A study of building envelope for a waste to energy plant in Jakarta

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Abstract. This paper presents the study of building envelope for a waste to energy plant through heat transfer simulation. The study aimed to investigate the required envelope for Municipal Solid Waste (MSW) incineration. The building envelope is important because of the possible heat transmission that might disrupt the safety of its surroundings. The results showed how secondary skin could obstruct the transmission of heat. The steps of study are as follows: (1) a study of heat transfer on building envelope, and (2) a study of different types of material and its level of conductivity.

Keywords: building envelope, heat transfer, MSW incineration, double skin, material conductivity

1. Introduction
This study was raised based on one of United Nations Sustainable Development Goals for 2030. The goals are made to address 17 global challenges for a sustainable future. All of the goals are interconnected and one of the main goals used for this study is goal number 11, which is “Sustainable Cities and Communities”. Each goal has specific targets, this study will focus on the 11.6 target that states ‘By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management’ [1].

Indonesia, as of 2019 generates 175 tons of Municipal Solid Waste (MSW) and most of the waste comes from major cities like the capital city, Jakarta [2]. Based on the 2016 data from World Bank, waste generation is expected to increase up to triple the amount by 2050 [3]. Currently, Jakarta as one of the biggest waste contributors have waste sent to the Bantargebang Landfill located in Bekasi where the local waste is also collected. In general, most of the waste generated are not properly recycled and is only dumped onto an open landfill in the Bantargebang Landfill. Meanwhile, that landfill is expected to run out of space in 2021 [4].

The local government of Indonesia is introducing the new idea of waste processing by incineration with energy recovery as an alternative to waste management. This is shown by the Presidential Regulation No. 18 of 2016 concerning the Acceleration of Development of Waste based Power Plants and Governor Regulation No. 50 of 2016 concerning the Development and Operation of the Municipal Waste Management Facility/Intermediate Treatment Facility [5]. Waste to energy plants is the perfect solution for the waste management problems and comes with other benefits that could solve other problems at once. Recently, there is one operating waste to energy plant in Bekasi which is the BTTP-DKI PLTSA. The plant is capable of incinerating 100 ton/day and create 700 kW/hour [6]. With that
amount, the plant only covers less than 1.5% of the total generated waste in Jakarta and that is without the addition of waste from Bekasi.

Waste goes through the facility with a certain cycle and incineration is one the main process. The process of incineration has temperature requirements in order for the MSW to be completely incinerated. Those requirements may effect on the design of building envelope especially when heat is involved and how it can be transferred to the exterior. This study will examine how the building envelope of a waste to energy plant could transfer heat through simulation.

Essentially, this paper presents the initial study and it contains of: (1) a heat transfer study of the plant’s building envelope section, and (2) to study waste to energy plant building envelope section with different types of local materials, to see whether the use of different materials for the envelope could affect the heat transmission from the incineration.

2. The methodology

2.1. The method of study

The method used for this study is literature review of the waste processing cycle in a waste to energy plant and precedents of similar projects. Based on the waste processing, the combustion of waste or incineration will be examined for the heat transfer simulation. There will be two simulation, both are the building envelope section. The difference between the two base geometries is the applied dimension for the second base geometry.

The simulation set up is made according to the heat transfer conduction on the building envelope where the heat flux is made based on Fourier’s Law of Heat Conduction [7]. The heat flux ($W/m^2$) is the rate of energy flow per unit area per time from the heat source.

![Figure 1 a). One-dimensional Heat Conduction in solid form](image)

**Figure 1 a).** One-dimensional Heat Conduction in solid form

**1 b).** Fourier Law Application on Building Envelope

**Source:** Process Heat Transfer, Principles and Application by R. W. Serth

2.2. Simulation

Heat transfer analysis of the building envelope is done by simulating heat transfer in the geometry that represents parts of the building envelope by using ANSYS Fluent. There are several settings used in the simulation based on the Fourier Law and material conductivity standards from ASHRAE such as:

- **Inlet Temperature**: 950°C (average temperature of waste processing machines)
- **Outlet Temperature**: 30°C (average temperature in Jakarta)
- **Material (solid)**: Concrete
  - Density (kg/sm$^3$): 2240
  - $C_p$ (specific heat) [J/kg (oK)]: 1000
  - Thermal Conductivity (W/mK): 10

For geometries of the first simulation, the thickness of each component is made with an equal dimension to determine the role of the conductivity of the material of the building wall (concrete) and
the second skin (aluminum). The second geometry for the first simulation, after the concrete component contains an intermediary, namely the outside air (cavity).

![Figure 2 a). Geometry A (Simulation 1) b). Geometry B (Simulation 1)](image)

In addition to comparing the results of heat transfer from geometry A and B, simulations are carried out again by comparing the use of several types of materials to determine how they affect the rate of heat transfer for the secondary skin. There are four materials to be tested, namely aluminum (Geometry 1), wood (Geometry 2), bamboo (Geometry 3), and stone (Geometry 4). From each geometry, the main wall of the building 15 cm and the distance between the main wall and the second skin 50 cm.

