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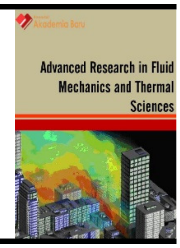


# Estimated of Energy Saving from the Application of Roof Shade on the Refrigerated Container Storage Yard

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**ABSTRACT**

The objective of this paper is to estimate the energy saving from the application of roof shade on the refrigerated container storage yard in Jakarta International Container Terminal, Jakarta, Indonesia. Energy saving was estimated by numerical analysis using thermal simulation from the computational fluid dynamics. Thermal simulation is used to investigate the heat transfer process through the wall of refrigerated container. The heat flow through the container walls is equal to the energy consumption by refrigeration determined from the heat transferred across the outside surface into the inside surface. Two conditions that is the simulation model without and with roof shade are performed. The comparison result from that condition concludes that installation of roof shade was confirmed in reduction energy consumption about 17%.



## 1. Introduction

Nowadays the reduction of energy consumption has been become trending issue in port and harbor sector to cut greenhouse gas effect. A greenhouse gas emitted from ships and cargo handling operations during at port for loading and unloading cargo. Reduction in greenhouse gas emissions has become a strong demand in container terminals after the Kyoto Protocol was implemented. Various alternatives were carried out to suppress greenhouse gases effect and to prevent climate changes. Some methods for greenhouse gas reduction has been implemented, such as electric power supplied system to rubber tired gantry crane, hybrid model straddle carriers instead of conventional straddle carriers and a trial system of roof shade for refrigerated container to reduce a load of solar insolation. Furthermore, reduction of energy consumption has direct impacts on emissions, minimizing the environment effect and reducing operational costs [1].

The electricity consumption in the refrigerated container storage yard has contributed the highest energy consumption in container terminal [2]. Electricity is used to run refrigeration system and to remove heat from the internal environment of the container. The amount of energy consumed

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by refrigerated will change depending on many external variables. These include the ambient air temperature and humidity, location of the refrigerated container, the age of the container, the refrigerant used and refrigeration technologies used [3]. Introduction of the roof shade over refrigerated container storage area could be effective in energy saving, however the amount save of energy effect is difficult to be estimated [4]. Stacking effect of containers provides thermal benefit to the power consumption of refrigerated containers that are located on the middle tier and bottom tier [5]. In order to reduce the energy consumption, protecting the refrigerated container from the environmental effect is the appropriate method that can be carried out in the container storage yard [6]. Study about energy saving in the refrigerated container is inadequate, this study provides an overview of estimated energy saving from the application of roof shade using simulation model. Figure 1 shows the basic mechanism of installation roof shade for refrigerated container. To predicting such circumstances numerical analysis using thermal simulation will provide an overview of the thermal performance of refrigerated container so that calculation of energy consumption in various conditions can be estimated.

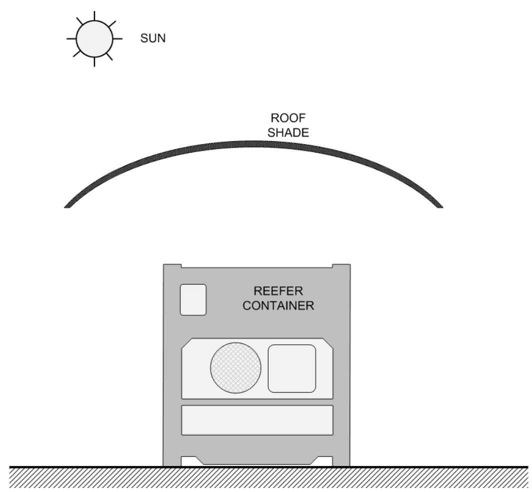


**Fig. 1.** Schematic of roof shade to protect refrigerated container [1]

## 2. Methodology
### *2.1. Thermal Simulation*

Thermal simulation is based on the solution of the partial differential equations governing the flow and convective heat transfer. The governing equations in the field of fluid flow based on incompressibility and heat transfer process were used of the generalized transport equations [7, 8]

Continuity equation

$$\nabla \cdot \mathbf{v} = 0 \tag{1}$$

Momentum equation

$$\rho(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v}) = -\nabla p + \mu \nabla^2 \mathbf{v} + f_B \tag{2}$$

Energy Equation

$$\int_V \rho C_p (\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T) dV = \int_V k \nabla^2 T dV + \int_S (q_R + q_S) dS \tag{3}$$

