

## Heat transfer on residential roofs with the HT-Flux software

L. M. F. Purwanto 

Doctoral Architecture Study Program Concentrating on Digital Architecture  
Universitas Katolik Soegijapranata Semarang  
Jl. Pawiyatan Luhur IV/1, Bendan Duwur, Telp. (024) 8441555,  
Semarang - 50234, Indonesia



ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received October 12, 2023 Received in revised form Nov. 01, 2023 Accepted November 15, 2023 Available online December 01, 2023</p> <p><i>Keywords:</i> Heat transfer HT-Flux Residential house Roof construction</p> <p><b>Corresponding author:</b> L. M. F. Purwanto Doctoral Architecture Study Program Concentrating on Digital Architecture Universitas Katolik Soegijapranata Semarang, Indonesia Email: <a href="mailto:lmf_purwanto@unika.ac.id">lmf_purwanto@unika.ac.id</a> ORCID: <a href="https://orcid.org/0000-0002-7081-489X">https://orcid.org/0000-0002-7081-489X</a></p>	<p><i>Buildings in Indonesia, which has a humid tropical climate, receive direct exposure to sunlight on the roof. The influence of this heat will directly affect the space under the roof and will increase the temperature significantly. Heat transfer is often not taken into account carefully in building physics calculations, even though increasing temperature will affect energy consumption. This research was carried out to determine the distribution of heat and how to prevent the entry of solar heat through the HT-Flux software. The aim of this research is to analyze heat transfer patterns and prevention efforts in buildings. The research method used is an experimental method, where roof construction patterns are tested, to obtain the right roof construction in tropical areas. The result of this research is to obtain damping on the roof by testing it with HT-Flux software.</i></p>

### Introduction

In residential buildings in tropical areas, thermal planning is often rarely taken into account carefully (L. M. F. Purwanto and Lake 2021). Solving the thermal problem will be easy to do with artificial air conditioning, be it a fan or AC. Meanwhile, the rate of entry of solar heat is the largest contributor to indoor heat and needs to be conditioned so as not to disturb thermal comfort, this needs to be considered, especially from the side of the building roof (Leonardus Murialdo Fransiskus Purwanto 2019). The choice of building materials, roof covering color, roof construction, ceiling covering and dampening efforts need to be carefully considered so that the

building becomes more comfortable and shadier (Banionis et al. 2012; Ashhar and Lim 2020).

Several studies on heat transfer have been carried out, especially in sub-tropical areas, which is useful for planning and implementing heat insulation from inside the building produced by space heaters, so that it does not radiate out through the walls, which results in a waste of space heating energy (Antonopoulos and Democritou 1993). Efforts to reduce heat entry through walls in buildings outside the tropics always suggest adding wall insulation (Abdullah and Aboud 2016). This wall insulation is not necessary in buildings in tropical areas. The shading design of the roof is important because it uses air movement to distribute hot air around the building.

Several studies on heat transfer through roofs were also carried out in sub-tropical climates, related to insulation that prevents heat from leaving the building, with an insulation design that is more rigid than that used on walls. Villi, Pasut, and Carli (2009) examined the rate of heat transfer on roofs using CFD software which is quite complicated in its calculations (Villi, Pasut, and Carli 2009). Calculations using trials of several roof material elements were carried out by Ravikumar and Srinivasan (2012), to obtain optimal results for reducing heat in India. Several building materials are recommended with the addition of insulation on the roof to limit the rate of heat transfer into the building.

The use of HT-Flux computer software for heat transfer calculations was carried out by Bienvenido-Huertas et al. (2018), but was not used to calculate heat transfer through walls and roofs. Therefore, it is concluded that the research that will be carried out in the form of calculations using HT-Flux software to calculate heat transfer through walls and roofs which influences the increase in temperature inside the building, has never been carried out.

In heat transfer calculations, we always use a finite element calculation approach, namely heat transfer calculations that divide the object of observation into small components, in order to obtain a more detailed and accurate depiction of the results. This Finite Element is a numerical procedural step that produces solutions to differential equations, both Ordinary Differential Equations and Partial Differential Equations in engineering problems and physics problems in everyday life, which can be applied in heat transfer calculations (Zhu 2018). This finite element processes data from heat transfer calculations which include; Surface resistance ( $1/\alpha$ ), Heat loss rate ( $q$ ), object resistance ( $1/\Lambda$ ), thus heat resistance ( $R$ ), surface conductivity (Uvalue) (L. M. F. Purwanto and Chandra 2023).

