The Utilizations of Plastic Bottle Waste (PET) in Architecture

S. R Andriani¹, H Isnaeni¹, N R Kusuma¹, and E Avandra¹
¹Department of Architecture, University of Indonesia, Jl. Margonda Raya, Pondok Cina, Beji, Depok, West Java. 16424, Indonesia
²Email: hendrajayaisnaeni@gmail.com

Abstract. The purpose of this study is to examine the capabilities of using plastic bottle waste (PET) in architecture. The controversy of using a plastic bottle in this world brings up the idea of how efficient this material could be but at the same time how this material could rise the environmental problems. Therefore, we need to think better waste management for PET by promoting the capabilities of PET specifically in architecture. By using the theory of Cradle to Cradle to produce a sustainable material product by Braungart and McDonough, we can improve the value of PET’s functional life residue. Research on PET’s capabilities was based on several case studies where PET was used in many different types of applications, but the focus was on physical uses of the material. Some of PET utilizations are in the form of furniture, wall, brick, and structure. The conclusion is that every application must not be applied all together at once in one design. On the other hand, we can use it as an element in architecture, because every application needs to stand with another material other than PET itselfs. These utilizations can enhance the life span of PET material after its functional cycle ended.

1. Introduction
As an architect, we always faced issues between human and environment; we are responsible for what we design and build in our environment. Identifying the problem that occurred, drives us to realize that the selection of material is crucial after the functional cycle ends and throws it to the environment. The material must return to the environment safely, that it doesn’t harm the environment. But what if it already harm the environment after its functional cycle ends? One of the materials that can damage the environment during its residue life cycle is plastic bottle or PET.

This material’s waste which is often underestimated and disposed of by humans, will eventually emit further environmental pollution. Production of PET-based material bottles are increasing every decade, and it will keep rising without any better waste management. [1] In Indonesia, from 100% of plastic waste, 69% ended up in landfills, 7% are recycled, and 24% are damaging the environment. Above all the production of a plastic bottle (PET) in the world, only 10% of its waste is recycled into a new plastic bottle. Humans tend to ignore plastic bottle waste on earth and consider it as trivial problems.

What makes plastic bottle waste unique is that it did not broken after being used. Compared to other plastic waste like food packaging, snack wrapper, or even your straw wrapper on juice box needs to be torn apart so you can consume the meals. When you are done using your plastic bottle, the plastic bottle waste will remain in its intact form. This makes plastic bottle (PET) can be recycled physically without adding any chemical substances in the process. Thus the purpose of this study is to examine the capabilities of using plastic bottle waste or PET in architecture.
It has become a common dilemma of how a plastic bottle waste can damage our environment, but at the same time, plastic bottle as a material can be considered as a strong, lightweight material. While plastic itself is not the kind of material that came naturally from nature; plastic is a man-made material. The scientist made a certain formula to create plastic chemically. As a result, plastic will not go to the environment safely like Braungart and McDonough (2002) stated; it is the kind of material that has its terms and cannot go well with the natural cycle in the environment. The natural cycle in the environment is when every phase of the material is giving a nutrient to the environment. Braungart gave an example of what a good product design should be; a cherry tree.

![Figure 1. The cycle of a cherry tree.](image)

Figure 1 shows the cycle of a cherry tree. Braungart explained that a good product design must not produce any waste. Like the cherry tree, from the seed until it dies, the cherry tree gives benefits to the environment. When it blossoms and produces cherries, it gives food to human and animals. When no cherries are produced, it still produces oxygen and nutrients for the soil. Furthermore, when it died, it still gives nutrients to decomposer and soil. This analogy is what Braungart proposed to start thinking for a better product design. However the cycle of a cherry tree is absolutely contrasted to the plastic bottle’s (PET) life cycle.

As written before, plastic bottle (PET) are not the kind of material that will return safely to the environment. Braungart (2002) mentioned that PET is a ‘cradle to grave’ product with linear cycle of life. A linear cycle is the product that is designed to be thrown away after its functional cycle ends. Even though a good product design must have a cycle of [2] cradle to cradle as Braungart & McDonough said about a cherry tree’s cycle where product continues to giving human and the environment benefits by their existence. On the other hand, while plastic bottle living its linear cycle, plastic bottle (PET) has a couple of characteristics after its functional cycle ends. First characteristic is when plastic bottle goes to incineration, it will release dioxins and toxic substances both as gas and solid form. Secondly, plastic bottle (PET) will not return to the nature safely because it is not a biodegradable material. However, PET will have a photodegradation which can make plastic bottle into tiny pieces or microplastics in a range of 450-1,000 years [3].