Where $t$ is the time, ***V*** is the velocity vector, ρ is the density, $p$ is the pressure, $\mu$ is the coefficient of viscosity, $k$ is thermal conductivity, $C_p$ is specific heat capacity and $T$ is the local temperature. Natural convection was modelled using the Boussinesq approximation, which uses a constant density fluid model, but applies a local body gravitational force throughout the fluid that is a linear function of the volumetric thermal expansion coefficient $\beta$ and of the local temperature difference. The buoyancy source is added to the momentum equation as follows [9, 10]

$$f_B = -\Delta \rho g = -\rho_{ref} \beta (T - T_{ref}) g \tag{4}$$

where $\rho_{ref}$ and $T_{ref}$ are the density and temperature at the boundary wall condition and $g$ is the gravitational force. Internal energy from thermal radiation ($q_R$) is taken into account at the surface of the objective cell in FVM within the immersed solid per unit volume as in equation [11]

$$q_R = \varphi_R \varepsilon_R \varepsilon \sigma (T_R^{\,4} - T^4) \tag{5}$$

where, $\varphi_R$ is the radiation shape factor from a view of radiation material, $\varepsilon_R$ is the emissivity of radiation material, $\varepsilon$ is the emissivity of the objective solid body, $T_R$ is the radiation temperature of the fluid and $\sigma$ is Stefan Boltzmann constant ($5.67\times10^{-8}$W/m$^2$·K$^4$). Particularly in Eq. (3), when the solid area in the model such as the container wall, roof shade and road are considered, the second term of the right side of equation is neglected, and Eq. (3) become the equation of heat conduction except the surface of the solid body. Energy of solar radiation ($q_S$) was considered in this model. A Dirichlet boundary condition at the surrounding container is used to specify a uniform inlet velocity. A no-slip boundary condition for all walls is assumed for the container wall. The inlet air temperature varies with time and the walls are assumed adiabatic. In order to close the set of governing equations, we used a k–ε turbulence model [12].

### *2.2. Simulation Model*

The simulation model was assumed to be symmetric with regard to perpendicular planes through the middle section of refrigerated container. Middle section of container is the most representative to catch heat distribution through the surface wall. The model assumed as open system simulation which consist of four regions i.e. outside air, body of container, inside air and road concrete. Within the body container composed of three materials of insulation are steel, polyurethane and aluminum. The total dimension of the model is 112.3m$^2$ was constructed in Cartesian framework with the total gird is 59,200 cells. The time discretization was set to transient calculation in 12 hours divided into 168 time-step start from 6:00 until 18:00. The simulation model shows in Figure 2.

