinforcement is required. In the architectural component, the part of the container that can be used directly is the exterior wall. The part of the container door is removed and partly used as a balcony wall area. Interior and ceiling walls added with glass wool insulation and gypsum wall coverings to keep the indoor temperature comfortable. Existing container floors reinforced by concrete floor panels with vinyl floor coverings to make the floor more stable and convenient to use as studio space. Components of doors and windows mounted on the side, front and rear by drilling the existing container wall first. Doors and windows use aluminum materials that are processed in the workshop.

It is concluded that the advantages of the use of containers as used materials can contribute to environmental conservation, can reduce time and cost of construction, and can be applied with accessible technology with the principle of structure and steel construction. Meanwhile, the disadvantages in the use of re-used containers as materials is a complicated delivery process because it requires a suitable infrastructure path so that it cannot reach remote areas with a narrow access road. If not correctly designed, the indoor temperature of the container will be hot and uncomfortable to use, and the container has low durability, it can be easily corrosive so that it should often to be maintained in some of the periods.

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