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Building heat transfer teaching with web tools

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Abstract: This paper introduces a web-based tool to help students understand building heat transfer and energy saving potential. Different building envelope thermal properties and heat loss were studied and compared between 5 cities in 5 climate regions in China. This method makes students to better understand how wall and roof construction materials influence energy demands of buildings.

Keywords: Building energy; Teaching; Heat transfer.

1. Introduction

Building heat transfer rate is a key factor influencing building energy performance [1-5]. Heat transfer is the science and art of predicting the rate at which heat flows through substances under various external conditions. The laws of heat transfer govern the rate at which heat energy must be supplied to or removed from a building to maintain the comfort of occupants or to meet other thermal

requirements of buildings. Heat transfer fundamentals and concepts are used in the course of building physics to help students estimate heating and cooling needs for whole buildings However, due to the complexity and time consuming of doing manual heat transfer calculation. This paper tries to introduce a web-based tool to help students understand the heat transfer knowledge and calculation in building physics.

2. Method

The basic ways of building heat transfer include conduction, convection and radiation. For traditional teaching, conduction heat transfer was asked students to practice and the basic formulas of conduction heat transfer calculation requires students to first calculate thermal transmittance value, which is shown as follows:

$$U = \frac{1}{R_{si} + \sum_{j=1}^{n} R_j + R_{se}} \tag{1}$$

Where U represents thermal transmittance value of a building component such as wall, roof. R represents thermal resistance. For a multi-layer construction, students need to separately calculate thermal resistance of each material and get the total value. Then heat transfer rate Q can be calculated by the following formula:

$$Q=U\times A\times(Ti-To) \tag{2}$$

Where A is area, Ti,To mean indoor and outdoor temperature. And to compare different constructions, this calculation will be repeated many times and thus it is time consuming. Therefore, a web-based tool (see Fig.1) was introduced to help students easily calculate U values and Q value. This tool is able to calculate different construction material layers and so it is suitable for realistic wall and roof settings.

An assignment was given based on this tool. Details of this assignment is listed below:

(1). Calculate the total energy loss during typical 3 days of winters (from 1.1 to 1.3) for 5 cities (shanghai, harbin, beijing, guangzhou, kunming) in China. Students need to use the web tool (http://cleanenergy4future.com/) to finish this assignment. Assume a 3×3×3 room model without windows. Wall, roof and floor construction settings should be about 3-7 layers of materials and U values of the constructions should be between 0.2-1.5W/m2K (baseline setting). So everyone will get different results.

(2). Calculation 1: You need to calculate hourly energy loss and draw graphs to illustrate the variation of energy loss with time and then sum them up to get the total for the following comparison. Use graph to demonstrate your data and analysis. Also screenshot the typical calculation processes of using the web tool and put them in ppt.

(3). Calculation 2: Calculate the energy savings for each city by reducing the above baseline U values by about 30% (energy saving setting).

(4). The epw file containing hourly outdoor temperature can be downloaded from energyplus.net. And the hourly temperature can be obtained using elements tool (link: https://bigladdersoftware.com/projects/elements/)

(5). Compare the difference in energy loss and energy savings between the 5 cities and analyze the impact of climate on energy performance. you also need to introduce the climate conditions for the cities.

(6). Your suggestions on building design based on the above analysis.

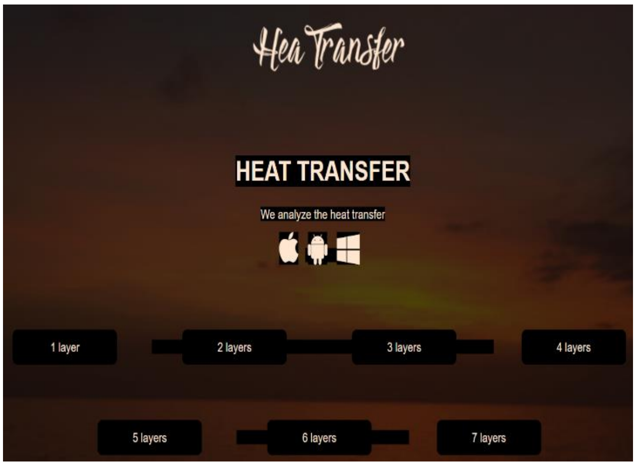

Fig. 1 The interface of the web-based tool

3. Results

The wall material setting of one student's assignment was illustrated in Fig.1. He used cement plaster, block concrete, polyurethane and bricks. Then the thermal properties and thickness of each material is inputted in the web tool and indoor and outdoor temperatures were also entered. By clicking the calculate button, the final results including R and U values of the wall construction were obtained. And the heat loss through this wall construction was also calculated and obtained. By this simple process, students can easily adjust wall and roof constructions and compare the heat loss between different time of day and different cities.