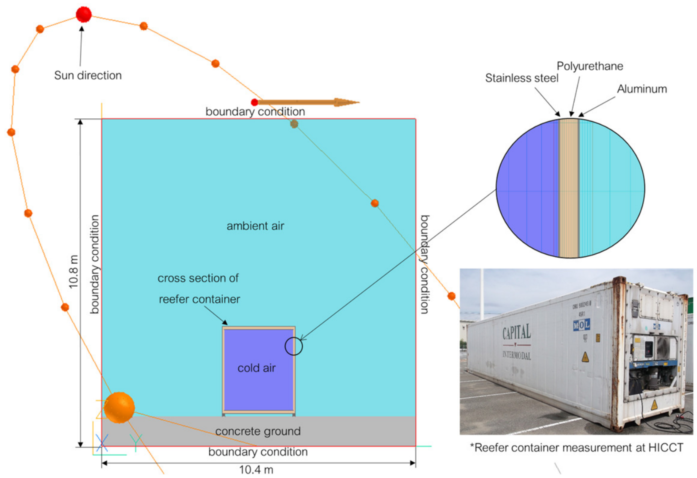


**Fig. 2.** Schematic view of simulation model

## 3. Results and Discussions

### *3.1 Location of Study*

The energy saving estimation at Jakarta International Container Terminal (JICT), Jakarta, Indonesia would be investigated from effect of the installation of roof shade. The refrigerated container storage yard on JICT in the area of Port Tanjung Priok, Jakarta, Indonesia. This terminal has 45.5 ha storage area consist 7 berth with container capacity is 39.884 TEUs. The dimension of the storage area are length 1640 meter, width 26.5 - 34.9 meter, draught 11-14 meter. This terminal also has 10,560 dry container slot and 546 refrigerated slot. The main equipment on this terminal are 16 unit quay crane container, 63 unit Rubber Tyred Gantry crane and 128 unit trailers [13]. This location was chosen since located in the tropical country near the equator which received high and stable solar intensity during a year. The average monthly solar insolation is 14 MJ/m$^2$ with the average temperature is 26°C. The introduction of the roof shade in this location potentially increase the energy saving on the container storage yard. Table 1 and Figure 3 shows the details of location and orientation of container terminal layout at JICT, Jakarta, Indonesia. The layout of refrigerated container terminal at this terminal has azimuth angle 92° from North and set the placement of refrigerated container facing to the south. Therefore, the orientation of the refrigerated container comply with the following rules, the refrigerated unit is facing the south, the door is facing the north, one side wall is facing the east and one side wall is facing to the west.

**Table 1**
Detail location of Port of Tanjung Priok, Indonesia

| | |
|---|---|
| Place | Jakarta International Container Terminal, Port of Tanjung Priok, Jakarta, Indonesia |
| Degree of longitude | 106.88° (106°52'57.8"E) |
| Degree of latitude | -6.09° (6°5'48.44"S) |
| Altitude above sea-level | 2.5 m |
| Time zone | Universal Time Coordinated (UTC) +7h |
| Orientation of refrigerated container | 92° from North (Wall Azimuth) |

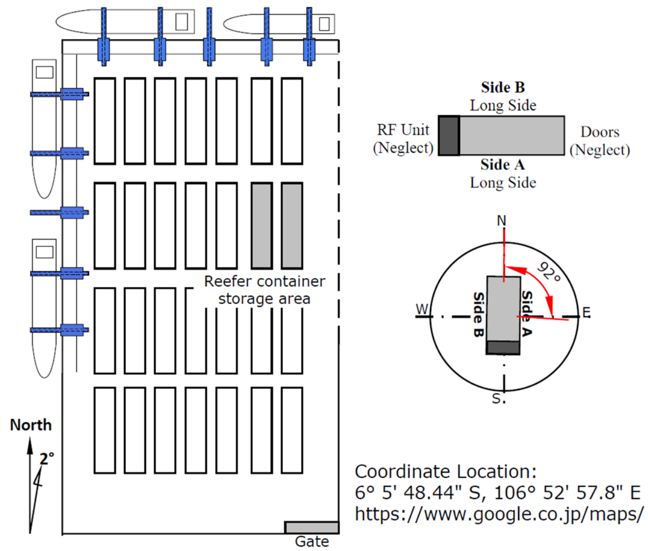


**Fig. 3.** Layout and orientation in Port of Tanjung Priok, Indonesia

### *3.2 Estimation of Energy Saving*

The intensity of the solar radiation occurs on this location can be predicted use the solar model by inputted data from the location and orientation. Figure 4 shows the prediction of the intensity of the solar radiation on 15th August 2015 in Port of Tanjung Priok used the solar radiation model. The solar radiation model on this simulation has been calibrated using empirical model studied by Nasruddin *et al.,* [14-16]. The location of this port that located in the near of equator provide the specific trend with the high solar intensity during the day. The peak of solar radiation starts to occur on the east surface with maximum intensity 650 W/m$^2$ occurs on 08:30 AM. The peak moves to the ceiling with the maximum intensity is 1000 W/m$^2$ occurs on 12:00 PM. After that the peak moves to the west surface with maximum intensity 650 W/m$^2$ occurs on 15:30. The north and bottom surface has lower peak with maximum intensity is 400 W/m2 and 150 W/m$^2$ occurs on the 12:00 PM. The profile of the solar radiation trend tends to be balanced between the morning and the afternoon. The south surface which has lower intensity due to the only diffuse solar radiation impinges on this surface.

