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ASSESSMENT OF THE COSTS AND THERMAL PERFORMANCE OF CONSTRUCTION MATERIALS

FINAL

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DATA

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ABSTRACT

Energy efficient buildings are designed to provide comfortable temperatures inside throughout the year, with minimal energy consumption and without expensive power supply systems.

This study evaluates heat insulation materials in Georgia, from quality, efficiency, and cost perspectives, to enable consumers and the construction sector to make informed decisions on alternative construction methods to the traditional concrete blocks

According to the results, building insulation has a number of positive impacts aside from increased energy efficiency (up to 50%). These include obtaining additional space and reducing the quantity of materials required as a result of decreasing the weight of the building. Taking these factors into account, insulating buildings can be profitable.

CONTENTS

DEFINITIONS

Building Envelope	The physical separation between the interior and the exterior environments of a building. It serves as an outer shell to help maintain the indoor environment. The physical components of the envelope include the foundations, roof, walls, doors, and windows.
Heat Transfer Coefficient	Defines intensity of heat transfer.
λ (lambda)	Measured in W/(mK), this is the thermal conductivity of a certain material.
R/C	Reinforced concrete.
R value	Measured in m^2K/W, this is the thermal resistance of the building envelope.
Rock wool (stone wool)	Insulation material made from natural stone (rock) fibers. The Rockwool Company owns the trademark with the same name.
Thermal Conductivity	The property determining a material's ability to conduct heat.

I. EXECUTIVE SUMMARY

This study evaluates heat-insulating construction materials available in Georgia, in terms of their quality, cost and efficiency to enable consumers and the construction sector to make informed decisions on alternative construction methods.

The research uses individual case studies to examine construction methods and the benefits of using insulation materials made from perlite and basalt fiber. These case studies use defined thermal resistance indices based on Georgia's current climatic conditions, which serve as the basis to calculate the energy efficiency of a building.

Thermal resistance (R) is the factor defining the ratio of building envelope thickness and thermal conductivity of materials used in the structure. If thermal resistance is known at the design stage, it is possible to determine the thickness of wall layers for specific thermal requirements. This report also calculates building energy consumption necessary to preserve a comfortable interior air temperature, e.g. 19-21°C. The heat conductivity factor (λ) of the building's layers and desirable thermal resistance (R) are used to define the thickness of the building envelope.

The recommended average thermal resistance for Tbilisi is R=1.6-1.8 m^2*K/W. In the future, this figure may require scientific recalculation according to local climatic changes and construction requirements.

DESCRIPTION OF MATERIALS USED

CONCRETE BLOCK

As wall filler, concrete blocks are widely used in Georgia, particularly in high-rise buildings. The standard block size in most cases is 40x20x20 cm. Concrete blocks are manufactured in Georgia, largely as a cottage industry. It is difficult to control block quality both for strength and heat conductivity.

PERLITE BLOCK

Perlite is a volcanic glass and, unlike other volcanic glasses, when heated to a high temperature expands 4-20 times in volume compared to its initial state. This characteristic makes perlite a very good insulator. A combination of perlite and concrete creates a perlite block. While an increased concrete/perlite ratio reduces heat efficiency, a reduced concrete/perlite ratio leads to reduced block strength. Perlite blocks are ecologically clean and are fire resistant.

ROCK WOOL (INSULATION MADE FROM BASALT FIBER)

Rock wool evolves from the treatment of fiber created from melting basalt fragments. In Europe and North America, rock wool is widely used, as its heat resistance factor is quite high. It is also an ecologically clean product and fire resistant. Rock wool in its classic form, a 4-20 cm thick dense basalt fiber-based material, is not produced in Georgia, though is imported. Due to the fact that Georgia has an abundance of basalt, this study recommends local companies take advantage of these resources and develop capacity to manufacture rock wool. .

The study considers five types of walls:

Option 1: The most widely constructed wall type in Georgia: concrete block, 40 cm thick and plastered with sand-cement mortar on both sides.

Option 2: Perlite block wall, 20 cm thick and plastered with perlite-cement mortar on both sides.

Option 3: Concrete block wall, 20 cm thick and plastered with sand-cement mortar on the inside, insulated with a 5 cm layer of rock wool made from basalt fiber on the outside, and also plastered on the outside.

Option 3a: Similar to Option 3, but in this case, two layers of basalt fiber mat, each 8 mm thick, used for insulation. This insulation material is produced in Rustavi.

Option 4: Perlite block wall, 20 cm thick, with a 5 cm rock wool layer, and also plastered appropriately on the outside.

Throughout the report, Options 2, 3, 3a and 4 are compared to Option 1 to give a clear understanding of their characteristics and costs.

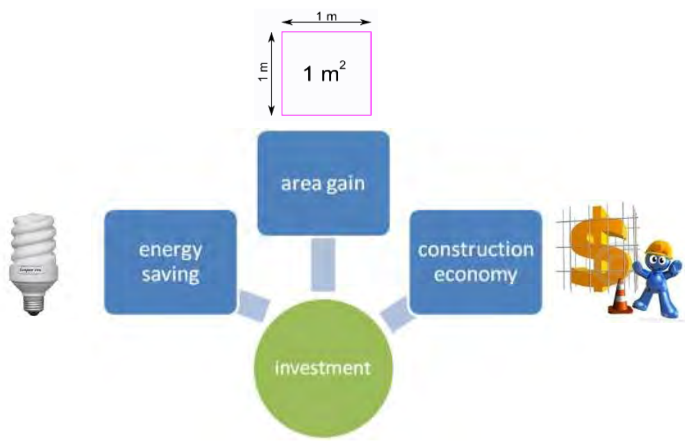
Each wall Option is analyzed for class II, III, and IV buildings as defined according to current Georgian legislation. These buildings are described throughout the study conventionally and in the simplest configuration:

- Class II Building - 2 Floors, 300m^2
- Class III Building - 8 Floors, 3015m^2
- Class IV Building - 18 Floors, 14,040m^2

Calculations show that the total thermal conductivity of Option 1 meets only minimal requirements of the Former-Soviet norms. Options 2 and 3 are within modern standards, although Option 3a has a low thermal conductivity index due to the limited thickness of the mat. Option 4 has the best results as both perlite and rock wool combined create high insulating characteristics.

Each Option and the benefits were evaluated according to the diagram below:

Factors Associated With Choice of Construction Materials and Design



Due to the physical properties and characteristics of perlite and basalt insulation materials, three distinct factors are affected when they are used in construction.

1. Firstly, construction using perlite blocks can decrease the overall weight of a building, reducing the pressure on the foundations and eliminating the need for thick walls at the base; thereby creating larger internal space than would normally be possible with concrete blocks.

2. Due to the reduced weight of the building and thinner walls from using perlite blocks, the quantity (and therefore cost) of construction materials also decreases.

3. Construction with perlite and basalt materials increases building insulation, thereby decreasing heating costs in winter and cooling costs in summer.

The first and second factors above apply during and soon after construction, while cost savings from energy efficiency are accumulated over time.

In the table below, the capital investment for the various construction options is compared to Option 1 for insulation of 1 m^2 of wall. In order to define this term, the average market cost of wall filling layers for each type of wall was calculated. The final amount of investment was obtained by multiplying this cost by the space for each building class (based on the floor area given above).

Percentage Difference in Capital Investment:

	Difference in Capital Investment Required (% Compared to Option 1)		
	II Class Building	**III Class Building**	**IV Class Building**
Option 1	0	0	0
Option 2	7	6	6
Option 3	52	48	45
Option 3a	27	25	23
Option 4	83	80	78

Heat loss was calculated for each Option to estimate potential energy savings. Natural gas was used as a fuel for the purpose of calculation. The table below shows gas savings in comparison to Option 1, per heating season, the five coldest months of the year in Tbilisi.

Percentage Difference in Energy Costs:

	Gas Saving per Season (% over Option 1)		
	II Class Building	**III Class Building**	**IV Class Building**
Option 1	0	0	0
Option 2	33	41	43
Option 3	42	51	53
Option 3a	13	16	16
Option 4	51	62	65

CONCLUSION

This study demonstrates that residential, office, or commercial constructions using a 40 cm thick external filler concrete blocks, without additional insulation, are not energy efficient and will not maintain a comfortable interior temperature without high-energy consumption. Existing buildings built with concrete blocks meet only minimal sanitary requirements, which explain the internal and external temperature differences.

Calculations show that Option 2, using perlite blocks, is the least expensive and has the quickest payback period, though in terms of energy efficiency, it drops slightly behind Option 3 using rock wool. It should be also noted that in the case of perlite blocks and plaster, the insulation of thermal bridges remains problematic. Thermal bridges are locations on the building envelope from where energy is lost due to lack of insulation, such as cantilever balconies, the bottom of bows, columns and beams. Rock wool can be used to insulate thermal bridges.

When using perlite blocks as an external filler (20 cm blocks with a desirable ratio of perlite and concrete), energy consumption required for heating decreases by 33-43%, in comparison to concrete blocks, depending on the class of building. A 20 cm perlite block successfully replaces a 40 cm concrete block with better heat indices and a cost difference of 6-7%. If the perlite block wall thickness is increased, its heat efficiency will be increase as well. For example, increasing a perlite wall thickness by 30 cm will increase energy savings by 55% in comparison to a concrete block wall, yet requires only around 30% more investment.