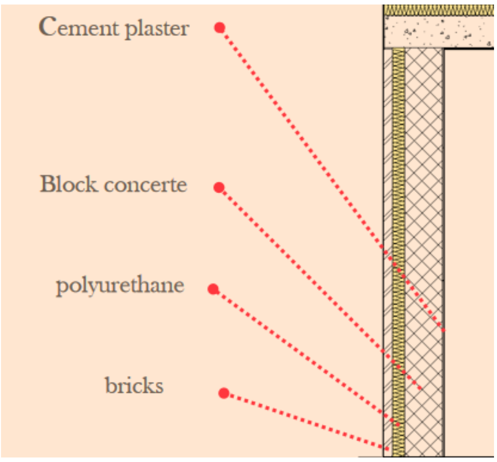

Fig. 2 Wall material setting

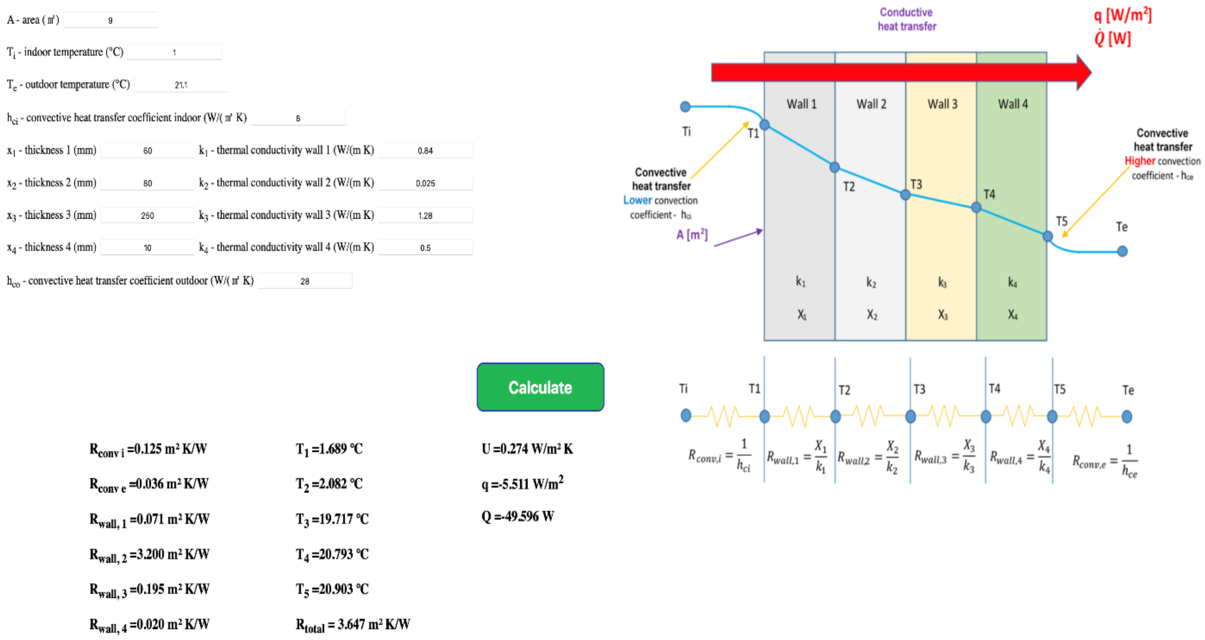

Fig. 3 Results of heat transfer calculation

Fig. 4 shows the heat loss for Harbin for 3 days. And similar calculation was conducted and heat loss for other cities were obtained and illustrated in Fig. 5. It shows that Harbin has the highest heat loss while Guangzhou has the least heat loss. Therefore, different energy saving measures can be proposed by students based on these calculations.