By knowing the cycle of a plastic bottle (PET), we also need to know about plastic bottle (PET) characteristics and ergonomics. [4] Four main parts of a plastic bottle are integrated to maintain substances inside the plastic bottle. Those four parts are bottle cap, bottle neck, bottle body, and bottle base. Bottle cap is useful for keeping the substances inside, while the bottle neck is where the ‘sealing system’ of plastic bottle happen. Other than ‘sealing system’ function, bottle neck links the bottle cap to the bottle body where the substances are. The last part is bottle base, a passive cap to keep the bottle
stable when it is unused. [5] After knowing the ergonomics of a plastic bottle, we should know that plastic bottle has some advantages such as durable, lightweight, thermoplastic, and efficient.

Despite all the controversies of plastic bottle material (PET), we can take advantage of its linear cycle to continue benefiting humans rather than polluting the environment. This paper will prioritize the use of plastic bottle waste (PET) in architecture based on the case study that already been done by the communities.

2. Method

To examine the capabilities of plastic bottle waste, we analyzed several projects done by the local communities. These projects are not interrelated but will show you how to proceed a plastic bottle waste into different kinds of product and usage. After analyzing the process of each projects we can associate the project’s final product to further applications of the product.

Please note that, these projects are related to the usage of plastic bottle waste (PET) conducted by local communities in different areas around the world. Those projects included PET as [6] furniture joints by Micaella Pedros (London), [7] hollow brick by Sina Safinia (Oman), [8] eco-brick by Hug It Forward (Guatemala), and [9] structure by Shigeru Ban (Japan). Several studies have been conducted by those projects. These are the processes of turning plastic bottle waste (PET) into different kinds of applications.

![Figure 2. The processes of turning plastic bottle waste into different kinds of usage based on actual projects.](image)

Figure 2 shows the process of 4 kinds of plastic bottle waste utilizations conducted by different people in a various areas. This shows how various communities can turn plastic bottle waste (PET) into different kind of products. Learning the process of this application is leading to the analysis based on how safe this process in according to the natural cycle of a plastic bottle (PET).

Subsequently, this study analyzed how the final product will respond and react to its surroundings. This study used two ways to analyze the final product; first method is process-based utilization, and second one is based on the safety in processing the plastic bottle waste.

3. Results and Discussions

3.1. Process-Based Utilizations

There are four kinds of projects examined. These four projects utilized different characteristics in producing its product. Please note, that the objective of this analysis is to show the potential of PET’s physical characteristics without adding any chemical substances to recycle PET.
Table 1 shows that every project have its process on how to utilize the plastic bottle waste. Project A, a project by Micaella Pedros as mentioned above, was using one of PET’s characteristic: thermoplastics. Pedros heated PET into a joint of 2 kinds of wood and after cooling down it become a strong joint without any nails. Thermoplastic is a more flexible plastic and it can be mold into different shapes through heating and cooling the plastic.

B & C projects had a same purpose of architectural element, which is a wall. The difference lies in PET lightweight used in project B to make a hollow brick and form void state inside. This PET can work as insulation because it creates an energy propagation. While project B used plastic bottle waste to form void state, project C used a plastic bottle as the brick itself. Hug It Forward, a local community spread awareness to schools on waste and environment and transformed waste into school buildings. Inorganic waste was inserted into PET and tighten up until the bottle becomes hard enough to be an eco-brick. This eco-brick can be installed then with the same process to make a regular wall with the help of chicken wire to tighten up the eco-brick.

Project D by Shigeru Ban utilized PET to form a structure installation. The structure used the bottle’s sealing system and base to create a bracing line. We did not aware beforehand that a plastic bottle already has sealing system to maintain the substances inside. This sealing system was then utilized by Ban to perform nodes in the structure. Ban subsequently used the base of plastic bottle to put the bracing of the structure which is useful to make the bottle stable and this base was then used by Ban to put the bracing of the structure. Figure 3 is the detail on Ban’s plastic bottle structure project.