The problem of this research is to determine the ideal roof covering that is able to inhibit heat transfer into the building and produce careful calculations through HT-Flux software simulation to produce appropriate roof construction in residential buildings in tropical climates. This research aims to provide a real picture of the influence of sunlight and solar heat into buildings which conduct heat into the building. This incoming heat will significantly affect thermal comfort. By studying this, this research can provide and benefit in designing

comfortable residential buildings with temperature increases that are not too large and make the temperature increase in the space below not too significant. The roof and ceiling construction in the house can be used as a reference for use in the community. This heat transfer calculation by providing a real picture through simulation in HT-Flux has never been done before and a picture of roof construction which is linked to the heat distribution that occurs, provides a real picture for architects and the public in determining a comfortable residential building design.

## Method

The research method used is an experimental research method by conducting trials on different roof shapes, measuring and analyzing the heat transfer that occurs. The use of HT-Flux Software helps calculate heat transfer on the selected roof construction.

HT-Flux software was developed by HT-Flux Engineering GmbH Austria, which can calculate Heat flow, U-value,  $\Psi$ -value, fRsi value, and temperature extreme values. Calculations of Heat flow, U-value,  $\Psi$ -value, fRsi value, and temperature extreme values are very necessary for heat transfer through walls and roofs which will affect thermal comfort in buildings and efforts to reduce energy use in tropical areas for the use of artificial conditioning. the optimal one. Heat leaks entering the building will increase the temperature inside the building which will impact energy consumption to reduce the temperature (Ghanim and Ahmed 2020).



Figure 1. HT-Flux Software

## Result and discussion

In residential buildings, the roof plays an important role in preventing the flow of solar heat into the building. Restraining this rate can be done by adding paint (coating) which prevents heat propagation into the building (Farhan et al. 2021; Kaduchová, Lenhard, and Malcho 2020). In

residential buildings in tropical areas, insulation is often neglected (Chowdhury and Neogi 2019). Residential buildings in Indonesia often use tile and asbestos roof coverings (Rafika, Ridwan, and Murtyas 2016; Joshi 2020). These two roof coverings are used as research objects with the addition of a ceiling as a damper or heat insulation so that the rate of heat is hampered. This research uses both types of roof covering as a trial (experiment) and the addition of a ceiling, which is then simulated with HT-Flux software to see the rate of heat that occurs.

Roofs with asbestos roof coverings have a smaller roof slope angle compared to roof constructions with clay tile coverings, resulting in the influence of heat and its distribution being even throughout the parts with very high temperatures. Heat distribution is important in heat transfer on roofs (Kaduchová, Lenhard, and Malcho 2020). The heat distribution on an asbestos roof is simulated with the following results:

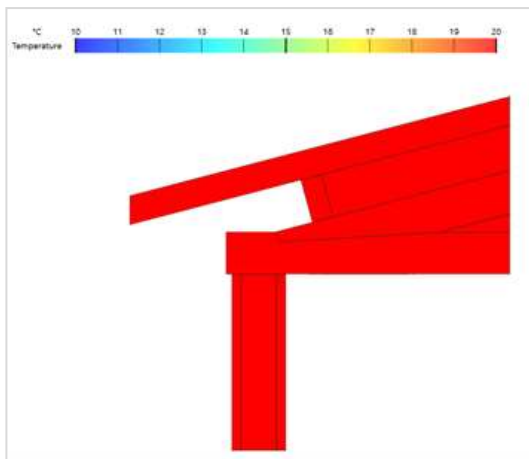


Figure 2. Temperature of asbestos roof covering

The distribution of heat transfer that propagates in asbestos roof coverings looks even and affects the entire surface according to the shape and construction material of the roof (Mahmoodzadeh and Fatehi 2019) as in the following picture:

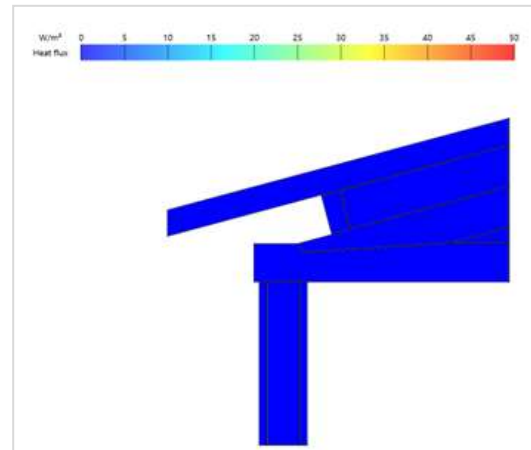


Figure 3. Heat flux in asbestos roof covering

#### Design solutions

##### A. Clay tile roof covering with gypsum ceiling

Providing a ceiling under the roof construction has a significant influence on heat attenuation in the building. Ceiling dampening slightly reduces the temperature under the roof, giving rise to differences in heat distribution in the roof construction (Rangel et al. 2022). The connection point where the roof and walls meet requires attention to be provided with a solution for thermal insulation that prevents heat from entering the building.

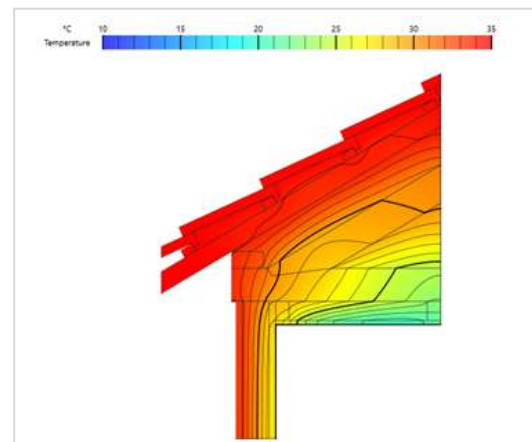
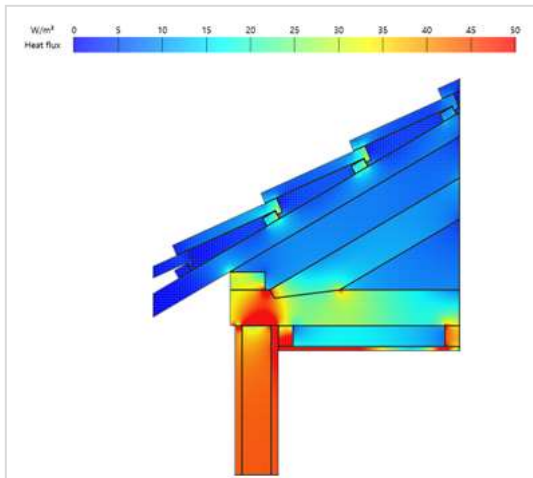


Figure 4. Temperature of clay tile roof covering with gypsum ceiling

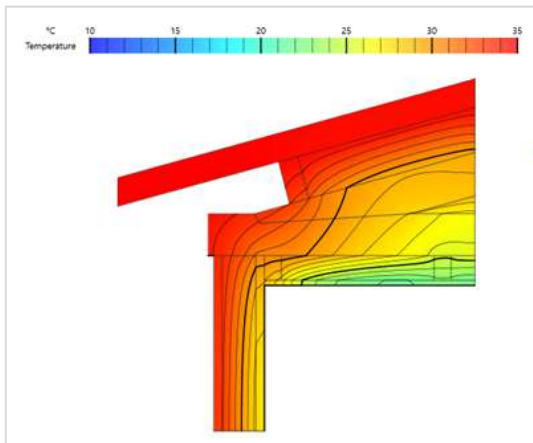
The distribution of heat transfer can be seen, that the roof connection becomes a thermal bridge and becomes heat flux to the building.



**Figure 5.** Heat flux in a clay tile roof covering with a gypsum ceiling

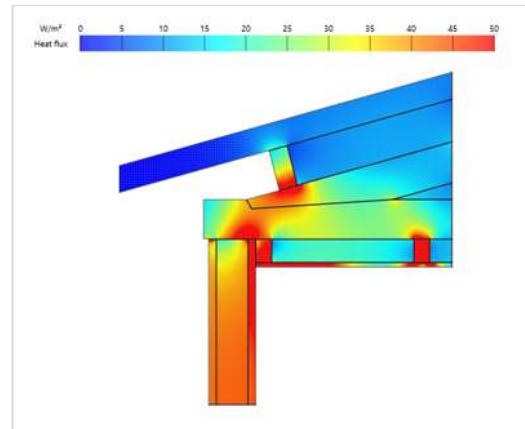
B. Asbestos roof covering with the addition of a gypsum ceiling

After being given a gypsum ceiling, it was seen that there was heat distribution and a decrease in heat in the roof area. However, the angle of the roof slope still has a significant effect on reducing heat, because a lower roof angle provides a small space under the roof, so that the air inside which can also be used as heat retainer has a small amount (Samah, Banna, and Zeghmati 2022), so it cannot optimally withstand heat.