As for Option 3, using an imported product, the return on capital investment takes longer to accrue due to the high costs of importing the rock wool. The necessity to locally manufacture or improve existing technologies is necessary as the thermal parameters of Option 3a make investment payback slow.

Option 4 is the most costly, although has the best thermal resistance qualities and the payback period is little more than with Option 3.

Saving on materials in the load-bearing structure of a building, on average, results in a 20-25% saving on investment required, except in class II residential buildings, where there are no savings.

Even in the most modest case of gaining additional area after decreasing the thickness in the external filler, the profit exceeds investment several times. In the case of the perlite block filler, the result is particularly cost-effective.

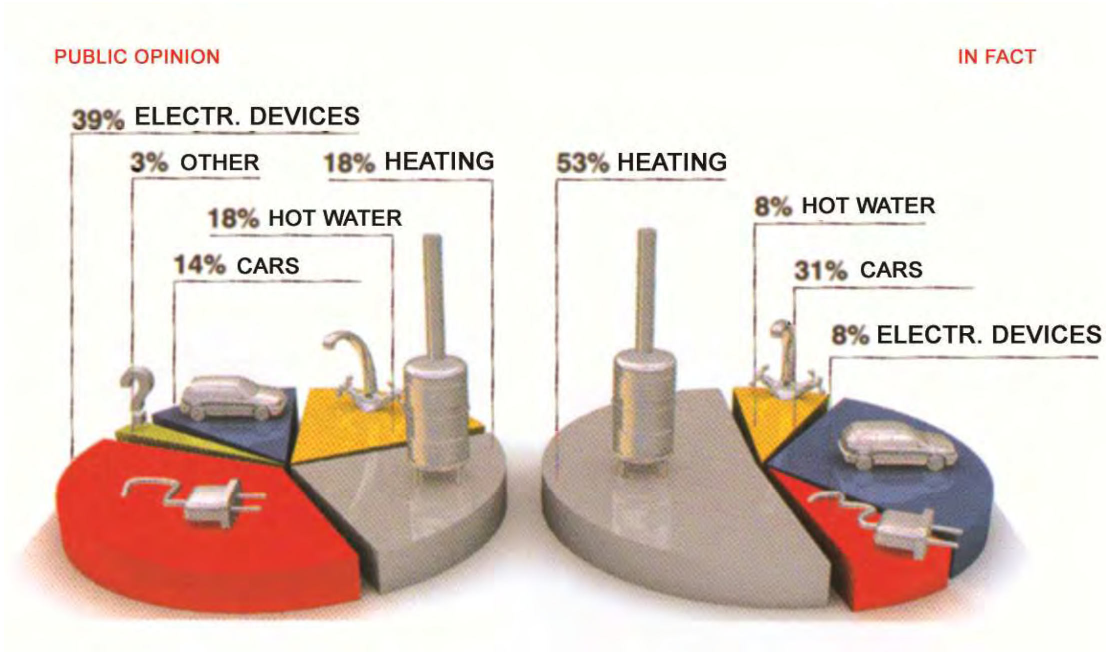
The analysis here shows that investing in insulating buildings can be quite profitable. Even if it is not in the investor's direct commercial interest to save energy, profits gained as a result of the increased floor area exceed capital investment several times. In some cases, savings can be gained from the purchase of construction materials, and in the end, an energy efficiency building is a good marketing tool.

II. MAIN STUDY

BACKGROUND

Building insulation conserves energy and therefore decreases emissions of harmful fumes into the atmosphere. The additional advantages of a well-designed energy efficient building are listed in Figure 1. However, Post-Soviet societies and governments often have different viewpoints concerning energy consumption. According to a Rockwool Company study, the general public in Russia believes that a significant proportion of energy is consumed by electrical equipment, while in fact 53% of energy consumed is used for heating (see Figure 1 below).

Figure 1: Energy Consumption Diagram (Public Opinion vs. Fact)



This study evaluates heat-insulating materials used in Georgia's construction sector according to quality, cost and efficiency to enable consumers and the construction firms to make informed decisions on alternative construction methods.

The research uses individual case studies to examine construction methods and the benefits of using insulation materials made from perlite and basalt fiber. Appropriate thermal resistance indices for Georgia's climatic conditions are defined, which facilitate calculation of building energy efficiency.

Thermal resistance (R) is the factor defining the ratio of building envelope thickness and thermal conductivity of materials used in the structure. If thermal resistance is known at the design stage, it is possible to determine the thickness of wall layers for specific thermal requirements. This report also calculates building energy consumption necessary to preserve a comfortable interior air temperature, e.g. 19-21°C.

	External wall	R
Pre-1918	Clay bricks or coursed random rubblemasonry	0.45
	Timber frame with loam infill panels	0.50
1880–1948	Clay brickwork, 250-380 mm	0.58
	Single-leaf masonry, 380-510 mm, or double-leaf	0.71
1949–1968	Lightweight masonry of hollow blocks, perforated bricks, aerated concrete	0.71
	Masonry of solid pumice concrete bricks	1.10
1969–1978	Lightweight perforated clay bricks with normal-weight mortar	1.00
	Precast concrete elements with core insulation or of ltw. concrete	0.90
	Timber stud walls with 60 mm insulation	1.67
1979–1983	Lightweight/vertically perforated clay bricks with lightweight mortar	1.25
	Masonry of aerated concrete	1.67
	Precast concrete elements with core insulation, or of ltwt. concrete	1.10
	Timber stud walls with 80 mm insulation	2.00
1984–1994	Lightweight/vertically perforated clay bricks with lightweight mortar	1.67
	Masonry of aerated concrete	2.00

Figure 2: Typical R-values [W/m^2K] for Components in the Building Stock

European countries have used a variety of different standards to determine the resistance factor. For instance, at the beginning of the 20th century the resistance factor was defined as 0.45 while towards the end of the century, the minimal factor for the external envelope wall increased to 2.0 (see Figure 2). These alterations were due to climate changes and an improvement of energy efficiency calculations.

The current factor for the thermal resistance of external walls, regulated by law, for some European countries is given in Figure 4, while Figure 3 shows the value of the recommended R factor for 100 cities in the European Union.

In Georgia, these factors were defined according to Soviet standards, which were subject to the political priorities of the Georgian Soviet State as opposed to appropriate energy efficiency standards. For example, if standards in the 1950's more or less met heat engineering requirements, then these measures also met the minimal efficiency and sanitary requirements in the 1970's and 1980's, especially given the low cost of construction. Certainly, these requirements did not consider any energy efficiency or ecological requirements.

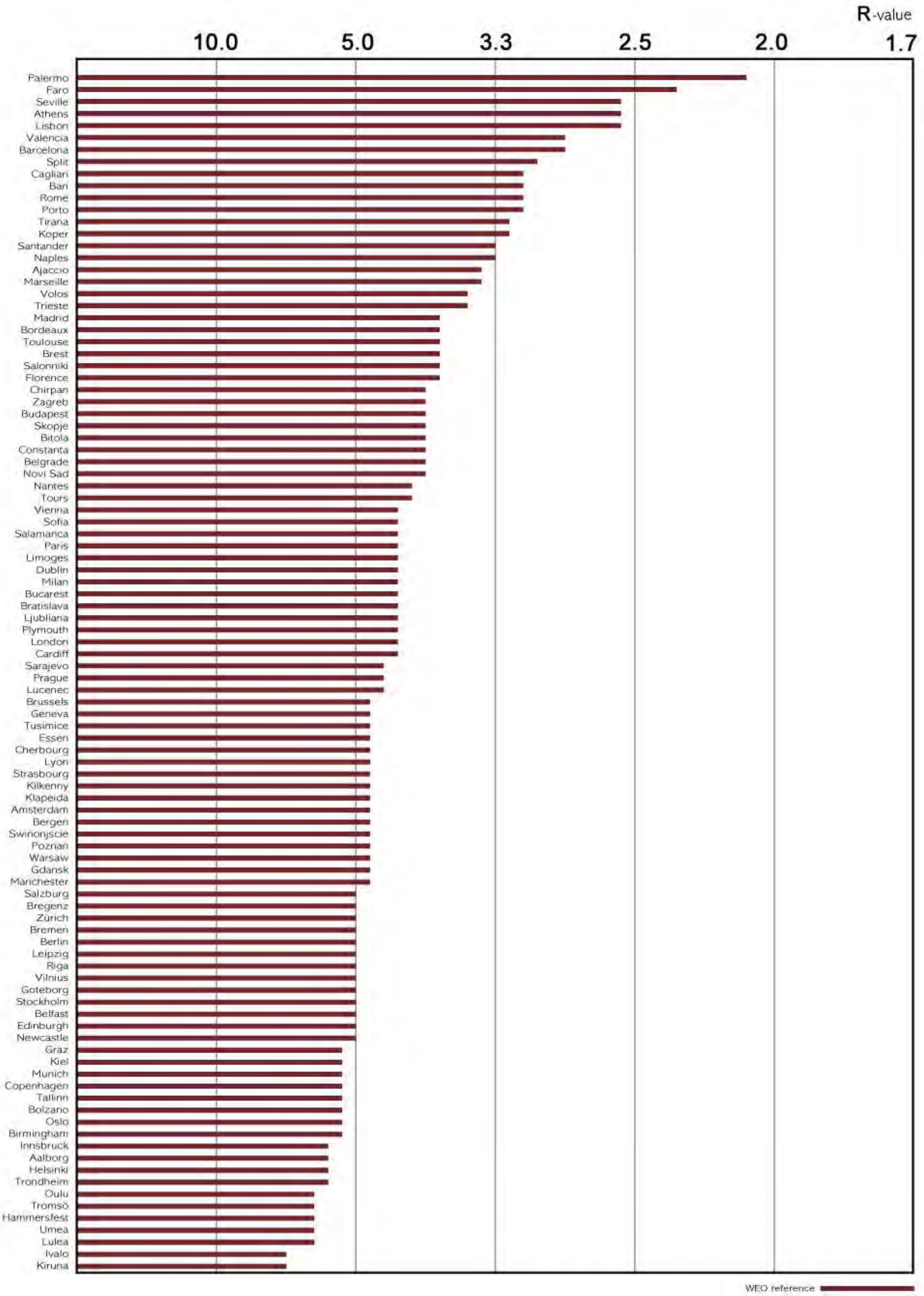
Contemporary Georgian heating engineers continue to calculate building energy consumption using standards established during the Soviet era rather than modern western methodologies. Accordingly, the thermal resistance factor "R" is 0.57 m^2*K/W for Tbilisi. Even these old norms are not obligatory in Georgia today.

