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Mathematical modelling of performance of new type of climate adaptive building shell

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Abstract

Authors have developed an idea – a new facade system able to adapt to ambient conditions in order to cut heating demand in winter. The facade is called Passive Heating Facade. The facade extracts ground heat from a shallow depth and consequently the temperature of the facade rises. The heat extraction is ensured by passive mechanisms only so no additional energy is necessary.
In this work feasibility of proposed system is assessed by the Computational Fluid Dynamics tool ANSYS CFX 16.2. A mathematical model is also applied to calculate possible heat gains of the Passive Heating Facade. Initial analysis of the simplified mathematical model shows that the proposed system is able to extract ground heat for facade heating purposes. It was calculated that one component of the Passive Heating Facade is able to generate around 45 kWh in one season, however the final design consists of several systems.

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Keywords: climate adaptive building shell; CABS; natural circulation loop; NCL; nearly zero energy building; NZEB

1. Introduction

In the European Union (EU) fossil fuels are still among primary energy sources, which contribute to greenhouse gases (GHG) emissions heavily. The building sector (households and industrial buildings), in particular, is responsible for 40 % of all energy consumed in the EU. The household sector is responsible for ¼ of total energy consumption in the union (26.8 % in 2013). There most of this energy is consumed by HVAC – 68 % on average through Europe [1].

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1.1. European policy

EU has developed a mechanism to cut GHG emissions in the household sector by at least 20 % below the levels of 1990 by the year 2020. One of the tools to reach it is Directive 2010/31/EU which sets minimal requirements for energy performance of all new and renovated buildings. The Directive states that after January 1st, 2021 all new buildings must be Nearly Zero Energy Buildings (NZEB) [2].

With current building designs, it is crucial to cut GHG emissions where they are produced the most, i. e., heating and cooling. In northern climates like Latvia most of the year ambient temperature is low and indoor climate is ensured by heating. In Latvia the heating season lasts more than 200 days a year in most of the country.

Studies have shown that for northern climatic conditions with common construction techniques it is quite challenging to achieve cost effective solution for NZEB. Thus new types of building construction materials and efficient engineering systems should be developed. This paper focuses on the development of a new facade system [3].

1.2. Climate adaptive building shell

Recently a new facade concept called Climate Adaptive Building Shell (CABS) has emerged. CABS is a facade system with an ability to adjust its performance in changing climatic conditions in order to save energy.

Loonen et al. [4] have defined CABS as follows “It has the ability to repeatedly and reversibly change some of its functions, features or behavior over time in response to changing performance requirements and variable boundary conditions, and does this with the aim of improving overall building performance”.

The authors propose to tackle NZEB challenges by offering new CABS concept. The idea is to extract ground heat in the winter for facade heating purposes. This way heat losses from inside will be “intercepted”. Key aspect for author proposal is to take advantage of buoyancy (natural convection) in order to avoid auxiliary energy use, this way the facade would automatically turn on heat extraction when ambient temperature drops to certain levels and it would turn itself off when heat extraction is not necessary or possible.

1.3. Natural Circulation loop

Natural circulation of fluids, both liquids and gases, is a circulation ensured without any external forces applied only due changes in fluid density and gravity. As generally known, most fluids, when heated, are expanding thus becoming less dense and moving upwards (buoyancy force). However, when a fluid cools, it becomes denser so the gravitational pull is stronger on molecules of the fluid and the molecules are pulled down [5].

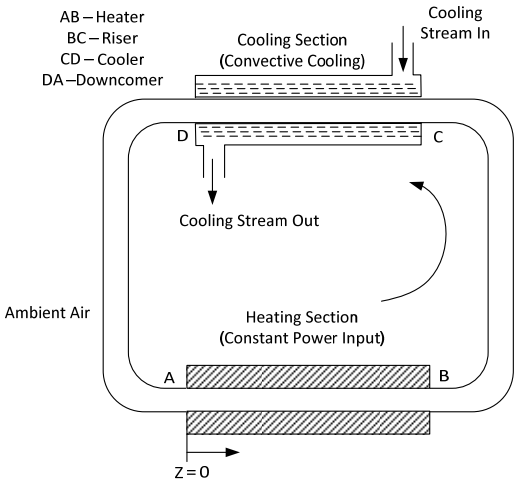

Fig. 1. Simple representation of the NCL [6].