**Figure 6.** Temperature of asbestos roof covering with gypsum ceiling

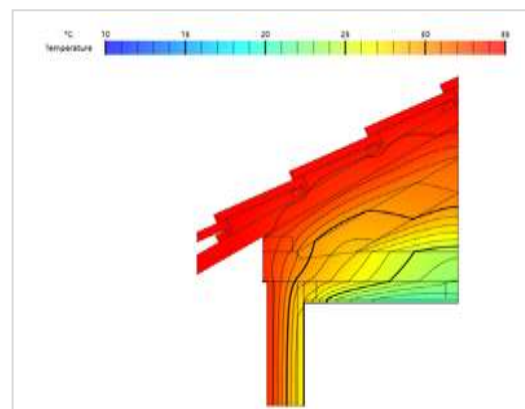
Heat transfer increases at the junction of walls and roofs, due to the influence of material, the angle of inclination of the building and the area of exposure to light which has an impact on heat distribution (Zhang et al. 2022).



**Figure 7.** Heat flux in asbestos tiles with gypsum ceilings.

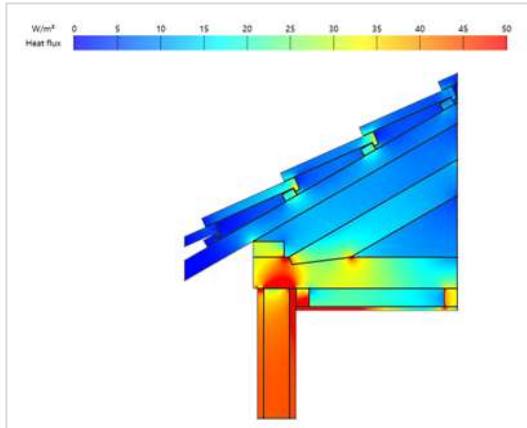
C. Clay tile wall and roof covering with gypsum ceiling and heat insulation on the roof

The addition of heat insulation space containing air spaces between the roof construction in the form of Styrofoam and glasswool, has not provided a significant temperature reduction in roof construction, both on roofs with clay tile roof coverings and asbestos roof coverings. This can be seen in the heat distribution in Figures 8, 9, 10 and 11. The connection point between the roof and wall construction shows that the highest heat influence occurs in that area. A computer simulation approach is very helpful in producing the distribution of heat transfer in this roof construction (Vazquez-Ruiz et al. 2022). The distribution of heat transfer on a dampened roof results in a significant reduction in the heat distribution area. The heat insulation used is Styrofoam 5 cm thick and glasswool + aluminium foil 2.5 cm thick.



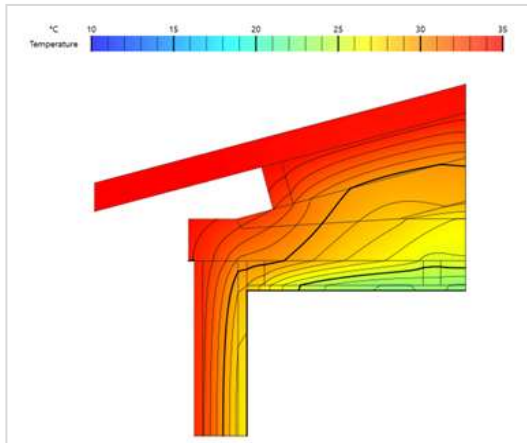
**Figure 8.** Temperature of clay tile roof covering with gypsum ceiling and heat insulation on the roof

The heat transfer rate begins to decrease and the roof space shows a decrease in temperature (Rajavel et al. 2020). This temperature reduction is influenced by the addition of appropriate heat insulation and placed under the roof covering which inhibits the rate of heat.