The desirable resistance factor, defined in this survey, is not a result of scientific study. It has been defined on the basis of general experience, data from Europe, and the recommendations of Georgian specialists[1].

Based on this data, the recommended average thermal resistance factor "R" for Tbilisi is R=1.6-1.8 m^2*K/W. In the future, this data will require scientific approval according to local climate requirements.

[1] Energia Magazine #6, S. Baramidze, O. Kighuradze

Figure 3: Recommended R-values Cost Efficiency for Walls.[2 3]



[2] *Source: Energy-Efficiency Upgrades,* Edition Detail, Munich 2007*; p. 24*
[3] *Eurima-Ecofys* VII report; p. 45

Figure 4: Code-Stipulated Thermal Resistance of External Walls in European Countries (m2·K/W)

Country	Thermal Resistance
Sweden	5.0 – 10.0
Finland	3.3 – 5
Denmark	3.3 – 5
United Kingdom	2.5 – 3.3
Netherlands	2.5 – 5
Germany	1.67 – 2
France	2 – 2.5
Italy	2 – 2.5
Russia	1.5 – 5.6

BRIEF DESCRIPTION OF MATERIALS USED

Concrete Blocks

Expanded Perlite

CONCRETE BLOCKS

Concrete blocks are widely used in Georgia's construction sector, particularly in high-rise buildings. Block sizes are typically 40x20x20 cm. They are manufactured in Georgia, largely as a cottage industry. It is difficult to control quality both for strength and heat conductivity.

PERLITE BLOCKS

Perlite is a volcanic glass and, unlike other volcanic glasses, when heated to a high temperature expands 4-20 times in volume compared to its initial state. This characteristic makes perlite a very good insulator. A combination of perlite and concrete creates a perlite block. While an increased concrete/perlite ratio reduces heat efficiency, a reduced concrete/perlite ratio leads to reduced block strength. Perlite

Perlite Blocks

Basalt Fiber

Basalt Mat

Basalt Wool

blocks are ecologically clean and are fire resistant.

Perlite-cement, perlite-sheetrock, and other such mortars can be used for plastering and also have high thermal insulation qualities.

Perlite and perlite-concrete blocks are both manufactured in Georgia.

ROCK WOOL: HEAT INSULATION, MADE FROM BASALT FIBER

Rock wool evolves from the treatment of fiber created from melting basalt fragments. In Europe and North America, rock wool is widely used, as its heat resistance factor is quite high. It is also an ecologically clean product and fire resistant.

Rock wool in its classic form, a 4-20 cm thick dense basalt fiber-based material, is not produced in Georgia, though is imported. Due to the fact that Georgia has an abundance of basalt, this study recommends local companies take advantage of these resources and develop capacity to manufacture rock wool.

METHODOLOGY

In order to define R-total for certain wall types, the following formula is used: $\mathbf{R_{(total)}=1/\alpha_{(i)}+R_{(sum)}+1/\alpha_{(e)}}$; where $R_{(sum)}$ is the sum of the thermal resistance values of all wall layers and $\alpha_{(i)}$ and $\alpha_{(e)}$ are heat transfer coefficients, for winter conditions, of internal and external surfaces of the building envelope defined by the following equation: (СНиП II-3-79*).

The survey examines five Options for wall types. Option 1 is the wall type most widely used in Georgia and comprises a concrete block, 40 cm thick, plastered with sand-cement mortar on both sides.

Figure 5: Option 1 – Concrete Block, 40 cm Thick, Plastered with Sand-Cement Mortar on Both Sides

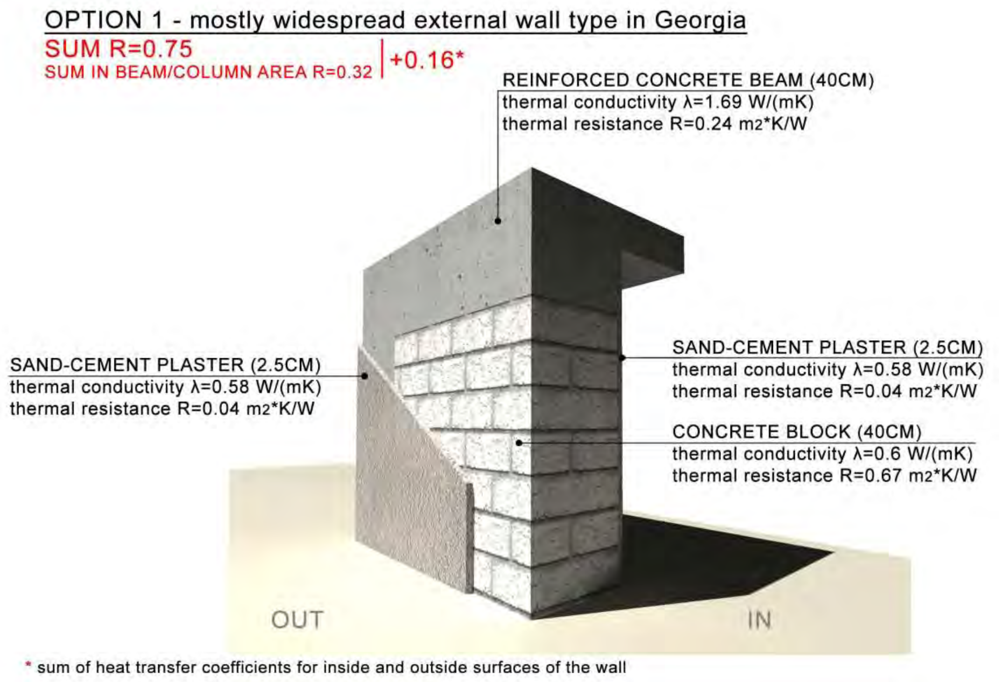


Figure 6: Thermal Resistance of Option 1

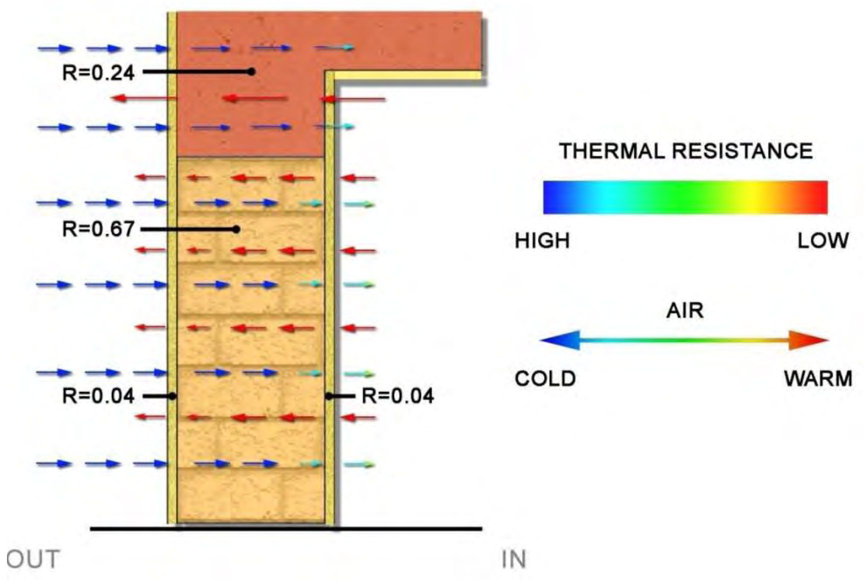


Figure 7: Option 2 – Perlite Block, 20 cm Thick, Plastered with Perlite-Cement Mortar on Both Sides