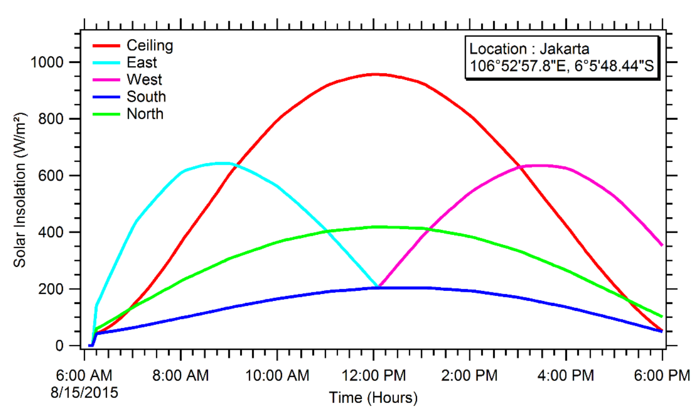


**Fig. 4.** Prediction intensity of solar radiation in Jakarta

**Table 2**
Expectation of energy saving in Indonesia

| Thermal Simulation | | Date: 15th August 2015 | |
|---|---|---|---|
| Location : JICT, Indonesia<br>Duration : 09:00 AM – 15:00 PM | | Heat Flow of container walls (*Watt*) | Ratio of Energy Consumption (%) |
| Without Roof Shade | Tier 3 | 2173.84 | 0 |
| | Tier 2 | 1819.83 | -16.29 |
| | Tier 1 | 1807.92 | -16.83 |
| Average of column | | | -11.04 |
| With Roof Shade | Tier 3 | 1683.76 | -22.54 |
| | Tier 2 | 1551.31 | -28.64 |
| | Tier 1 | 1447.21 | -33.43 |
| Average of column | | | -28.20 |
| Total energy saving for 3 tiers containers | | | -17.16 |

Table 2 shows the expectation energy saving in the port of Tanjung Priok, Jakarta, Indonesia. The calculation uses the thermal simulation result with the set date on 15th August 2015 with duration time from 09:00 AM until 15:00 AM. This period selected due to the profile of solar insolation suggest that the peak of solar radiation occurs in the morning until afternoon, wherein the effect of the roof shade could be effective during this period. The expectation results in this location estimated the energy saving from the effect of roof shade is 17.16% for the 3 container tiers in the refrigerated container storages yard.

### *3.3. Temperature Distribution*

The surface temperatures of simulation model was validated using experimental data of preceding study conducted by Budiyanto *et al.,* [17]. Temperature result on the ceiling surface has closest form with the experiment result. After ensure the simulation result has good agreement with experiment result, we try to investigate the effect installation of roof shade. Individual container with roof shade and without roof shade has been done calculated.

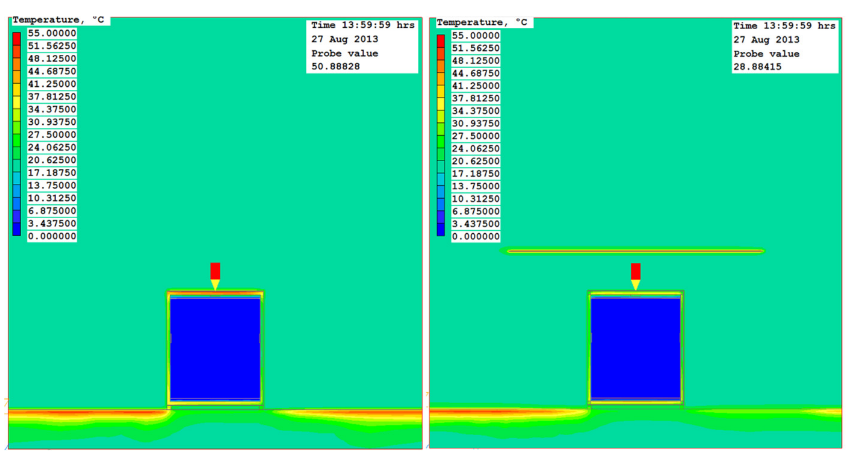


**Fig. 5.** Comparison of temperature contour between installation roof shade and without roof shade

Figure 5 show the temperature contour between both of the model. Installation of the roof serves as a sunshine shade to reduce the intensity of the solar insolation that reaches on ceiling surface and to decrease heat penetration through the wall of reefer container. In summer condition heat from the sunshine penetrated on the ceiling surface and distributing temperature to other side. Temperature on wall surface along the reefer container penetrate through the wall into container and influenced to the cooling capacity from refrigerator.

## 4. Conclusions

Thermal simulation analysis by means of computational fluid dynamic has been performed to estimate the energy saving by the installation of roof shade for refrigerated container storage yard. The simulations estimate the energy saving from effect of installation of roof shade is about 17% in the Jakarta International Container Terminal (JICT). From the simulation cases, concluded that design of installation roof shade effective to reduce energy consumption.

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