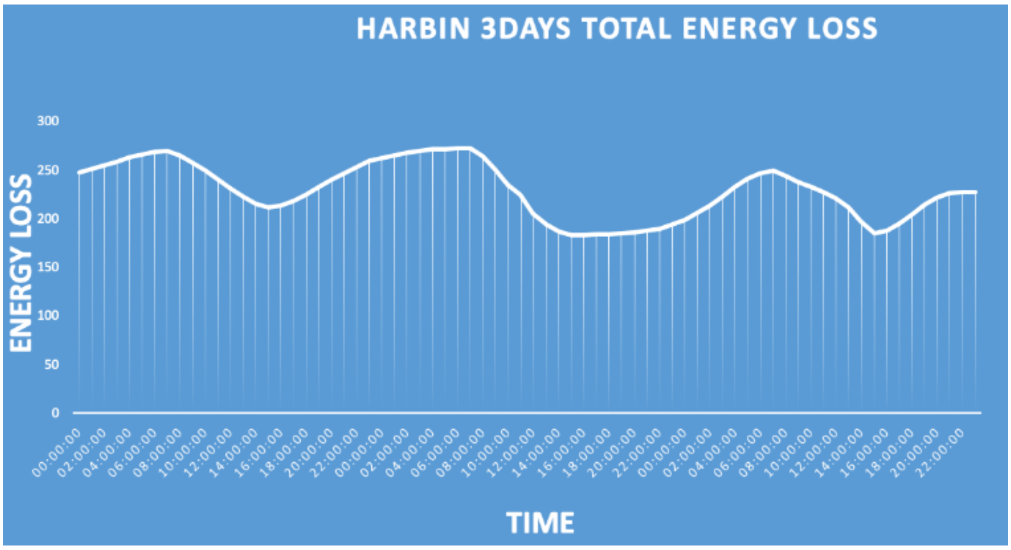

Fig. 4 Heat loss for Harbin for 3 days

			AVARAGES	
CITIES	TOTAL ENERGY LOSS FOR 3DAYS	TOTAL ENERGY SAVING FOR 3DAY	AVARAGE ENERGY LOSE FOR 3DAYS	AVERAGE ENERGY SAVING
HARBIN	1652.406	23607.72286		
BEIJING	10134.62	14478.02857		
SHANGHAI	8195.965	11708.52143		
GUANGZHOU	4069.797	5813.995714		
KUNMING	5750.132	8214.474286		
			5960.584	12764.54857

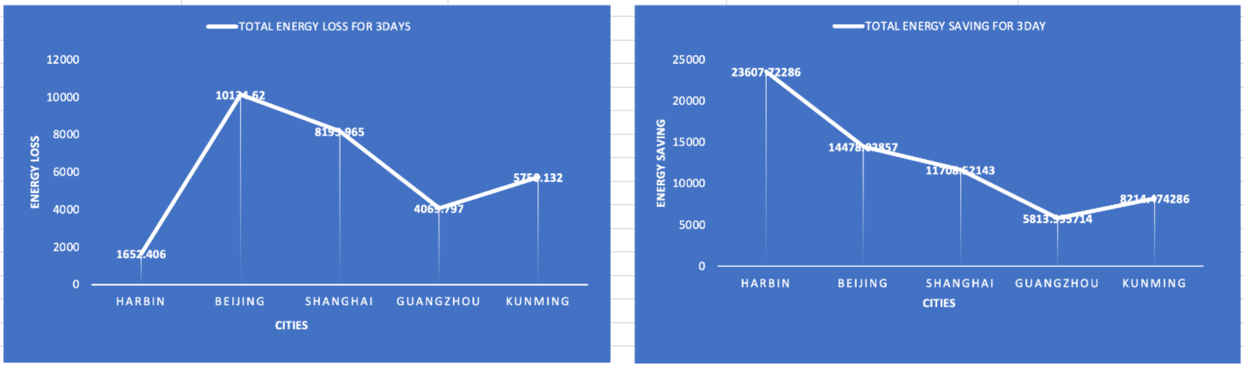

Fig. 5 Heat loss comparison

4. Conclusions

A web-based tool was used in teaching heat transfer calculation and it can be easily used by students without any difficulty. In addition, energy saving measures can be proposed by students based on these calculations.

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