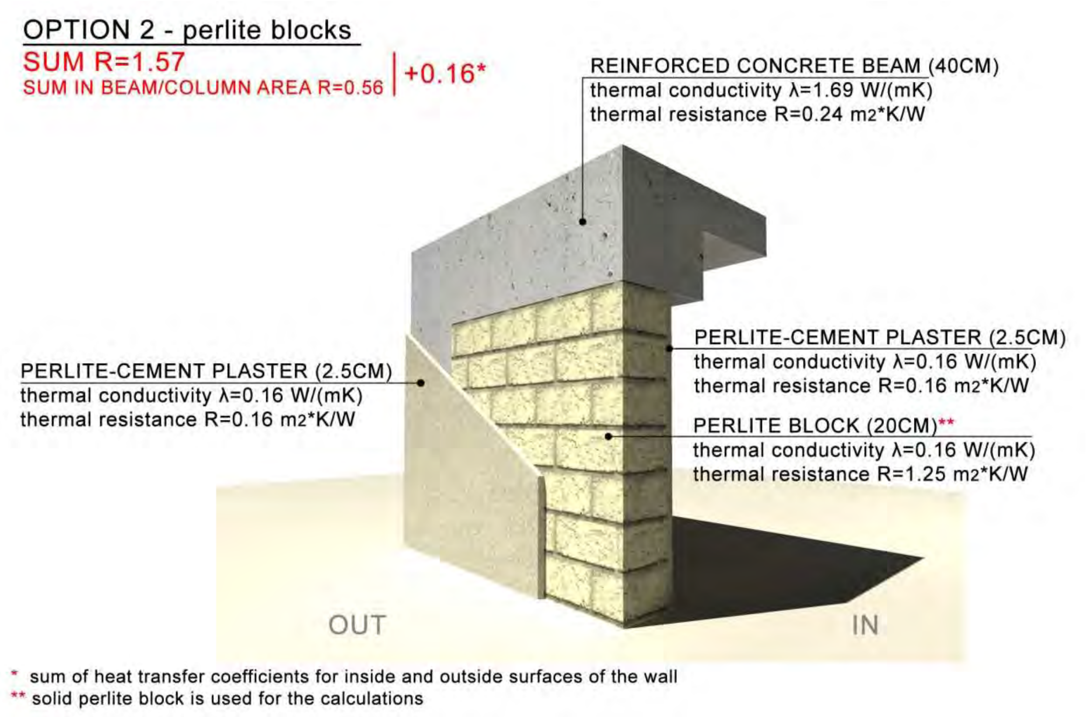


Figure 8: Thermal Resistance of Option 2

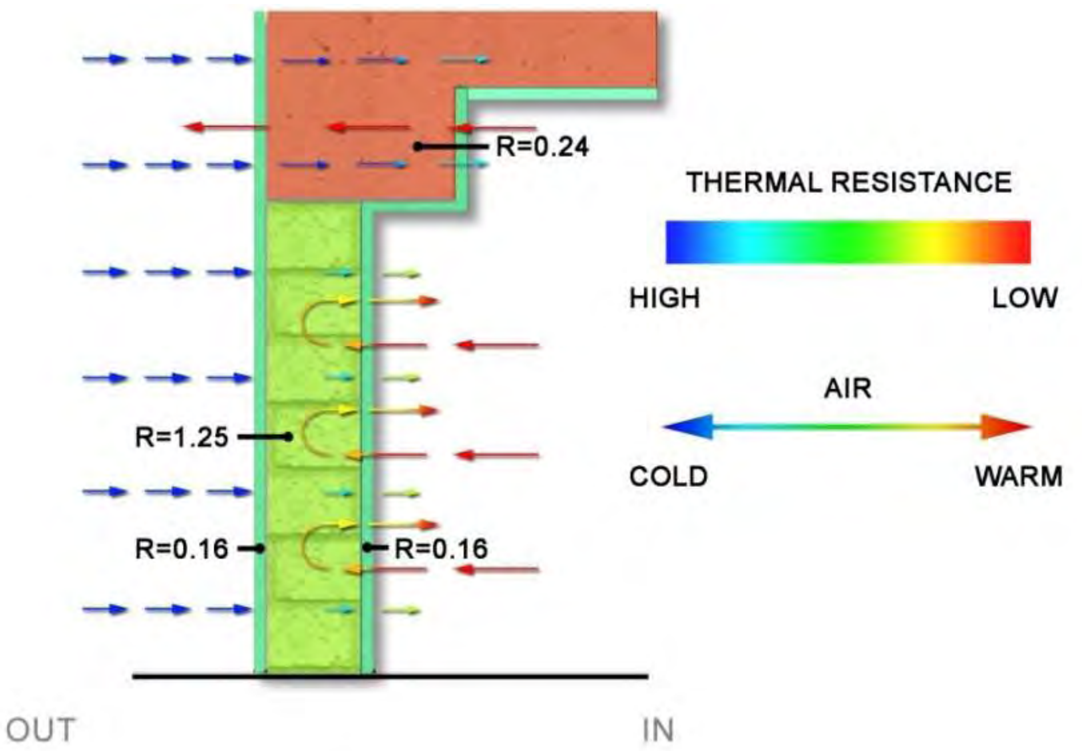


Figure 9: Option 3 – Concrete Block, 20 cm Thick, Plastered with Sand-Cement Mortar on the Inside and Insulated with 5 cm Layer of Rock Wool from Basalt Fiber on the Outside.

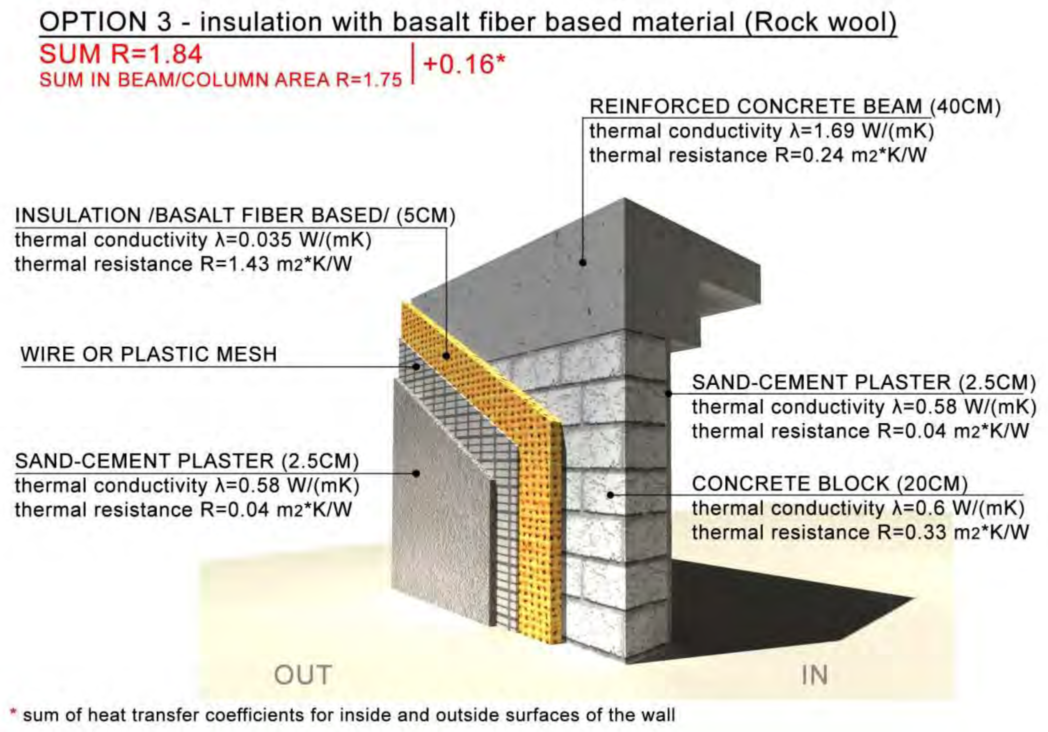


Figure 10: Thermal Resistance of Option 3

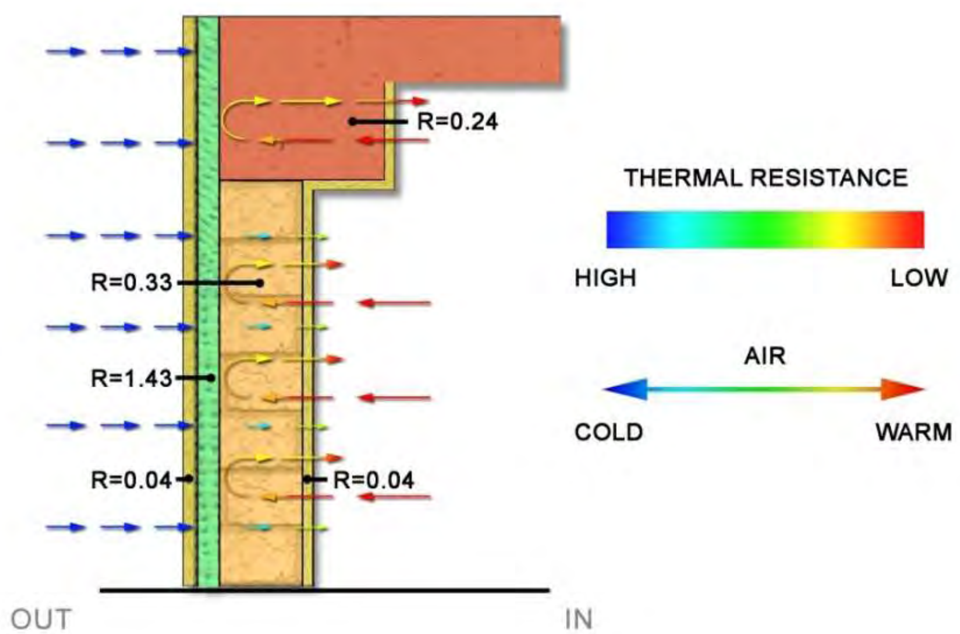


Figure 11: Option 3a – Same as Option 3, but with 2 Layers of Basalt Fiber Mat, 8 mm Each

It should be noted that Option 3, uses 5 cm rock wool not manufactured in Georgia, while the material used in Option 3a, a similar product, is manufactured in Rustavi.

