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Feasibilty study on thermal insulation of existing load-bearing masonry buildings with calcium silicate bricks using ETICS solutions. Case study Lezhë, Albania

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Abstract: In today's world, energy efficiency has become a significant topic, influencing choices made daily across society. As one of the largest energy consumers, the construction industry holds significant potential for improvement. Therefore, it is necessary to explore ways to reduce its environmental impact. This paper assesses the feasibility of implementing exterior thermal insulation systems in existing residential buildings. This measure is currently being implemented by several municipalities in Albania, which are covering half of the related costs through taxpayer funding. Since load-bearing masonry buildings with calcium silicate bricks account for the majority of older existing structures in Albania, one of these buildings is the focus of this paper. The building taken under consideration, known as "PallatiMbreti Gent", is located in the municipality of Lezhë in the northern region of Albania. A 3D model of the building has been created using Autodesk Revit, based on the current architectural and structural plans. Subsequently, an energy analysis of the building is performed using Autodesk Insight, assessing its current state. Based on the results of the energy analysis and the region's climate conditions, a proposal for an External Thermal Insulation Composite System (ETICS) is made. The energy analysis is then repeated for the insulated building. Ultimately, the costs of this undertaking is compared to the savings resulting from enhanced energy performance, and conclusions are drawn. This paper aims to assess the feasibility of implementing thermal insulation for existing load-bearing masonry buildings made of calcium silicate bricks using ETICS solutions, with the assistance of the latest software applications. The study also aims to provide a reference for similar projects in the future.
Keywords: Feasibility study, ETICS, calcium silicate bricks, energy analysis, Autodesk Insight.

I. INTRODUCTION

In recent years, energy efficiency has emerged as a critical concern, influencing decision-making across society. The construction industry stands out as one of the biggest energy consumers. Therefore, reducing the energy consumption of buildings has become a priority for policymakers, engineers and architects. One of the proposed solutions for improving energy efficiency is the implementation of modern insulation solutions in existing buildings.

In Albania, older buildings often suffer from poor thermal performance due to outdated construction techniques and insufficient insulation. Load-bearing masonry buildings with calcium silicate bricks make up the majority of Albanian's existing building stock and therefore they will be the focus of this paper.

This study focuses on the feasibility of the application of External Thermal Insulations Composite Systems (ETICS) to improve the thermal performance of existing residential buildings with load-bearing calcium silicate bricks. More specifically, the study centers around a case study of the "PallatiMbreti Gent" building, located in the municipality of Lezhë in the northern region of Albania. This building can be seen as a representative of a broader category of structures that dominate the Albanian landscape.

This paper aims to evaluate the current energy performance of the case study building and the potential benefits of an ETICS retrofit using advanced software applications, such as Autodesk Revit, which is a cutting-edge architectural design and documentation software that supports BIM workflows, and Autodesk Insight which is a cloud-based software that allows us to perform energy analysis, lighting analysis and solar analysis.[1]

A comparative analysis is conducted between the pre- and post-insulation energy performance of the building, allowing for the assessment of the project's economic feasibility. The findings of this study will not only provide insights into the energy-saving potential of ETICS solutions but also offer a practical guidance for similar projects in Albania and other regions with comparable building typologies.

This paper seeks to contribute to the growing body of knowledge on energy-efficient retrofitting by demonstrating the practical benefits and challenges associated with implementing ETICS in existing masonry buildings. The goal is to provide a reference for policymakers, construction professionals, and building owners interested in reducing energy consumption and environmental impact through effective thermal insulation solutions.

