Plastic material as building façade

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Abstract. According to the United Nations Environment Programme, buildings account for nearly half of the world’s energy expenditures, 40% of greenhouse gas emissions, 25% of the earth’s potable water, and, in developed countries, over 20% of all solid waste generated (including food waste, yard waste and unrecycled materials). Reuse of used materials as one of the building materials is becoming a global trend in the world of architecture. It aims to minimize the damage to nature when producing new materials. The Microlibrary Bima is one example of a building that reuses plastic as a building façade. The writing of this thesis aims to understand how plastic material can be suitable as a building façade. This paper presents an analysis of case studies in library interior spaces with a focus on plastic material as building facades. This thesis demonstrates a design approach in terms of material and the presence of building facades. This study explores the use of plastic material in building facades.

1. Introduction

According to Ulrich Knaack, Marcel Bilow, Tillmann Klein, the façade separates the usable interior space from the outside world, which is composed of materials [1]. Material selection is becoming an important aspect when it is used as building façade because material will interact with the environment [2]. The requirements of material when it used as building façade can be shown in Figure 1.

![Figure 1. The Requirements of material when it used as building façade](image)

The façade defines the architectural appearance of the building, provides views to the inside and outside, absorbs push and pull forces from wind loads, bears its self-weight as well as that of other building components. The façade allows sunlight to penetrate the building while usually protecting...
from the sun at the same time. It resists the penetration of rainwater and has to handle humidity from within and without. The façade provides insulation against heat, cold, and noise and also can facilitate energy generation [1]. So, it can be said that the requirements of material on the building façade must fulfill its function which is viewed from the characteristics of the material itself. The examples of material that commonly used as building façade are natural stone, clay, concrete, timber, metal, glass, and plastics.

Material that exists in nature is divided into three elements, namely surfaces, substances and mediums. The material has a substance made from natural or artificial materials. Medium is elements that exist in nature that are needed by humans. These elements will be felt by humans through the five senses, which will then be responded to by humans. If there is a change, then this substance can potentially change the surface and the appearance of the material. A surface is a place for interaction between medium and substance in materials. Material surface is the first thing that looks visually very real [3].

Within technology development, the used of plastic as a building material is becoming a trend in architecture. It caused by plastic is one of the materials that difficult to decompose in nature. Thus, reusing plastic as a building material is one of the ways to minimize nature's damage and also it caused that reusing used plastic material as the main topic in this paper.

Based on Stephan Engelsmann, Valerie Spalding and Stefan Peters (2010) in their book “Plastic: In Architecture and Construction” plastics are a group of materials with a broad spectrum of properties that makes them predestined for numerous different applications. Plastics are inexpensive, light weight and durable materials, which can readily be molded into a variety of products that find use in a wide range of applications. Most plastics, however, are both thermal and electrical insulators, meaning they show high resistance to electrical current and are poor conductors of heat. Plastics are generally differentiated according to their degree of cross-linking. One of the examples of plastic is thermoplastics. Thermoplastics are heat-deformable because the polymer chains do not form atomic bonds between each other but are linked only by secondary valance forces. Thermoplastic are particularly prone to stress cracking because of their brittle nature. Their appearance can be opaque or transparent. The examples of thermoplastics are Polyethylene, Polypropylene, Polyvinylchloride, Polycarbonate, Polystyrene, et cetera [4,5].

Plastics application on building can be distinguished between loadbearing and non-loadbearing building elements. Non-loadbearing application is, for example, interior fittings and façade cladding in particular. The use of plastics for building skins depends on the thermal and physical characteristics required. For loadbearing structure, fiber-reinforced plastics are still the most commonly used option [4]. The example of building that reusing plastic as building façade is Micro library Bima. Thus, the objective of this paper is to examine requirements of material as building façade based on properties material of plastics.

2. Method
Literature studies is the main method on defining indicators that can answer the objective of this paper. This literature studies are based on plastic’s characteristic, which can fulfill building façade’s function. Thus, the requirements of material as building façade are going to be an assessment tool based on properties material of plastics.

| Table 1. Material properties and criteria material of analyzing case study |
|-----------------------------------------------|
| Material Properties | Criteria Material as Building Facade |
| Substance | Durability, Sustainability, compatibility, health, functional performance, thermal performance, acoustic |
| Surface | Cleanability |
The method for research in this paper encompasses three approaches. The first was literature study, the second a series of interviews of staff in Micro library Bima, and the third an observation at Micro library Bima to get the facts and data about it.