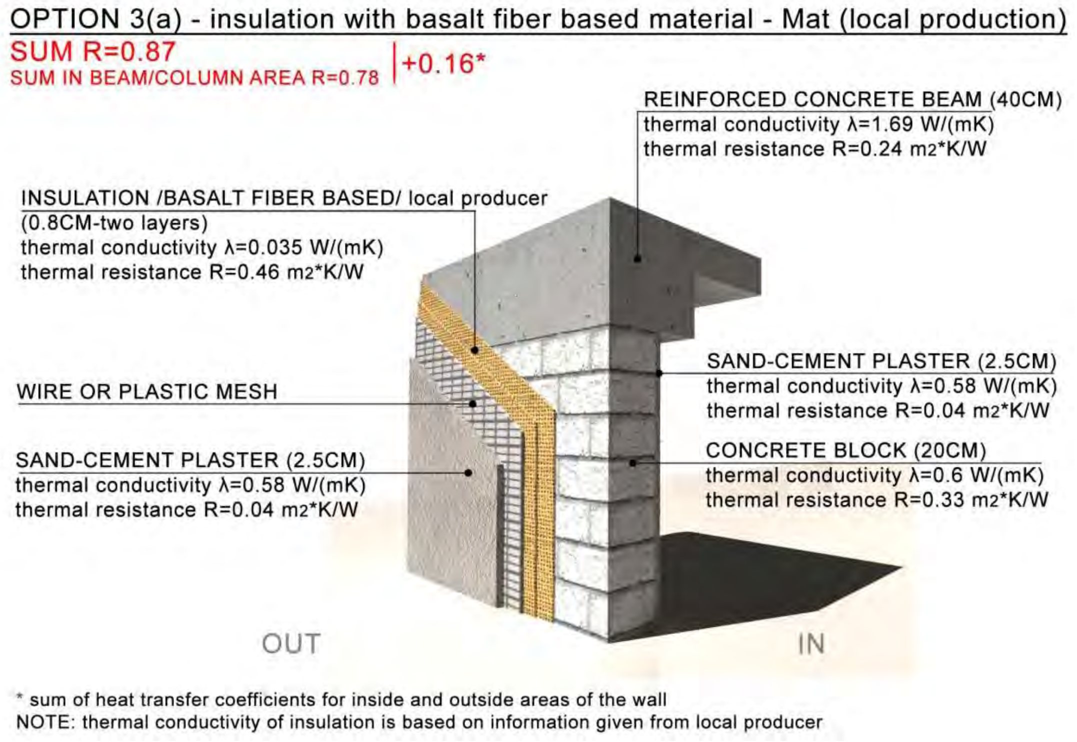


Figure 12: Thermal Resistance of Option 3a

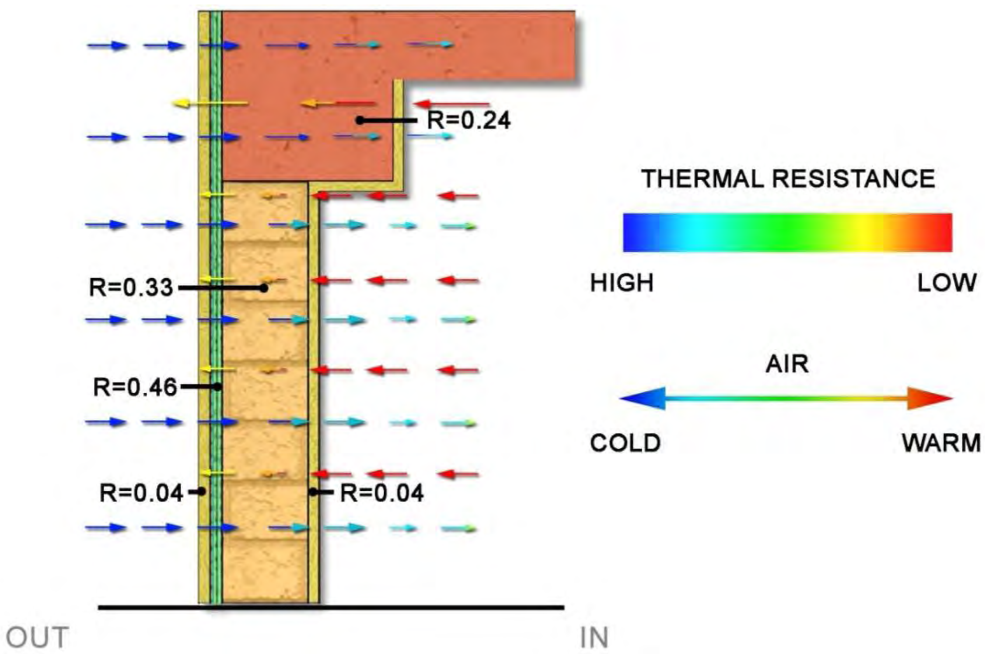


Figure 13: Option 4 – Perlite Block, 20cm Thick, with 5cm Rock Wool Insulation.

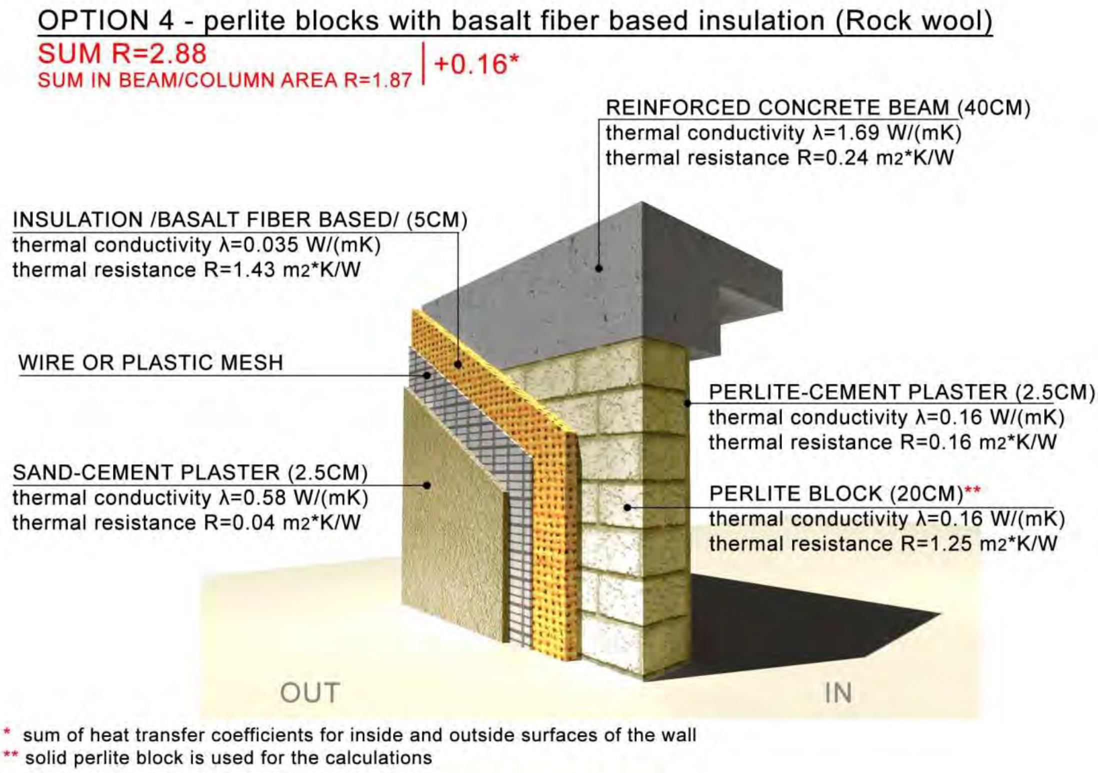
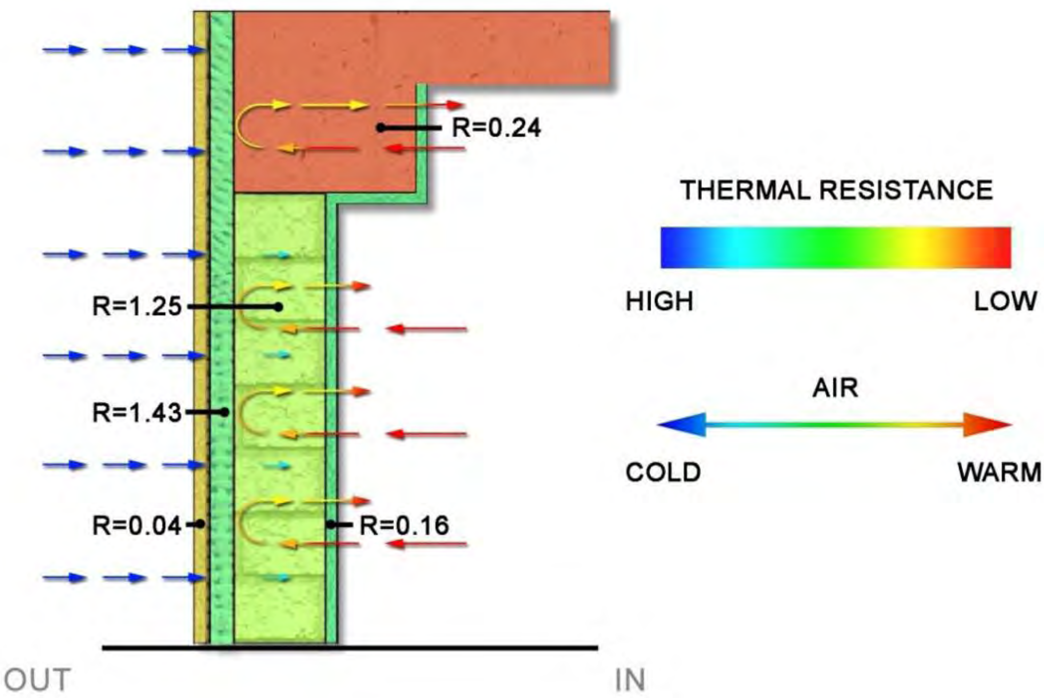