II. ETICS

An External Thermal Insulation Composite System (ETICS) is a multi-layered insulation solution that includes adhesive, leveling mortar, insulation panels, an alkali-resistant reinforcement grid, primer, a finishing coat, sealants, and various accessory materials required for installation. [2]

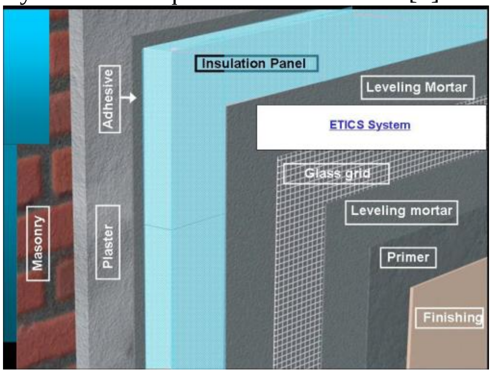

Fig.1. ETICS Stratigraphy. Source [2]

For this case study, materials for each layer will be selected from local manufacturers to ensure a realistic approach.

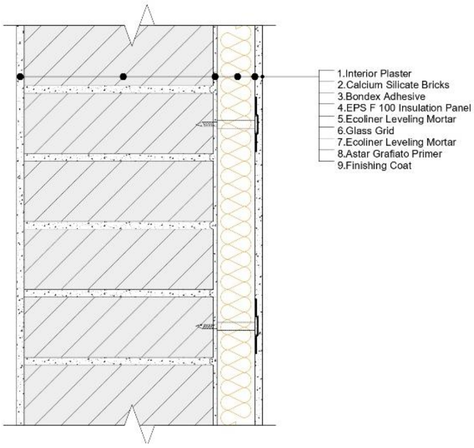

Fig.2. Proposed ETICS for the case study. Source: Authors

II.1 Adhesive

Bondex will be utilized as the adhesive for this project. It serves as an adhesive and smoothing mortar for thermal insulation boards, including EPS, XPS, and stone wool, making it suitable for facades and finishes. Bondex offers excellent workability and high resistance to harsh weather conditions, with a maximum leveling thickness of 5 mm.[3]

Fig.3. Bondex adhesive. Source [3]

Table.1. Bondex properties. Source[3]

Granulation	**0.7mm**
Bulk Density	1.4 g/cm^3
Flexural Strength after 28 Days	0.8 N/mm²
Compressive Strength after 28 Days	2.1 N/mm²
Water Absorption (24h)	≤ 0.3 kg/m²
Thermal Conductivity Coefficient	0.50 W/mK
Water Vapor Diffusion Resistance Coefficient	μ = 20
Fire Rating	**Class A1**

II.2 Insulation Panel

EPSF 100 will be used as the insulation panel for this project.

Fig.4. EPSF Insulation Panel. Source [4]

Table.2. EPSF Insulation panel properties. Source [8]

I. Properties	II. Symbol	III. Eurocode	IV. Description	V. Value	VI. Unit
Thermal conductivity	λD	EN 12667	Value measured at 10°C	0.037	W/m*K

II.3 Leveling mortar

Ecoliner will be applied as the leveling mortar. This universal undercoat, based on white cement, is suitable for leveling and smoothing thermal insulation boards (EPS) as well as cement-lime filling plaster, making it ideal for facades and moldings. Ecoliner offers excellent workability and high moisture resistance, with a maximum layer thickness of up to 3 mm. [3]

Fig.5. Ecoliner leveling mortar. Source [3]

II.4 Primer

AstarGrafiato will be used as the primer for this project. This acrylic resin-based liquid material is resistant to alkalis and ensures excellent workability with decorative layers. Applying ASTAR GRAFIATO Dekoll Liquid creates a water-resistant coating that adheres effectively to surfaces treated with decorative finishes, enhancing durability and ease of use. [3]

Fig.6. AstarGrafiato Primer. Source[3]

Table.3. AstarGrafiato Primer properties. Source [3]

Color	Packaging	Consumption
Transparent,white	Bucket 9l	5-6m^2/l

III. CALCIUM SILICATE BRICKS

Calcium silicate bricks are a type of masonry product made by mixing lime, silica, and water, which are then subjected to high-pressure steam curing. This process, known as autoclaving, results in a durable, fire-resistant, and dimensionally stable bricks. Calcium silicate bricks are commonly used in construction due to their strength, thermal insulation properties, and resistance to weathering.