1. Literature study – the literature study was undertaken to understand plastic material can be applied as building façade.
2. Interviews with staff in Micro library Bima
3. Observation at Micro library Bima to get data and facts

An issue analyze in this paper is limited to plastic materials which are reviewed from its properties as building façade.

3. Results and Discussions

This paper is assigned to search and review the literature on plastic material can be suitable as building façade with Micro library Bima as a study case. The primary data was produced through qualitative content analysis.

3.1. Plastic Material Properties

Plastic is materials composed principally of large molecules (polymers) that are synthetically made or, if naturally occurring, are highly modified. In addition to their similar nature as synthetic polymers, all plastic materials have the property that at some stage, they have been or can be readily formed or molded into a useful shape. The polymer materials can be further divided into synthetic polymers and natural polymers (Strong, A, 2006) [5]. According to Cowen and Smith (2004), plastic is condensation or polymerisation, which become plastic under heat or pressure. They can then be shaped by molding or extrusion [6]. Most plastics are produced from mineral oil (petroleum based), but some are made from renewable natural substances. Plastics are organic chemical compounds that begin in a granular form. The granules are then heated, injected, and molded into shape. Other methods for shaping plastic include extrusion, roto molding, calendering, expansion, and foaming. Plastics are homogeneous materials and are well suited for industrial production and digital fabrication. They are distinguished by their long molecular structure and are categorized into one of three categories: thermoplastics, thermosetting plastics, and elastomers (Gesimondo and Postell, 2011) [7].

Thermoplastics have a long molecular order. They have low gross and thermal conductivity, which means that they are ideal materials for insulating the transmission of heat through an assembly. They also tend to have a high coefficient of thermal expansion and high tensile strength and are resistant to water and many chemicals. In high temperatures, plastics begin to lose their strength, become elastic, and begin to deform. In cold temperatures, plastics will become brittle (Gesimondo and Postell, 2011) [7]. One of the examples of thermoplastic is Polypropylene.

Polypropylene (PP) is the most widely used thermoplastic since it is very cheap and flexible for molding. Polypropylene is a colorless and odorless thermoplastic polymer. Related to Gibson (2015) Polypropylene can be understood through his approach about material which can be divided into three elements (Substance, Surface and Medium). The resin manufacturers convert chemicals (derived from crude oil, natural gas, coal, and other sources) into basic polymer materials. Hence, these processed are called polymerization processes. The first major polymer types (Polypropylene) are often given a special name, polyefins. The terms mean “oil-like” and refer to the oily or waxy feel that material has. Polyefins consist only carbons and hydrogens, without other atoms in polymer. Substance from Polypropylene can be formed through melting and molding process of polymer granule. The purpose of adding an additive matter is to improve its performance [5].

On the other hand, Polypropylene surface and form is caused by the substance itself and the process of plastic making. Thus, the used of PP’s polymer characteristic produce opaque or transparent on its surface. Although Polypropylene can be made transparent, it is normally produced to be naturally opaque in color. Polypropylene can be used for applications where some transfer of light is important or where it is of aesthetic value [4, 5]. Afterward, the medium that interacts with
Polypropylene is coming from the sun’s light, rain water, the air, and the sounds. All of these mediums are affecting Polypropylene’s durability, thermal performance, functional performance, and acoustical performance.

3.2. Micro library Bima

Micro library Bima is the first realized prototype of a series of small libraries in different locations throughout Indonesia, which we intend to build in Indonesia designed by an architectural firm named SHAU Architects. This library is located on Bima street, Arjuna Village, Cicendo District, Bandung City. Previously before the library was built, this area was only a field and was a place for children to play and residents to gather. The designer sees a potential in this region which it is located between middle-up residents housing and middle-low residents housing. The designer hopes that the present of this library will lead to warm interactions between these residents. This library is also located near several educational institutions. Therefore, students and teachers can make Micro library Bima as an infrastructure for learning and teaching activities [8].

This Micro library is built on an area of approximately 28 m². This library consists of 2 floors which have different functions. On the first floor, it was a multifunction room which usually used to be a place for modern dance training of the school cabaret group. A ladder that functions to connect to the library building on the second floor can also be used as a visitor’s seat. The second floor of this building has a function as a library. Collections that exist in the library include general knowledge books, children’s books, traditional toys, PAUD teaching aids. This Micro library has an unique design which can be seen through the selection of material for building façade [8, 9].