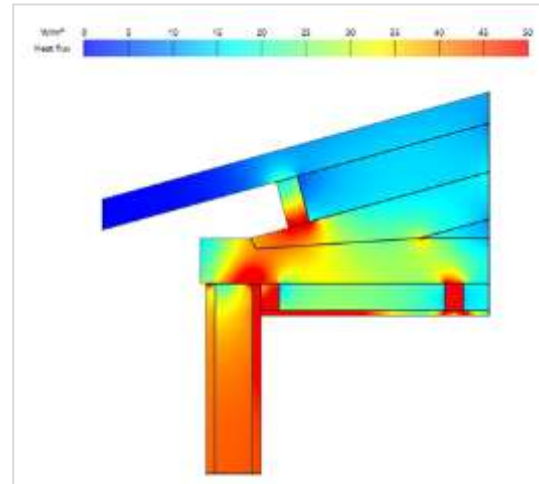
**Figure 9.** Heat flux in clay tile roof covering with gypsum ceiling and heat insulation on the roof

The asbestos roof covering is treated with the same heat insulation addition as in the tile roof covering construction. For asbestos, the temperature decrease is not seen as significantly, because the slope is gentle. However, a decrease in the heat transfer rate still occurs.



**Figure 10.** Temperature of asbestos roof covering with gypsum ceiling and heat insulation on the roof

The heat transfer rate can be slightly reduced by the addition of thermal insulation. Thermal insulation construction provides a good impact and increases the ability to withstand the rate of impact inside the building.



**Figure 11.** Heat flux in asbestos roof covering with gypsum ceiling and heat insulation on the roof

## Conclusions

The addition of heat insulation in roof construction has a significant effect in inhibiting heat transfer into the building. Heat insulation can be done under the roof covering and adding a ceiling is the right step. The reduction in heat transfer affects the heat transfer rate which affects the space under the roof.

## References

- Abdullah, Hassan Kareem, and Sajad M. Aboud. 2016. 'Reduction of Heat Transfer through Walls in Buildings by Using Insulation'. *International Journal of Computer Applications* 141 (4).
- Antonopoulos, K. A., and F. Democritou. 1993. 'On the Non-Periodic Unsteady Heat Transfer through Walls'. *International Journal of Energy Research* 17 (5): 401–12. <https://doi.org/10.1002/er.4440170508>.
- Ashhar, Muhamad Zahin Mohd, and Chin Haw Lim. 2020. 'Numerical Simulation of Heat Transfer in a Roof Assembly with Reflective Insulation and Radiant Barrier'. *Building Simulation* 13: 897–911.
- Banionis, Karolis, Edmundas Monstvilas, Vytautas Stankevičius, Raimondas Bliudžius, and Kestutis Miškinis. 2012. 'Impact of Heat Reflective Coatings on Heat Flows through the Ventilated Roof with Steel Coatings'.