Table.4. Thermal and Physical Properties of Calcium Silicate Bricks. Source[6]

General Information	
Sample type	Calcium Silicate Brick
Sample number	CS01
Date of collection	March 6-8,2019
Raw material	Fly ash, stone dust and lime
Production process	**Mixture preparation** : 70% stone dust, 10% fly ash and 20% lime is used **Shaping and curing** : Mechanized production line, consisting of pan-mixer, Hydraulic Power compacting machine and steam curing(autoclaves)
Thermal and Physical Properties	
Bulk density ρ (kg/m^3)	2071
Thermal Conductivity λ(W/m*K)	0.7069
Specific Heat C (J/Kg*K)	969.2
Water Absoprtion (%)	12
Compressive Strength σ(N/mm^2)	18.79

IV. LOCATION AND CLIMATE

Lezha's climate is primarily characterized by hot, dry summers and mild, wet winters. During the summer, temperatures typically range from 25°C to 38°C, while winter temperatures usually fluctuate between 5°C and 15°C. Due to its proximity to the Adriatic Sea and the presence of several wetlands, Lezha experiences high humidity levels, around 70%. Rainfall is more frequent in the colder months, contributing to the elevated humidity.

These climatic conditions significantly affect the behavior of building facades throughout the year. Given that climate is a key factor in thermal insulation, our goal is to identify the most effective solutions for enhancing the thermal performance of buildings, balancing construction and economic considerations. Older buildings, especially those constructed with silicate bricks, are particularly vulnerable to the impact of these climate factors. Therefore, addressing the thermal insulation needs of such buildings is crucial for improving energy efficiency and thermal comfort.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	4.8 °C (40.7) °F	6 °C (42.8) °F	9.2 °C (48.6) °F	13.3 °C (56) °F	17.7 °C (63.9) °F	22 °C (71.5) °F	24.4 °C (76) °F	24.8 °C (76.6) °F	20.1 °C (68.2) °F	15.6 °C (60.1) °F	11.1 °C (51.9) °F	6.4 °C (43.4) °F
Min. Temperature °C (°F)	1.2 °C (34.1) °F	2 °C (35.6) °F	4.7 °C (40.5) °F	8.8 °C (47.9) °F	13.4 °C (56.1) °F	17.4 °C (63.3) °F	19.8 °C (67.6) °F	20.1 °C (68.2) °F	16 °C (60.8) °F	11.7 °C (53.1) °F	7.4 °C (45.4) °F	3 °C (37.4) °F
Max. Temperature °C (°F)	8.8 °C (47.8) °F	10.1 °C (50.1) °F	13.3 °C (56) °F	17.2 °C (62.9) °F	21.2 °C (70.2) °F	25.5 °C (77.9) °F	28.2 °C (82.7) °F	28.8 °C (83.9) °F	23.9 °C (75.1) °F	19.6 °C (67.2) °F	15 °C (59) °F	10.1 °C (50.2) °F
Precipitation / Rainfall mm (in)	119 (4)	121 (4)	124 (4)	123 (4)	98 (3)	54 (2)	37 (1)	38 (1)	108 (4)	136 (5)	170 (6)	160 (6)
Humidity(%)	73%	71%	71%	71%	72%	68%	65%	63%	67%	73%	74%	74%
Rainy days (d)	8	8	8	9	8	5	4	4	7	7	9	10
avg. Sun hours (hours)	6.4	7.2	8.4	9.9	11.5	12.6	12.8	12.0	10.2	8.4	7.1	6.3

Fig.7. Climate data for the city of Lezhë. Source [5]

V. METHODOLOGY

V.1 CREATING THE 3D MODEL AND GENERATING THE ENERGY ANALYTICAL MODEL

The initial step involves developing a detailed 3D model of the building in Autodesk Revit, utilizing the provided architectural and structural plans. This model will also incorporate the thermal properties of the materials to facilitate subsequent analysis.