Figure 14: Thermal Resistance of Option 4



The figures above show that the total thermal conductivity of Option 1 meets minimal requirements for Soviet era standards and norms. Options 2 and 3 are within modern standards, while Option 3a has a low index due to the thickness of the mat. Option 4 has the best results, as the perlite and rock wool materials combined result in high insulating properties.

In this report, Options 2, 3, 3a, and 4 are always compared to Option 1, to give a clear understanding of their characteristics.

The Options considered in this report are the simplest and most widely practiced. It is also possible to make other wall types using various combinations of the materials, resulting in different heat efficiencies.

Each wall option is considered for class II, III, and IV buildings as defined according to current Georgian legislation and efficiency standards. Among other features, building classes are defined by the total area of the facilities with class II being 0-300m^2, class III being between 300-6,000m^2, and class IV being 6,000 m^2 and above. Buildings are described conventionally in the study and in the simplest configuration as shown below.

Figure 15: II Class Building, 2 Floors, 3,075 m^2

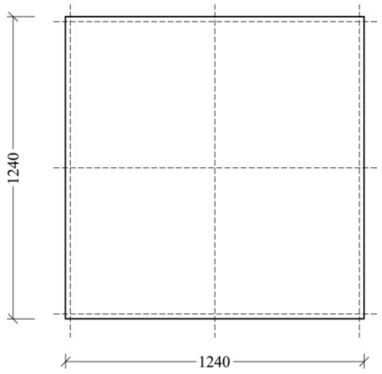


Figure 16: III Class Building, 8 Floors, 30,157 m^2

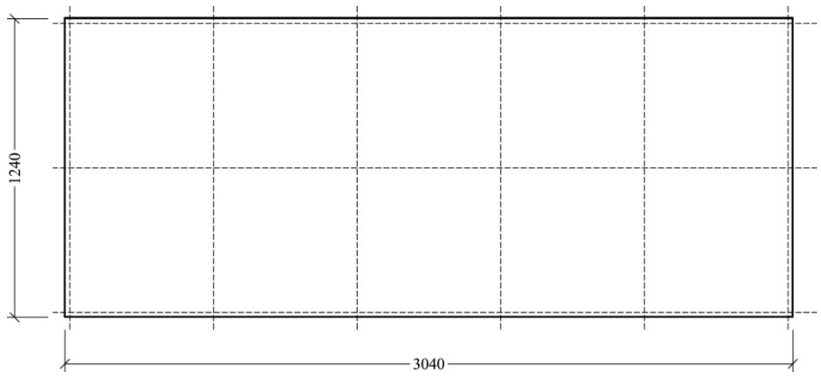
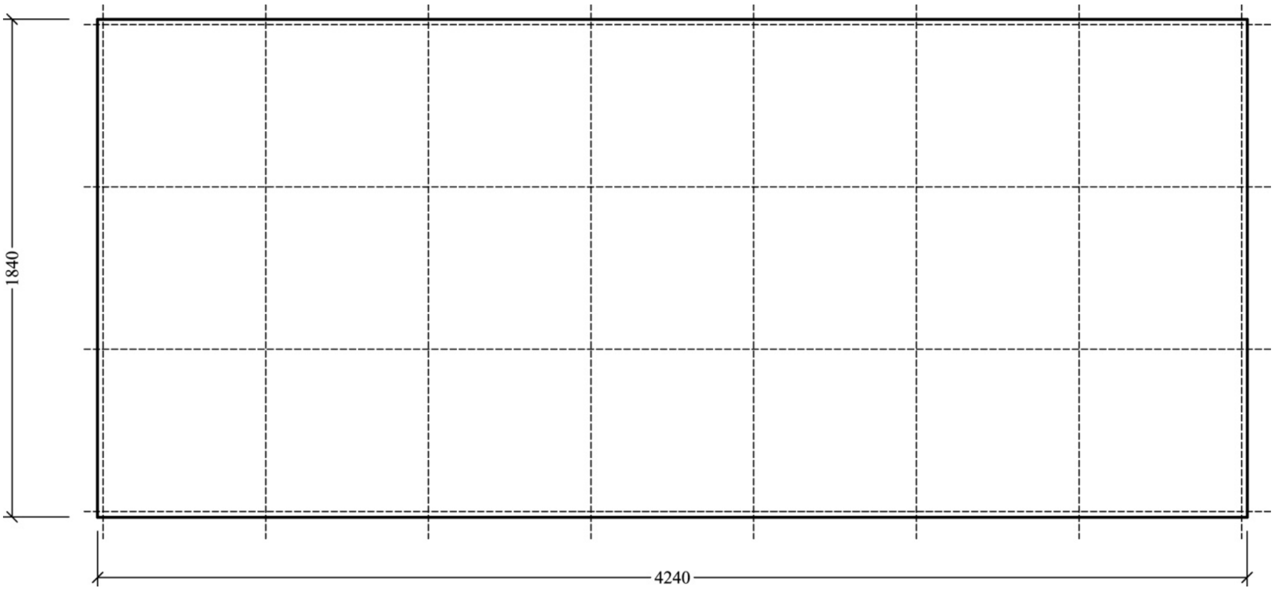
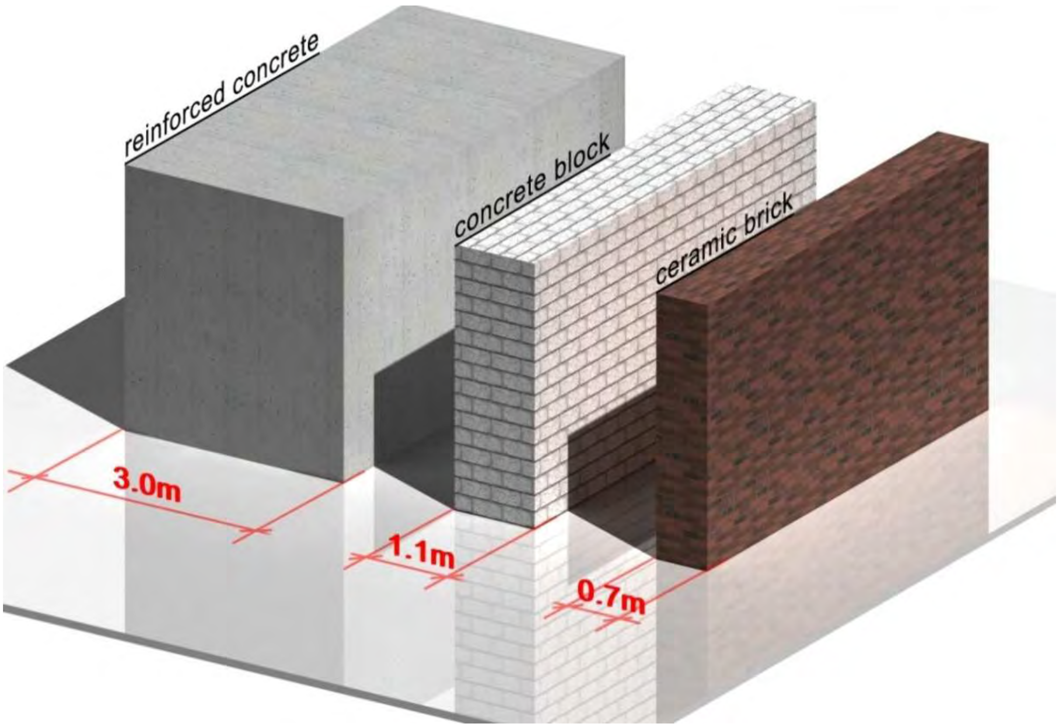


Figure 17: IV Class Building, 18 Floors, 140,427,800 m^2



The heat conductivity factor (λ) of the wall's layers and desirable thermal resistance (R) are used to calculate the thickness of the building envelope and should be a known value.