![Figure 3. Components of Base Geometry in Simulation 2](image)

3. Result and Discussion

3.1. Heat transfer on building envelope

Based on the results of the simulation 1, it is proven that there is heat transfer in the building envelope, especially on the dividing walls of the inner and outer spaces of the building. Heat transfer is seen in the fluid component in both geometries. The heat that passes through the building wall appears to propagate upwards due to the nature of heat which tends to lead to cooler temperatures. Heat transmissions from the building wall to the outside is seen to be higher in Geometry B.
Table 1. Results of Simulation 1

| Geometry   | Results | Heat Flux   |
|------------|---------|-------------|
| Geometry A | ![Diagram](image1.png) | Q = 4600 W/m² |
| Geometry B | ![Diagram](image2.png) | Q = 3607 W/m² |

Without the use of a secondary skin, heat that passes through the building wall would have direct contact outside the building. This can be seen from the comparison of the two geometry, which is why it is better to inhibit heat transfer outside the building, it takes a secondary skin which acts as a barrier to inhibit the heat caused by the temperature of the waste combustion (incinerator).

3.2. Types of materials and its conductivity

In the second simulation, results are seen resembles the previous simulation where in the area between the building wall and the second skin, there is heat transmission but the heat does not propagate through the second skin. Therefore, it can be concluded that the type of material and its thickness does not affect heat transfer transmission out of the building. Even so, the second skin of the building is still needed as a barrier to propagate heat from the wall of the building and in the event of fire as well as a limit to solar radiation.

Table 2. Results of Simulation 2

| Geometry  | Base Geometry | Result | Heat Flux [Q] |
|-----------|---------------|--------|--------------|
| Geometry 1: Aluminum | ![Diagram](image3.png) | ![Diagram](image4.png) | Thickness: 0,05 m  
Conductivity: 202,4  
Q = 1971,42 W/m²  
 Lowest Temp.: 30°C  
Highest Temp.: 155 °C |
The choice of material is considered from the lowest temperature level of transmission namely aluminum and wood. Because the results of the second skin surface are similar, the materials can be applied as a combination to provide an attractive appearance and will adjust to the solar radiation levels analyzed in the next simulation.

Solar analysis is studied to determine which side of the building is exposed to the most solar radiation or requires certain types of material to be resistant to the solar radiation. This simulation is carried out using the building index of the site in the Formit software. This simulation shows the solar radiation in buildings through the color of the object with the cumulative data set per year.

It can be seen that the highest solar radiation of the building is on the roof side because of its position parallel to the sun heat. The east and west side of the building are the other sides that are exposed to the highest solar radiation. Meanwhile, the north and south side of the building has the lowest radiation level. This analysis can be used as a guide where to use various types of materials from the results of simulation 2.
Table 3. Results of Solar Analysis

| Building Side | Results       |
|---------------|---------------|
| Roof          | 1848 kWh/sqm  |
| East          | 914 kWh/sqm   |
| West          | 817.3 kWh/sqm |
| North         | 746.1 kWh/sqm |
| South         | 574 kWh/sqm   |

For reducing radiation on the roof of the building requires a sloping roof form that reduces direct contact with the sun and can also drain rainwater. The east and the west side are the hottest after the roof side of the building. The north and south side are the lowest solar radiation from the building.
From the previous simulation, it was determined that the materials to be used were aluminum and wood. Based on the thermal properties of the two materials, aluminum has a higher conductivity level compared to wood, which means that aluminum has a low heat insulation capacity, therefore on the hot side of the building, wood will be used as the main material on that side of the building. On the other hand, the side of the building that is not too hot, will use aluminum as the main material on that side of the building to block heat transfer from inside the building and inhibit solar radiation from entering the building.

In terms of the physical form of the double skin, because several material are used, a framework that supports the façade panels is required, which makes it possible to use several material for the façade. In terms of position, the slope of the panel does not have a significant effect on heat transfer, especially with the distance between the double skin and the building wall which corresponds to the minimum corridor width for double skins, therefore the double skin alternative depends on the design process where the panel placement of each material is determined from research and the physical form of double skins are made from other several considerations such as the environmental context in the design application.
4. Concluding Remarks
The study of building envelope for a waste to energy plant has been conducted and the remarks can be conclude as follows:
- The waste to energy plant has heat transferred to its building envelope which is seen through the heat transfer simulation results of two geometries with and without the secondary skin
- The building with secondary skin has a 16% chance of reducing the outer surface temperature of the plant compared to the building without the secondary skin
- The building without the secondary skin has a higher rate of heat flux than the building with secondary skin
- A waste to energy plant should use a secondary skin to reduce the heat transmission from the MSW incineration and possibly be used for other purposes.

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