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Embodied Carbon comparison between Vernacular Architecture and modern techniques in Albania

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Abstract:
Alarming CO2 levels from rapid industrial developments, including construction, are calling on architects to find better design solutions. Today in Albania, despite the continued growth of high-rise facilities, about 83% of buildings are individual 1-2 floors dwellings with reinforced concrete and bricks, whereas 4.2% are built with adobe bricks and timber before 1945, representing an opportunity to rethink the way low-high building materials are chosen. This study investigated traditional vernacular techniques and the impact of 2-3 floors houses with local earth techniques on energy consumption and CO2 footprint compared to modern reinforced concrete systems currently in use. The energy assessment was performed using Revit 2019 with the integration of Insight and H\B:ERT. The traditional model not only had an annual operational energy consumption of 8% lower than RC construction but it also had a CO2 footprint almost 50% lower than the technique most used for construction in Albania.
Keywords: Vernacular Architecture, Albania, Embodied Carbon, Energy Consumption, Adobe Bricks

1. Introduction

The construction sector is responsible for one-third of energy consumption and 30 % of global carbon emissions, ranking among the largest industries affecting the rise of temperatures and climate change (Peng, 2015).
Green building solutions, influenced by policies and global awareness of climate change such as the Kyoto and Paris Protocol, have largely assumed great importance during design, pushing architects to return to the use of ecological materials and traditional local techniques that provide the highest efficiency and comfort and the lowest impact on the environment. National and regional plans to reduce the construction carbon footprint started to be part of many countries' agendas, among them Albania. (RICS, 2014)

Despite the progress made by Albania in implementing the 2030 SDGs through the national strategic plan Albania 2030, in ensuring the implementation of sustainable policies in the construction industry, the levels of CO2 in the atmosphere have risen (Urban, 2017). In 2019 approximately 1 million m2 of new buildings were constructed, with over 60% of them in Tirana (INSTAT, 2019), causing an increase in pollution and stress levels in urban areas. Albanian cities were not only polluted, Tirana ranking as the third most polluted city in Europe for 2019, with fewer green spaces per person but also noisy, with 5 cities that exceed the recommended noise levels in the centres inhabited by 15-20% (Environment, 2017).

Facing such challenges architects have turned to sustainable solutions for their design, embracing old techniques and materials to satisfy the needs of small-scale projects. Among these materials is the earth (soil). Although it houses about half of the world's population, about 3 billion people on 6 continents live and work in buildings made of earth, it is still perceived negatively (Real, 2000). In Albania, despite the continuous construction of modern high rises, about 83% of buildings are individual 1-2 floor buildings with reinforced concrete and bricks, of which 4.2% are built with adobe bricks and timber before 1945 (INSTAT,2012). These houses, built mainly in a personal informal way represent the ideal typology which could have been built with vernacular materials and techniques.

This paper attempts to estimate and compare the energy consumption and embodied carbon emission between traditionally built buildings using vernacular architecture and reinforced structures in Albania, to increase awareness of local construction techniques and their impact on the environment.

2. Vernacular Architecture in Albania

Earth dwellings have been part of Albanians’ cultural heritage and history for many years passed down from generation to generation in the form of knowledge with a rich heritage of buildings both in urban and rural areas (Muka, 1998). Influenced by economic status and local resources, those dwellings can be found standing today as one, two and even three floors buildings, from an open plan with Hajat to the northest versions of Kulla, suggesting the rigidity and longevity of the materials, against natural disasters and atmospheric conditions.

Figure 1 Street in Tirana 1916 Lambertz (www.albanianhistory.net)

Figure 2 Outer wall of a destroyed vernacular house

Figure 3 Floor plan and front view of the Ethnographic Museum of Kavaja (IKM)

3. Case Study

In order to evaluate the energetic performance and CO2 emission, a hypothetical 2 floors social house module, according to national regulations, was designed being the bases of two models that were compared together, No. 1 and No. 2, whose differences lie only in the construction techniques, respectively with vernacular architecture and reinforced concrete(RC).

