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Modular retrofitting solution of buildings based on 3D scanning

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Abstract

Building stock is one of the crucial energy consumers in Europe. The majority of the European residential and public buildings were constructed after the Second World War. The external building envelope of these buildings has very poor thermal insulation properties with regards to modern requirements. There are several well known building retrofitting technologies such as rendered and double facades. These retrofitting technologies require large amount of on-site human working mounts. However, there might be significant limitations in mounting processes of the unclassified buildings such as prisons, military buildings and other buildings with specific safety requirements. In scope of this article the benefits of modular retrofitting solutions are taken into consideration. The paper presents the results of the architectural project development specifics as well as selection of the optimal modular panel layout, integration of existing communication and modular panels junctions solutions.
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Keywords: modular retrofitting; 3D scanning; BIM; thermal bridges

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1. Introduction

The building envelope has a major impact on the building's energy use, especially when it comes to its thermal properties. Buildings with high infiltration rates have generally good indoor air quality, however, high infiltration rates lead to high heat losses that will increase heating bills dramatically. On the contrary, buildings with low infiltration rates may have good thermal properties, whereas, indoor air quality requirements may not be satisfactory without either a natural or mechanical ventilation. The multi-active façade is a building façade that compiles both the structural function and energy-efficiency function by integrating various building materials and active components such as heat recovery elements, ventilation and/or water pipes, BIPV and others. Their main function is to satisfy thermal and indoor air requirements as well as significantly reduce energy bills on heating and ventilation (and cooling). The project group [1] at LTH defines a multi-active façade element as a building envelope integrated with additional insulation in combination of integrated active heating and ventilation systems as a prefabricated façade element [2]. The prefabricated thermal insulation panels are one of the most appropriate technology for retrofitting not only the apartment buildings but also the unclassified buildings since it reduces the on-site installation time and allows integration of active component. Thus, it also minimizes the amount of on-site human working hours. Recent EU projects such as MORE-CONNECT, Ri.Fa.Re, RENEWSchool, ANNEX etc. have proven the benefits of prefabricated renovation. Almost all prefabricated renovation solutions for apartment buildings are based on wooden frame. While the light wood framing is not recommended for such buildings, according to the document U.S. Army Corps [3] the heavy timber or glued -laminated columns are acceptable for army facilities. The US army experience shows that energy efficient measures can be effectively implemented also in military buildings and ensure energy reduction of almost 65% depending on the climate zone [4, 5]. In addition, a study [6] has shown that there is a strong potential to significantly reduce energy consumption in military buildings. The unique brick building has a special bomb shelter with ventilation shaft was chosen to carry out a case study. The heat consumption of selected building is similar to average heat consumption of military buildings, which allow later technology adaptation of special purpose buildings. The wood frame construction can be easily adopted for efficient solar heating and natural ventilation application [7, 8]. Such types of the facades can be combing with active components [9] which allows significant increase of on-site renewable use. Application of the modular multi active facades requires precise data on the building geometry and production process. 3D laser scanning technology in combination with BIM allows precise building measurements and development of prefabricated thermal insulation modules. A number of theoretical and practical studies have proven the benefits of 3D laser scanning in further project development in BIM environment, like presented in on of the most recent studies [10].

2. Methods

Selected methods are based on the analysis of the 3D scanning results, calculation of two-dimensional heat losses and modules selection in a specialized software SEMA. For the 3D scanning Scaner FARO 3D 120 was used. It captures objects in a range from 0.6 m to 120 m and provides high measuring speed at a maximum of 976.000 measuring points per second. ArchiCAD and REVIT softwares were used to transfer point cloud into 3D building mode. The developed 3D building was transferred to SEMA environment for development of pre-fabricated modules. The weak point of the prefabricated modules is their relatively high share of thermal bridges. The 3D building modules allow data import to the thermal bridges calculation software. For calculating the thermal bridges the THERM calculation software was used. software performs calculation [11] in compliance with ISO 10211:2007 Thermal bridges in building construction -- Heat flows and surface temperatures -- Detailed calculations. The Linear thermal transmittance was calculated as proposed in ISO10211:

$$\Psi = L^{2D} - \sum_{j=1}^{J} U_j \cdot l_j = \frac{Q}{\Delta T} - U_a \cdot l_a +_a U_b \cdot l_b [W/(m \cdot K)] \quad (1)$$