Plastic is chosen to be building façade materials due to nature’s impact. Plastic application on Micro library Bima can be categorized as non-loadbearing building elements. Plastic material is used only as a filler on building facades.

The buckets were then placed in between vertical steel ribs spanning from floor to roof and are inclined towards the outside to repel rainwater. The inclination of the bucket can also make plastic’s surface not completely exposed by the sun and minimize the degradation of the plastic itself. The inclination of bucket is shown in Figure 1.

For harsher tropical rainstorms translucent sliding doors in the inside can be closed temporarily. Mounting 2000 buckets, making the fixture and punching out bottoms of more than half of them is time-consuming. However, the local craftsmen made their own punch out/cutting tools to be faster while also maintaining sharp and clean edges. While studying design options of how to arrange, the SHAU team realized that they could be interpreted as zeros (opened) and ones (closed), thus giving them the possibility to embed a message in the façade in the form of a binary code Figure 2. Bandung mayor suggested ‘buku adalah jendela dunia’, which means ‘books are the windows to the world’ [8,9].
The Substance of Polypropylene will determine material requirements when it’s used as building façade. The requirements are including its durability, its sustainability, its compatibility, its effect for human’s health, its functional performance, its thermal performance, its acoustical.

**Table 2. Criteria material of analyzing case study**

| Material’s requirement as facade | The Explanation |
|--------------------------------|-----------------|
| **Durability** is the capability of material to execute their necessary functions throughout their life cycle with minimal regular maintenance work | Polypropylene’s durability relates to the interaction between PP itself with medium (UV radiation’s from Sun). When UV radiation affects PP, it can attenuate the thickness of PP, and it will crack easily when it touched and also can make yellow color on the surface. After 4 years it was used as building façade, this plastic did not show any cracks yet. |
| **Material sustainability** can be described as those materials that are drawn from renewable sources that do not adversely affect the natural environment | PP is categorized as one of the type of plastic that is difficult to decompose in nature and it will take 20-30 years to be decomposed. Reusing PP’s plastic is one of the ways to reduce pollution caused by itself. Thus, reusing this plastic as Micro library Bima is the right way. |
| **Health and safety** aspects of façade materials can be described as the amount and combination of ingredients in a material that is known not to cause any injury, illness, disease, damage or pharmacological effect in human beings | When PP is applied as building façade it can affect human’s health because when UV energy absorbed by plastics can excite photons, which then create free radicals. Therefore, visitors who have visited this micro library have not yet been infected by plastic’s degradation. |
| **Functional Performance** is an efficient performance of the materials to the best of their abilities and in efficient manner with minimum downtime of repair and reduced maintenance costs | The use of plastic in the micro library facade has not made plastic changes until now. This happens because PP is material that difficult to decompose naturally in nature. |
**Thermal Performance** describes how well a structure reacts to changes in external temperature during the daily and seasonal cycles.

PP is an insulator which can not absorb any heat from any resources. But PP is not resistance to UV energy caused by the sun.

**Acoustical façade** defined as a façade that designed to absorb or control exterior sound.

Polypropylene has hard and has no pore on its surface. Thus, PP can not absorb the sound but it reflects it and also it will effect the acoustic’s comfort in the building.

**Cleanability** is the capability of the building to be easily dirt-free easily and without damage.

Polypropylene is material that resistant to water and has no pore on the surface. Thus, when the dirt lay on its surface, it can be cleaned easily.

**Compatibility and suitability** can be defined as ability of materials to integrate orderly and efficiently with other materials in a system with fewer modifications or conversions.

PP is not compatible with strong chemical oxidants such as hydrogen peroxide, permanganate, and osmium tetroxide.

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### 4. Conclusions

Selection of façade materials for building construction is one of the most important design decisions in the early phase. Material selection as building facade must consider several aspects based on material properties. Plastic is one material that can be used as facade material. The use of plastic can reduce natural damage because of it. One of the buildings that apply plastic as facade material is Micro library Bima. After 4 years built, the plastic on the Micro library Bima facade has not shown any significant degradation yet. But it can not also be said that plastic material is the right material to be used for long periods. Plastics will degrade if it is exposed to sunlight, which we know that sunlight contains UV energy. UV energy can damage the chain of polymer bonds which is contained in plastic. Thus, it can make plastic performance decrease every year.

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