- Journal of Civil Engineering and Management* 18 (4): 505–11.  
<https://doi.org/10.3846/13923730.2012.700943>.
- Bienvenido-Huertas, David, Juan Antonio Fernández Quiñones, Juan Moyano, and Carlos E. Rodríguez-Jiménez. 2018. 'Patents Analysis of Thermal Bridges in Slab Fronts and Their Effect on Energy Demand'. *Energies* 11 (9): 2222.  
<https://doi.org/10.3390/en11092222>.
- Chowdhury, Debasish, and Subhasis Neogi. 2019. 'Thermal Performance Evaluation of Traditional Walls and Roof Used in Tropical Climate Using Guarded Hot Box'. *Construction and Building Materials* 218 (September): 73–89.  
<https://doi.org/10.1016/j.conbuildmat.2019.05.032>.
- Farhan, Syed Ahmad, Fouad Ismail Ismail, Osamah Kiwan, Nasir Shafiq, Azni Zain-Ahmed, Nadzhratul Husna, and Afif Izwan Abd Hamid. 2021. 'Effect of Roof Tile Colour on Heat Conduction Transfer, Roof-Top Surface Temperature and Cooling Load in Modern Residential Buildings under the Tropical Climate of Malaysia'. *Sustainability* 13 (9): 4665.  
<https://doi.org/10.3390/su13094665>.
- Ghanim, Mohannad, and Sabah Ahmed. 2020. 'Reducing Roof Solar Heat Gain by Using Double-Skin Ventilated Roofs'. *Engineering and Technology Journal* 38 (3A): 402–11.  
<https://doi.org/10.30684/etj.v38i3A.462>.
- Joshi, Vijesh. 2020. 'Heat Transfer Characterization of Test Rooms with Six Different Roofs'. *International Journal of Heat and Technology* 38 (1): 131–36.  
<https://doi.org/10.18280/ijht.380114>.
- Kaduchová, Katarína, Richard Lenhard, and Milan Malcho. 2020. 'Numerical Simulation of Heat Transfer Using Cooling Roof Panels'. Edited by R. Lenhard and K. Kaduchová. *MATEC Web of Conferences* 328 (November): 02014.  
<https://doi.org/10.1051/mateconf/202032802014>.
- Mahmoodzadeh, Milad, and Rouhollah Fatehi. 2019. 'Numerical Investigation of Roofing Materials Effect on Solar Heat Gain in Different External Conditions'. *Journal of Heat and Mass Transfer Research* 6 (1).  
<https://doi.org/10.22075/JHMTR.2018.3059.1143>.
- Purwanto, L. M. F., and Budijanto Chandra. 2023. *No Title Transfer Panas Pada Desain Bangunan Tropis*. Semarang: Universitas Katolik Soegijapranata.
- Purwanto, L. M. F., and Reginaldo Chistophori Lake. 2021. 'Architecture and Culture, Architecture Grows'. *ARTEKS : Jurnal Teknik Arsitektur* 6 (2): 155–56.  
<https://doi.org/10.30822/arteks.v6i2.1269>.
- Purwanto, Leonardus Murialdo Fransiskus. 2019. 'Simulasi Transfer Panas Pada Dinding Dengan Software Therm 7.7'. *ARTEKS : Jurnal Teknik Arsitektur* 4 (1): 111–16.  
<https://doi.org/10.30822/arteks.v4i1.215>.
- Rafika, Anggi, Kholid Ridwan, and Solli Dwi Murtyas. 2016. 'Pengaruh Variasi Material Penutup Atap Terhadap Distribusi Temperatur Pada Bentuk Atap Tradisional Joglo'. Universitas Gadjah Mada.
- Rajavel, R., A. Makudesh Arjun Kumar, N. C. K. Amaranath, J. Harishkumar, and Mahendran. 2020. 'Analysis of Heat Reduction through Technique Roof Using Innovative Insulation Technique'. *International Research Journal on Advanced Science Hub* 2 (1).
- Rangel, Caribay Godoy, C.I. Rivera-Solorio, M. Gijón-Rivera, and Seyedehniloufar Mousavi. 2022. 'The Effect on Thermal Comfort and Heat Transfer in Naturally Ventilated Roofs with PCM in a Semi-Arid Climate: An Experimental Research'. *Energy and Buildings* 274 (November): 112453.  
<https://doi.org/10.1016/j.enbuild.2022.112453>.
- Ravikumar, M., and P. S. S. Srinivasan. 2012. 'Analysis of Heat Transfer Across Building Roof with Phase Change Material'. *Journal of Computational Information Systems* 8 (4): 1497–1505.
- Samah, Hodo-Abalo, Magolmèèna Banna, and Belkacem Zeghmati. 2022. 'Double Diffusive Convection Heat and Moisture Transfer Inside a Planted Roof Building Under Hot Humid Climate: Case of Lomé City in West Africa'. *American Journal of Applied Sciences* 19 (1): 6–20.  
<https://doi.org/10.3844/ajassp.2022.6.20>.
- Vazquez-Ruiz, A., J. M. A. Navarro, J. F. Hinojosa, and J. P. Xamán. 2022. 'Computational Fluid Dynamics and Experimental Analysis of the Heat Transfer in a Room With a Roof Solar Chimney'. *Journal*

- of Thermal Science and Engineering Applications* 14 (4).  
<https://doi.org/10.1115/1.4051454>.
- Villi, Giacomo, Wilmer Pasut, and Michele De Carli. 2009. 'CFD Modelling and Thermal Performance Analysis of a Wooden Ventilated Roof Structure'. *Building Simulation* 2 (3): 215–28.  
<https://doi.org/10.1007/s12273-009-9414-7>.
- Zhang, Ying, Hongfa Sun, Jibo Long, Li Zeng, and Xiaohang Shen. 2022. 'Experimental and Numerical Study on the Insulation Performance of a Photo-Thermal Roof in Hot Summer and Cold Winter Areas'. *Buildings* 12 (4): 410.  
<https://doi.org/10.3390/buildings12040410>.
- Zhu, Bofang. 2018. *The Finite Element Method: Fundamentals and Applications in Civil, Hydraulic, Mechanical and Aeronautical Engineering*. singapore: John Willey & Sons Ltd., Chichester.