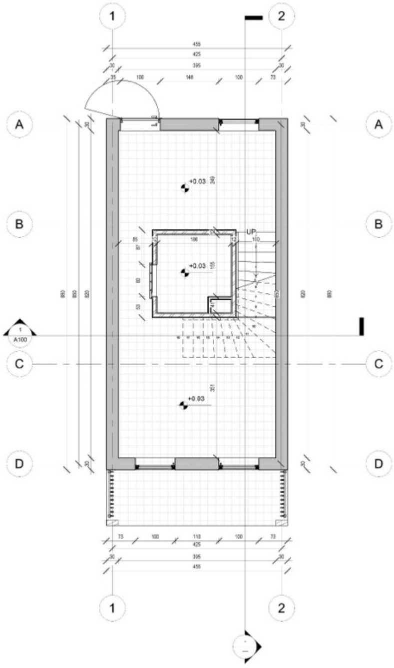

Figure 4 Ground floor plan

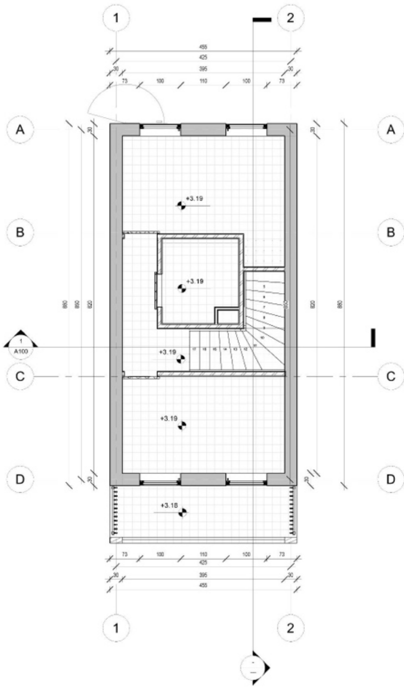

Figure 5 First floor plan

Model No. 1 consists of a structure relying on a continuous foundation at a 1.2 m depth, on top of which the 30 cm rammed earth walls (canst in situ) are built, bearing all the loads coming from the building. Wood beams are placed on top of the walls to create the floors, supported by a 10-15 cm concrete layer to better distribute the weight, followed by wood panels and finishes. The stairs are designed with wood.

Model No. 2, is designed with a rigid reinforced concrete structure with the foundation going 1.5 m deep and placed below each column. The building has 8 columns with a grid of 4 by 2, with spam of 250cm on the y and 475cm on the x-axis. All the construction is cast on-site and the floors are 12cm of RC on top of which we have 2.5 cm of the finishes. The walls are built with local bricks 25 cm and surrounded by 8cm of Rockwool for thermal insulation. The stairs are also built with RC for a total of 18.

Both models have the same windows, doors and materials for interior walls and finishes. To determine the energy performance and carbon dioxide CO2 in buildings, we will refer to international norms and Albanian legislation. In Albania, energy performance is determined based on law no. 8937 "For the preservation of heat in buildings". The necessary calculations will be performed by Insight, a program that enables the analysis of the building's performance, after designing both models accurately in Revit. Material technical details are based on VKM No. 38, Dt. January 16, 2003, and Autodesk data. The energy analysis model for the windows is Double glazing - domestic SC=0.7, for the interior doors R=0.35 and U value=2.85. Meanwhile, the main door has an analytical model with its data R=0.53 and U=1.87. Model 1 has an exterior wall of δ=0.3 m with R=0.52 and U=1.93, a ground floor of δ =0.225 cm with R=0.4 and U=2.52 and a roof of δ= 0.16 cm with R=3.02 and U=0.33. Meanwhile, model 2 has an exterior wall of δ=0.39 with R=2.81 and U=0.35, a ground floor of δ=22.5 with R=0.4 and U=2.52, and a roof of δ=0.26 with R=3 and U=0.33. All calculations and formulas were performed through the program. Below we have the legend of the symbols.: δ (m) – Thickness (m); R (m^2K / W) – Thermal resistance; U (W / m2K) – Thermal transmittance coefficient