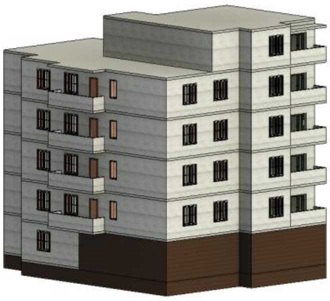

Fig.8. 3D Model of the building in its current state. Source [Authors]

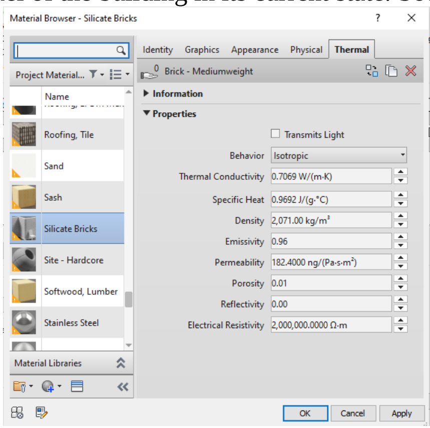

Fig.9. Assigning the thermal properties to Silicate Bricks. Source [Authors]

Subsequently, the building's geographic location must be specified to enable Autodesk Insight to retrieve accurate climate data for the analysis.The software retrieves climate data from the nearest meteorological station, located approximately 4.63 km from the building site.

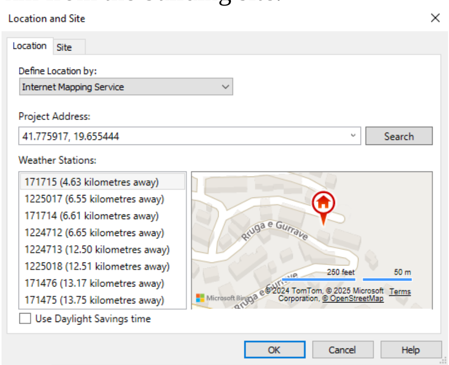

Fig.10. Providing the location of the building in Autodesk Insight. Source [Authors]

Upon completing these steps, the energy analytical model can be generated and analyzed using Autodesk Insight.

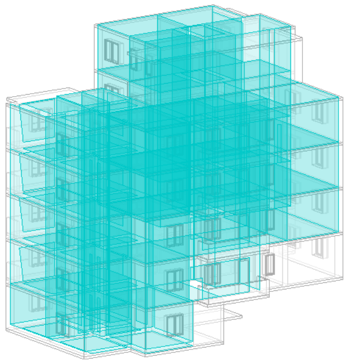

Fig.11. Energy Analytical Model generated by Autodesk Insight. Source [Authors]

V.2 Information from the Energy Analysis

The energy analysis provided by Autodesk Insight offers valuable insights into power consumption, expressed in kWh/m²/year. This analysis highlights the impact of various building parameters, including orientation, window-to-wall ratio (WWR), window shading, glazing type, wall construction, roofconstruction, infiltration, lighting efficiency, HVAC systems, and operating schedules, on overall energy performance. Given that an exterior thermal insulation system will be installed, particular attention is warranted to the effects of wall and roof construction. These components play a crucial role in the building's thermal performance, influencing both energy demand and efficiency, and will be key considerations in optimizing the building's energy profile.

