学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Study on Vacuum Insulation Panels with Slim-thickness and Light-weight and Their Application Method for Retrofitting Insulation to Existing Buildings
(既存建築の断熱改修に寄与する薄型・軽量の真空断熱材とその適用方法に関する研究)

Of late, energy is required more to satisfied with the development of human society. With such a situation, more energy demand makes the energy shortage issue serious and the global warming also increased growth up. According to the "Kyoto Protocol" and "Strategy of sustainable development", conversation of energy and reduction of CO2 emissions is already a global topic.

Traditional buildings consume 40

This study aimed at retrofitting insulation to existing buildings by applying vacuum insulation panels (VIPs). The VIPs have relative long history to install to the refrigerators as insulation material. And now it's popular to apply to buildings to improve the insulation performance. Conventional VIPs also have issues, such as: expensive production cost, lack of airtightness, complex construction, low durability and big thermal bridge.

Chapter 1 is the introduction, background of this study is presented. Applying VIPs to retrofit insulation to existing buildings is good for energy conversation. And objective and proposal is established in this Chapter.

Chapter 2 presents the historic development of VIPs. The conventional studies is discussed and compared with our proposal, then the significance of our objective is proposed show the position of this study.

Chapter 3, The authors are developing slim and light-weight vacuum insulation panels (VIPs) by producing vacuum layers with spacers and plastic plates, firstly. The developed VIPs have the advantages of a low cost and easy installation in existing buildings. In addition, one of the developed VIPs is slim and translucent so that it can be easily used for windows. In this view, the authors propose a vacuum layer type slim translucent VIP and focus on a reasonable design method. Next, the authors introduce the design process in which the structural design is obtained with element mechanical analysis and a three-dimensional analysis is conducted for the VIP element. In the study, a heat transfer model is used to predict the insulation performance through numerical analysis. Subsequently, the authors perform an experiment to measure the thermal conductivity to validate the performance prediction. Finally, case studies are performed to confirm how the different design conditions affect the insulation performance. The optimum design of the vacuum layer type slim and translucent VIP will have sufficient structural strength to hold and maintain the vacuum layer. The thermal conductivity is approximately 0.007 W/(m·K) that can effectively improve the insulation performance in applications.

Chapter 4, to ensure the performance of our proposal, the authors proposed a frame structural VIP so that the total material area should be reduced and the possibilities of gas generation should be reduced. Then, the authors propose a frame structural slim translucent VIP and focus on a reasonable design method. The same process as Chapter 3, after design and validation, the thermal conductivity is approximately 0.0049 W/(m·K) that can effectively improve the insulation performance in applications.

Chapter 5, the authors give 5 different proposal to test and validate the VIP performance, of course these 5 models are totally transparent design. In this Chapter, the authors analyzed the experimental result and the outgassing and desorption issue should be the largest effect to VIP production. Additionally, the mesh and frame structural VIPs can achieve a relatively better insulation performance, however, the thermal bridge is large and the transparency is not good due to the concentrated web. Finally, the authors summarized the properties of those transparent VIP models, and the reasonable suggestion can be proposed to improving the performance further.

Chapter 6, proposal of an overlapped VIP combination to the walls. Slim and multiple layered VIPs can be applied to reduce the effect of the thermal bridge, for improving the architectural insulation performance. In this Chapter, a calibration hot-box apparatus is setup to evaluate the "U" values and the apparent thermal conductivity of a multilayered combination of VIPs. Then, a calculation model is generated for analyzing the insulation performance of full-scale VIPs, which is solved using Finite Element Analysis (FEA). As per the experimental results, the apparent thermal conductivity in a triple layer application should be 1.083 times that of the original; numerical results demonstrate that for a large VIP application with a triple layer, the apparent thermal conductivity is 1.004 times the original.

Chapter 7, summary of this study, discussed the design method and every proposal has been validated and the objective is reached with various achievements. Finally, the outlook and perspective is given in the end.