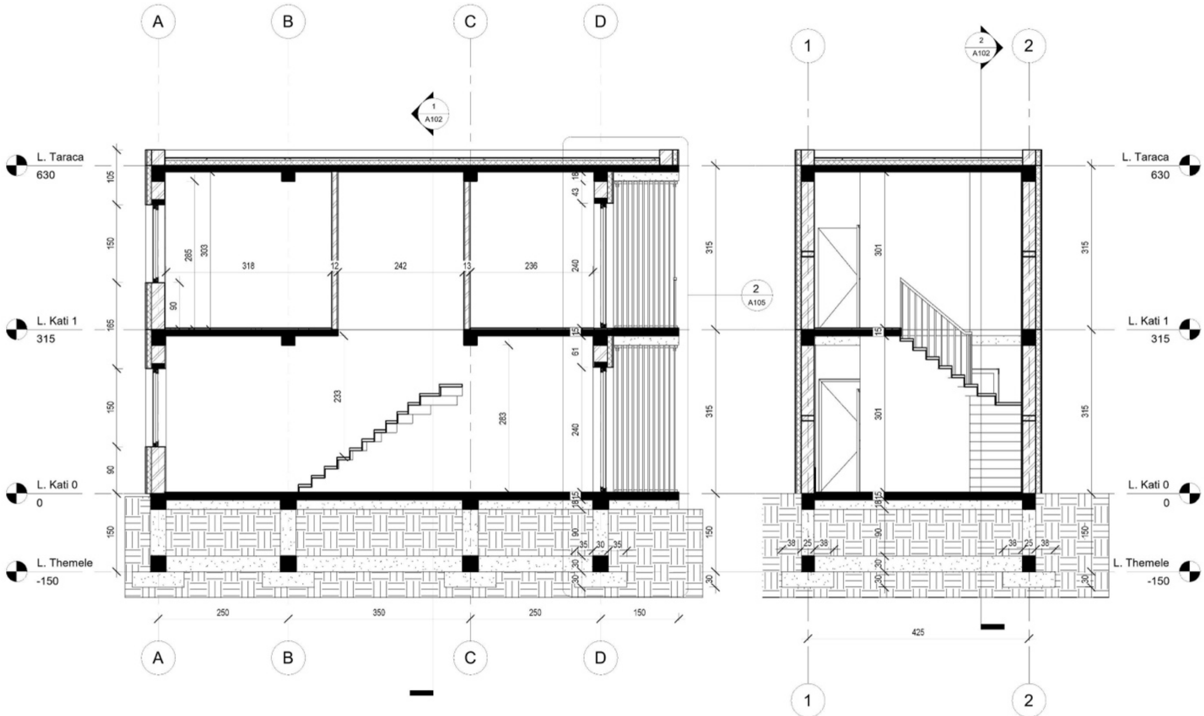

Figure 6 Sections of the building (Model 2)

For the energetic analysis performed in Insight, the Revit model settings were: Single Family building type, with an Operation Schedule of 24/7, central VaV, HW, Chiller 5.96 COP, Boiler 84.5 eff and Outdoor Air ventilation per person 8.00 L/s.