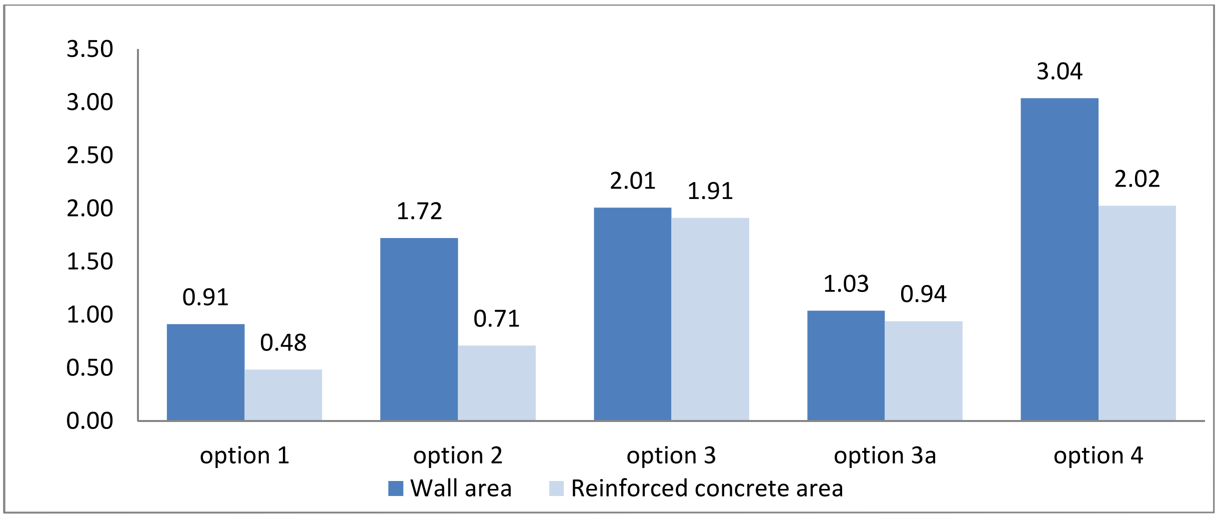
Figure 18: Wall Thickness in Case of Thermal Resistance R=1.8



In the figure above, each wall is comprised of different materials and each has a thermal resistance measurement of 1.8.

When calculating heat loss in the skeleton building, the reinforced-concrete areas, such as columns and girders, are good heat conductors and have poor thermal resistance. Therefore, the sections of the building envelope with the reinforced-concrete elements have an R index lower than in other parts of the envelope, the latter built with filler materials as shown in Figure 19 (below).

Figure 19: Thermal Resistance in Wall and R/C Areas



The proportion of these reinforcing elements in different class of buildings is calculated and shown below in Figure 20. The mean R-values for each option are calculated according to this data and are shown below.

Figure 20: Percentage of Wall and R/C Areas in Different Class Buildings

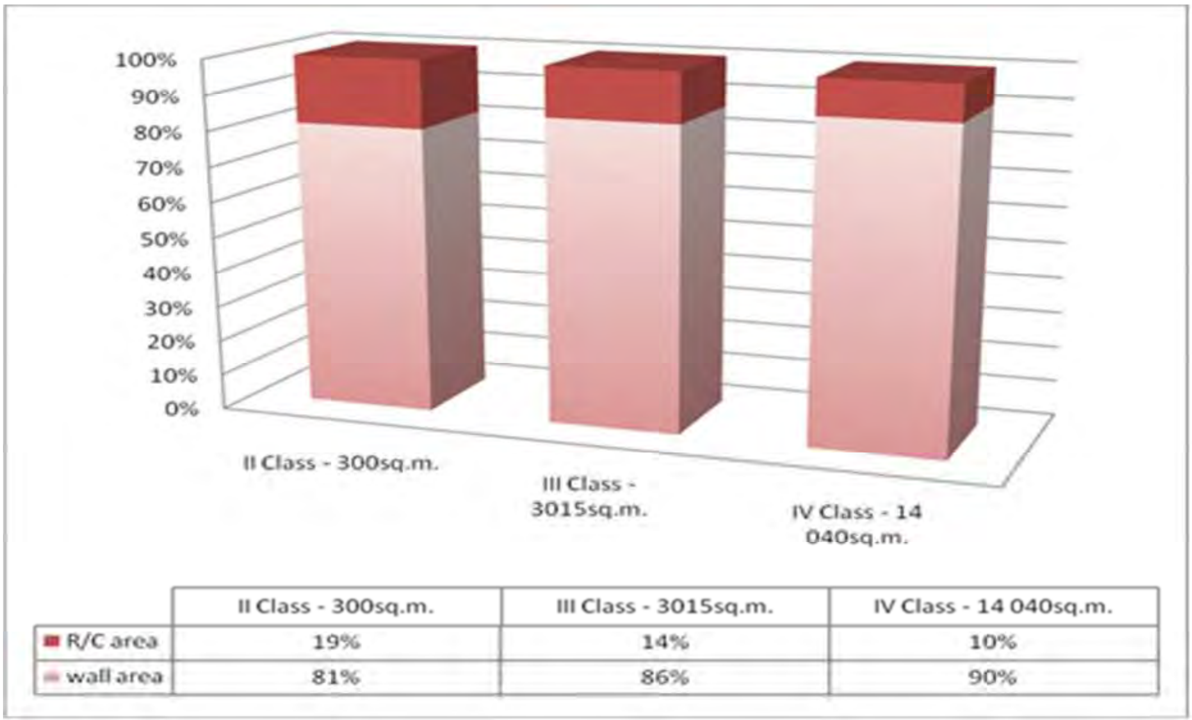
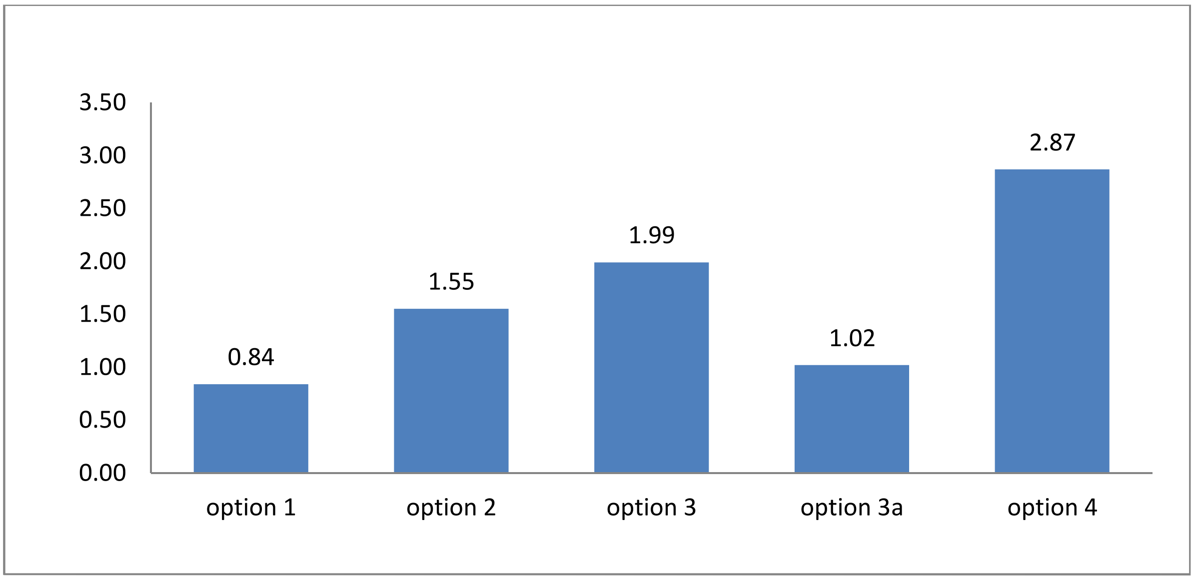
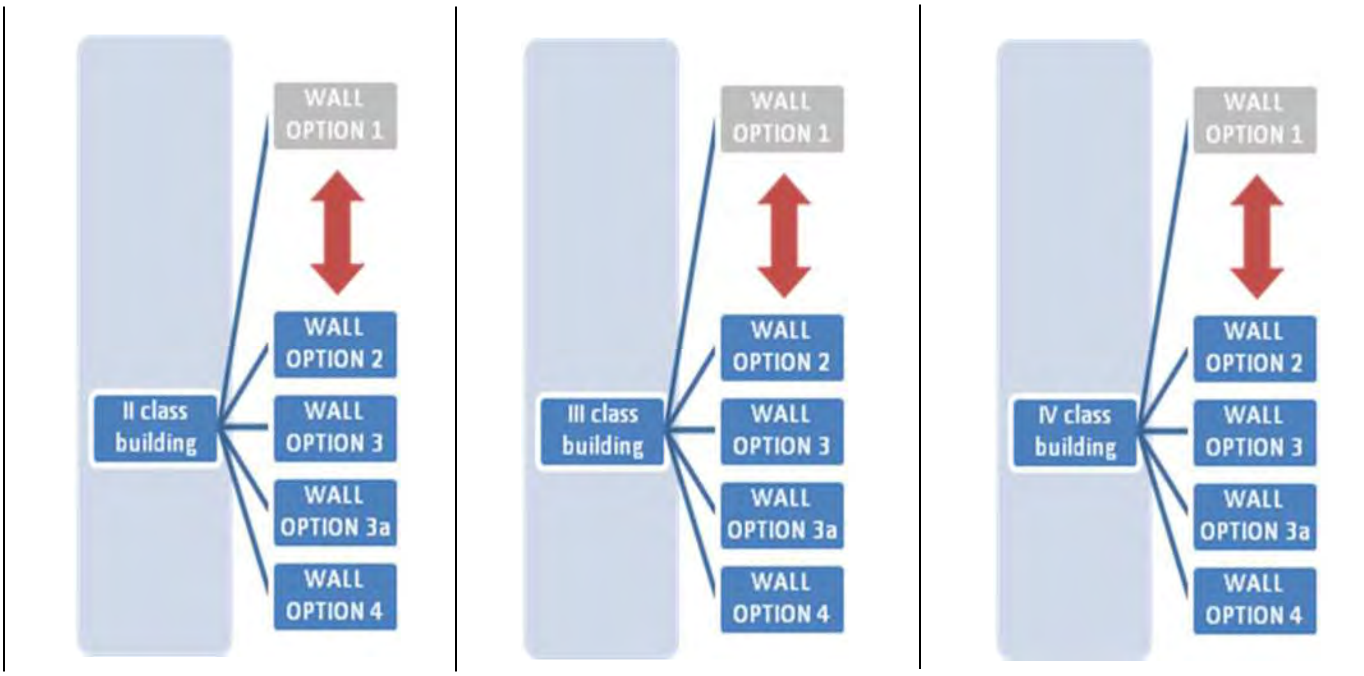