![Figure 3. Detail on Shigeru Ban’s plastic bottle structure: sealing and bracing system.](image)

3.2. Safety on Processing Plastic Bottle Waste
Every utilizations process creates a different kind of product that leads to the safety of the final product living in the natural cycle of PET. In this natural cycle, PET is thrown away either in incineration, landfill, or environment. The plastic bottle itself was designed to be living in a linear cycle and is not continued to return to the environment safely.
Table 2. Projects Response on PET Natural Cycle.

| PET processes after functional cycle ends | Project A | Project B | Project C | Project D |
|------------------------------------------|-----------|-----------|-----------|-----------|
| Incineration                              |           |           |           |           |
| Photodegradation                          | 0         |          | 0         |           |
| Broken-Down                               | v         | v         | v         | v         |
| Direct contact                            | v         |          |           |           |
| Indoor use                                | v         |          |           |           |

Table 2 shows how the usage of plastic bottle waste might or might not harm people or the environment. From project A and D, there are ‘o’ in photodegradation, it means that it is still unknown whether the plastic bottle experiences the photodegradation process as this process will proceed under the sunlight in a long time before becoming micro-plastics. Even though in this case PET might not experience photodegradation process, it will still experience a ‘broken-down’ process. It is a natural process of PET to become microplastics. This process will drain some chemical substances; therefore the cycle of PET is polluting the environment. This natural process took at least 450-1,000 years to finally reach the end of PET’s life.

Plastic bottle waste in project B and C will no longer have direct contact with human and environment once it becomes a wall. So the ‘broken-down’ process will happen inside the wall and will not harm human nor the environment. For the indoor use, the plastic bottle has direct contact with people, and it still needs further studies on how it will affect people and the environment.

All the projects did not go to the incineration or burning process, however, project A went to a heating up process. This process generates small emissions rather than gas or dust that can still pollute the air around the heating process. The heating up process was on a heat range of 255°c - 300°c. [10] As stated by Quarmby, the plastic heating up process below 800°c can still produce emissions even in a small scale, it still can pollute the air quality.

4. Conclusions
The conclusion of this study is that we can utilize the remaining cycle of a PET, instead of going on linear cycle (useless). We can manage to utilize PET waste, so it can be useful for human and the environment. In this study, we conclude that PET waste can be used as material related to building technology in architecture. PET waste can also can be a sustainable material as stated by Braungart and McDonough that sustainability is local. We can easily find plastic bottle waste anywhere, and we can process plastic bottle waste anyway without adding any chemicals to process them.

However, the usage of PET waste in architecture applies only to the elements of architecture. We cannot use it in a whole building stages because PET needs other material to enhance its potential. Hence, the application of PET waste needs further study on how to utilize plastic bottle waste without affecting human and environment.

Acknowledgments
This research is funded by PIT-9 2019, the Directorate of Research and Community Engagement (DRPM) Universitas Indonesia.

References
[1] Wirawan J, 2018, Ke mana Perginya Botol, Gelas, dan Sedotan Plastik yang Anda Buang on BBC Indonesia
[2] Braungart M and McDonough W, 2002, Cradle to Cradle 28
[3] Juniata F, 2016, Berapa Lama Sampah Plastik Dapat Terurai on KlikDokter
[4] Kumar M, no date, Ergonomical Aspects of Water Bottle In Terms Of Usage: Ergonomics Interventions, Advancements and Suggested Design 2
[5] Widojoko L, Purnamasari P. E, 2012, Study The Use of Cement and Plastic Bottle Waste as Ingredient Added to The Asphaltic Concrete Wearing Course 2, 832-841
[6] Tucker E, 2016, Micaella Pedros Uses Heat-Shrunk Plastic Bottle to Join Furniture on Dezeen
[7] Safinia S, and Alkalbani A, 2016, Use of Recycled Plastic Water Bottles in Concrete Blocks, 214-221
[8] N.d, 2009, Bottle School on Hug It Forward
[9] Miyake R, 2009, Shigeru Ban Paper in Architecture 182-183
[10] Quarmby A, 1974, Plastics and Architecture