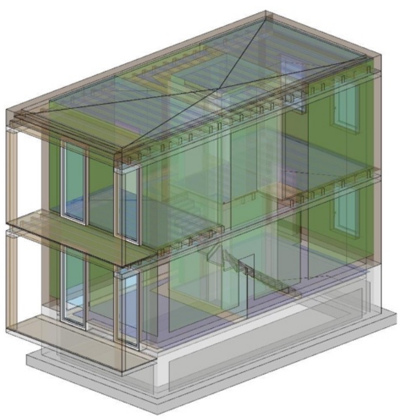

Figure 7 Insight Energetic Analytic Model 1

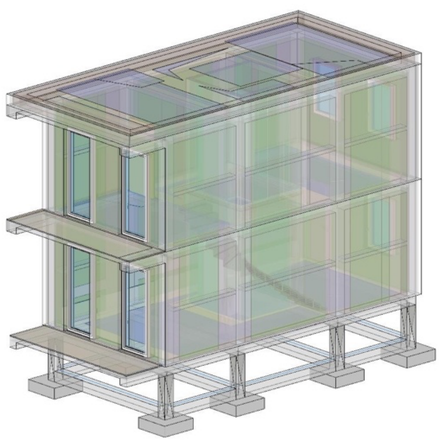

Figure 8 Insight Energetic Analytic Model 2

The results of the analysis show that Modul 1 has an annual energy consumption of 8% lower compared to Model 2, respectively with 321 kWh / m² / yr with 351 kWh / m² / yr. Despite the consumption being similar we should state that Modul 1 doesn't have an insulation layer as compared to the 8cm Rockwool that Model 2 has.

The second analysis performed on the case study was the calculation of CO2 emission with the integration of H\B:ERT to Revit, a plug-in designed by UCL to help architects evaluate the impact of different materials during the design stage. The CO2 footprint for each material is, is based on the material database from Bath -ICE from the University of Bath (https://ghgprotocol.org/Third-Party-Databases/Bath- ICE).

Embodied Carbon Modul1															
Material: Name	Material: Volume	Material: Density (ton/m3)	Material weight (ton)	Material: Waste rate (%)	Overall material weight	Material: Embodied Carbon	Overall material EC (tonCO2e)	Material: Transport coefficient (%)	Overall transport EC (tonCO2e)	Material: Construction coefficient (%)	Overall Construction EC tonCO2e)	Material: End of life coefficient (%)	Overall End of life EC (tonCO2e)	Material: Replacements over 60	Overall EC sum (tonCO2e)
HBA_Bitumen	0.00 m³	0.72	0	0.05	0	0.5	0	0.03	0	0.07	0	0.02	0	1	0
HBA_Brick	5.09 m³	1.92	9.768069	0.2	11.721683	0.24	2.813204	0.03	0.084396	0.07	0.164104	0.02	0.056264	0	3.117968
HBA_Ceramic Tiles	0.57 m³	2.13	1.20753	0.08	1.304133	0.78	1.017223	0.03	0.030517	0.07	0.065931	0.02	0.020344	0	1.134016
HBA_Concrete - Cast In Situ	24.69 m³	2.4	59.260188	0.05	62.223197	0.138	8.586801	0.03	0.257604	0.07	0.572453	0.02	0.171736	0	9.588595
HBA_Concrete - Screed	3.80 m³	1.9	7.21547	0.05	7.576244	0.163	1.234928	0.03	0.037048	0.07	0.082329	0.02	0.024699	0	1.379003
HBA_Insulation - Polystyrene, Ex	3.91 m³	0.024	0.093837	0.15	0.107912	4.4	0.474813	0.03	0.014244	0.07	0.028902	0.02	0.009496	0	0.527456
HBA_Plaster	1.30 m³	0.85	1.106897	0.05	1.162242	0.13	0.151091	0.03	0.004533	0.07	0.010073	0.02	0.003022	1	0.337437
HBA_Soil	42.25 m³	1.5	63.377348	0.13	71.616404	0.024	1.718794	0.03	0.051564	0.07	0.106474	0.02	0.034376	0	1.911207
HBA_Wood - Glulam	4.56 m³	0.45	2.050976	0.1	2.256073	0.87	1.962784	0.03	0.058884	0.07	0.124904	0.02	0.039256	1	4.371654
HBA_Wood - OSB	1.11 m³	0.65	0.718788	0.1	0.790667	0.99	0.78276	0.03	0.023483	0.07	0.049812	0.02	0.015655	1	1.74342
Grand total: 120	1.11 m³		144.799103		158.75855		18.742398		0.562272		1.204981		0.374848		24.110756