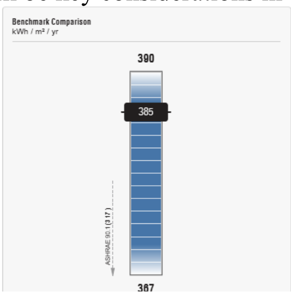

Fig.12. Energy Consumption KWh/m2/year. Source [7]

Fig.13. Wall Construction. Source [7]

Fig.14. Roof Construction. Source [7]

V.3 3d Model after the Application of the Etics System

The energy analysis will be repeated using the updated 3D model, which incorporates the newly installed exterior thermal insulation system. The results from this revised model will then be compared to those obtained from the initial analysis. This comparison will provide a comprehensive understanding of how the added thermal insulation influences the building's energy performance, specifically in terms of energy consumption, thermal load, and overall efficiency. By evaluating the impact of this modification, we aim to quantify the potential energy savings and assess the effectiveness of thermal insulation in enhancing the building's energy performance.

Fig.15. 3D Model after the application the ETICS System. Source [Authors]

Figure 16. Energy Model. Source [Authors]

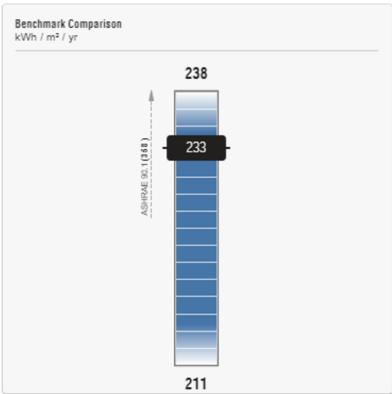

Figure 17. Energy consumption after the thermal insulation. Source [Authors]

Table 5. Comparison of energy consumptions in the two cases. Source [Authors]

Condition	Energy Consumption (KWH/m2/year)	Average Apartment Surface (m2)	Energy Consumption (KWH/year)	Energy cost in Euros (€)	Energy bill (€)	Savings (€)
Existing Building	385	80	30800	0.12	3696	**1459.2**
Building after the thermal insulation	233		18640		2236.8	

The results of the energy analysis reveal a significant potential for energy cost savings. The implementation of an exterior thermal insulation system could result in an annual reduction of approximately 142,272 Lek (or 1,451.66 Euro) per household. This substantial saving underscores the potential economic benefits of thermal insulation in enhancing energy efficiency, particularly in reducing heating and cooling demands. Such measures could offer considerable financial relief for households while simultaneously contributing to broader sustainability goals.

It is important to consider that the energy consumption calculated by Autodesk Insight is based on European comfort standards, which may not align with local conditions. These standards prescribe indoor air temperatures ranging from 25°C to 28°C during the summer and 15°C to 21°C in the winter. Maximum air velocities are set between 0.15 and 0.30 m/s, with many regulations not adjusting these limits based on air temperature. Additionally, humidity limits are typically defined as 30% relative humidity (r.h.) in winter and 70% r.h. in summer. As a result, the energy consumption—and consequently the associated costs—may be significantly higher than what would be expected for an average household in Albania. Given the economic challenges faced by many Albanian families, it is unlikely that they would be able to achieve the comfort standards prescribed by European regulations. Consequently, the results of this study should be interpreted with caution, as they may not accurately reflect the practical energy consumption and associated costs for typical households in Albania. The discrepancy between the prescribed standards and the local economic realities must be taken into account when assessing the applicability and relevance of the findings.

VI. CONCLUSIONS

In conclusion, the application of exterior thermal insulation systems (ETICS) represents a promising solution for improving energy efficiency in existing masonry buildings constructed with calcium silicate bricks in Albania. The energy analysis indicates that ETICS can lead to significant energy cost savings, demonstrating the potential of this approach to enhance building performance. However, it is important to note that the benefits observed in the analysis may not fully reflect the actual impact in the local context. The energy consumption calculations are based on European comfort standards, which differ from the comfort preferences and economic conditions in Albania. Due to these differences, the real-world savings for Albanian households may be less pronounced than the results predicted by Autodesk Insight. Therefore, while ETICS presents a viable option for improving energy efficiency, the economic challenges and local comfort standards must be considered when evaluating its potential benefits for Albanian families.

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