Figure 9 HBERT results and CO2 emission for Model 1

Embodied Carbon Moduli 2															
Material: Name	Material: Volume	Material: Density (ton/m3)	Material weight (ton)	Material: Waste rate (%)	Overall material weight (waste inc.)(tons)	Material: Embodied Carbon (tonCO2/ton)	Overall material EC (tonCO2e)	Material: Transport coefficient (%)	Overall transport EC (tonCO2e)	Material: Construction coefficient (%)	Overall Construction EC tonCO2e)	Material: End of life coefficient	Overall End of life EC (tonCO2e)	Material: Replacements over 60 years	Overall EC sum (tonCO2e)
HBA_Bitumen	0.00 m³	0.72	0	0.05	0	0.5	0	0.03	0	0.07	0	0.02	0	1	0
HBA_Brick	35.96 m³	1.92	69.043445	0.2	82.852134	0.24	19.884512	0.03	0.596535	0.07	1.15993	0.02	0.39769	0	22.038668
HBA_Ceramic Tiles	0.55 m³	2.13	1.181367	0.08	1.275877	0.78	0.995184	0.03	0.029856	0.07	0.064503	0.02	0.019904	0	1.109446
HBA_Concrete - Cast In Situ	32.69 m³	2.4	78.459776	0.05	82.382765	0.138	11.368822	0.03	0.341065	0.07	0.757921	0.02	0.227376	0	12.695184
HBA_Concrete - Screed	6.24 m³	1.9	11.854162	0.05	12.44687	0.163	2.02884	0.03	0.060865	0.07	0.135256	0.02	0.040577	0	2.265538
HBA_Insulation - Polystyrene, Expan	16.84 m³	0.024	0.404224	0.15	0.464858	4.4	2.045375	0.03	0.061361	0.07	0.124501	0.02	0.040907	0	2.272145
HBA_Plaster	5.89 m³	0.85	5.004993	0.05	5.255243	0.13	0.683182	0.03	0.020495	0.07	0.045545	0.02	0.013664	1	1.525772
Grand total: 171	98.18 m³		165.947968		184.677747		37.005914		1.110177		2.287656		0.740118		41.906752

Figure 10 HBERT results and CO2 emission for Model 1

The CO2 footprint is almost 50% lower for the first Model, using rammed earth and vernacular techniques compared to the second Model built with reinforced concrete. Model 1 has a footprint of 24.11 tonCO2e while Model 2 of 41.9 tonCO2e, due to the high usage of concrete and bricks.

4. Conclusion

Through the use of a quantitative approach and design programs to evaluate energy performance and CO2 footprint, this research identified that buildings using natural vernacular construction materials and techniques have a low impact on the environment, compared to modern techniques using reinforced concrete for 2-floor buildings. Two models were designed using BIM and the latest data coming from Autodesk, UCL and Bath University, helping understand the weight of each material and its impact on EC. The model was designed by using rammed earth walls as the main structural component, and despite not having insulation, had an 8% lower yearly energy consumption compared to the model designed with reinforced concrete, brick walls and insulation. The same result is true for the second analysis, the first model releases half the CO2 amount compared to the second model. Such figures prove the importance of reevaluation the way architects choose materials, by reconsidering the use of earth, where it's possible, to build small-scale projects, like two-floor houses., highlighting the importance of material selection during the design process. Our results confirm the initial hypothesis that most of the individual buildings in Albania can be built with traditional vernacular architecture and can have better performance and lower impact on the environment. To ensure such consideration, policies building habits and design solutions need to change, followed by more research with computer-designed models and real-world prototypes.

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