Figure 21: Mean R Values



For each of the conventional building types (all 3 classes), the study examined each wall type Option. Options 2, 3, 3a and 4 were the compared with Option 1 as can be seen in the diagram below.

Figure 22: Study Methodology



As can be seen in Figure 23 (below), due to the physical properties and characteristics of perlite and basalt insulation materials, three distinct factors are affected when they are used in construction.

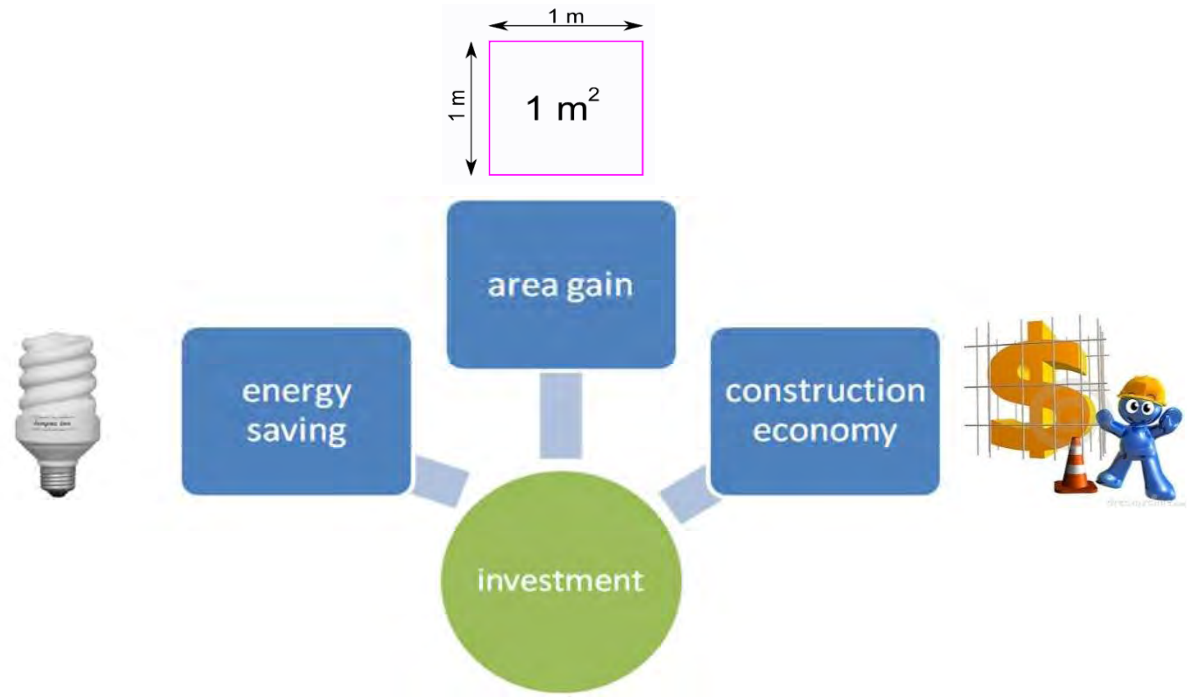
1. Firstly, construction using perlite blocks can decrease the overall weight of a building, reducing the pressure on the foundations and eliminating the need for thick walls at the base; thereby creating larger internal space than would normally be possible with concrete blocks.

2. Due to the reduced weight of the building and thinner walls from using perlite blocks, the quantity (and therefore cost) of construction materials also decreases.

3. Construction with perlite and basalt materials increases building insulation, thereby decreasing heating costs in winter and cooling costs in summer.

The first and second factors above apply during and soon after construction, while cost savings from energy efficiency are accumulated over time.

Figure 23: Factors Associated With Choice of Construction Materials and Design



Additional capital investment is needed with Options 2, 3, 3a and 4 that is not necessary in Option 1. In order to estimate the additional capital required for these Options, the average market cost of wall filling layers for each type of wall was calculated. The total additional investment was obtained by multiplying this amount by the specific area of each class of building as shown in Figures 24, 25 and 26.

Figure 24: Capital Investment Required per 1m² (GEL)

	Investment Required per 1 m² wall / GEL (Compared with Option 1)
OPTION 1	0
OPTION 2	4.3
OPTION 3	27.5
OPTION 3a	12,5
OPTION 4	51.3

Figure 25: Total Capital Investment Required (GEL)

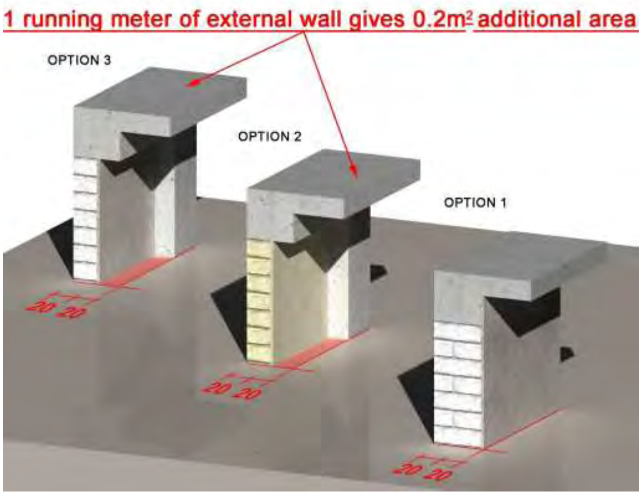
	Total Additional Investment Required / GEL (Price Difference Compared to Option 1)		
	Class II	**Class III**	**Class IV**
OPTION 1	0	0	0
OPTION 2	1,312	12,285	29,889
OPTION 3	10,388	92,430	215,578
OPTION 3a	5,483	47,205	106,888
OPTION 4	16,681	153,990	370,451

Figure 26: Additional Capital Investment Required (%)

	Additional Investment Percentage (Difference Compared with Option 1)		
	Class II	**Class III**	**Class IV**
OPTION 1	0	0	0
OPTION 2	7	6	6
OPTION 3	52	48	45
OPTION 3a	27	25	23
OPTION 4	83	80	78

AREA GAIN

Figure 27: Area Gain for Different Options



The additional area obtained, upon reducing the wall thickness, was calculated for each type of building. The cost of $1m^2$ is defined on the basis of the minimal real estate price in Tbilisi calculated at GEL 700.

ENERGY SAVINGS

Heat loss was calculated for each Option in order to determine energy savings when natural gas is used as fuel. The figures below show gas consumption and savings in comparison with Option 1, per heating season, which are the five coldest months of the year in Tbilisi.

Figure 28: Gas Consumption per Season (m3)

	Class II	Class III	Class IV
	Gas Consumption per Season (m^3)		
Option 1	4,971.2	28,180.1	85,793.6
Option 2	3,310.7	16,717.8	49,273.9
Option 3	2,888.1	13,800.098	39,978.0
Option 3a	4,337.2	23,803.6	71,849.7
Option 4	2,435.2	10,674.0	30,018.1

Figure 29: Gas Savings per Season (m3)

	Class II	Class III	Class IV
	Gas Saving per Season (m^3)		
Option 1	0	0	0
Option 2	1,660	11,462	36,520
Option 3	2,083	14,380	45,816

Option 3a	634	4,377	13,944
Option 4	2,536	17,506	55,776

Figure 30: Gas Saving per Season (%)

	Class II	Class III	Class IV
	Gas Saving per Season (%)		
Option 1	0	0	0
Option 2	33	41	43
Option 3	42	51	53
Option 3a	13	16	16
Option 4	51	62	65

Figure 31: Gas Cost Saving per Season (GEL)

	Class II	Class III	Class IV
	Gas Cost Saving per Season (GEL)		
Option 1	0	0	0
Option 2	847	5,846	18,625
Option 3	1,062	7,334	23,366
Option 3a	323	2,232	7,111
Option 4	1,293	8,928	28,446

The figures below show the time period needed to regain investment, in terms of gas savings.

Figure 32: Gas Economy for Heating II Class Building

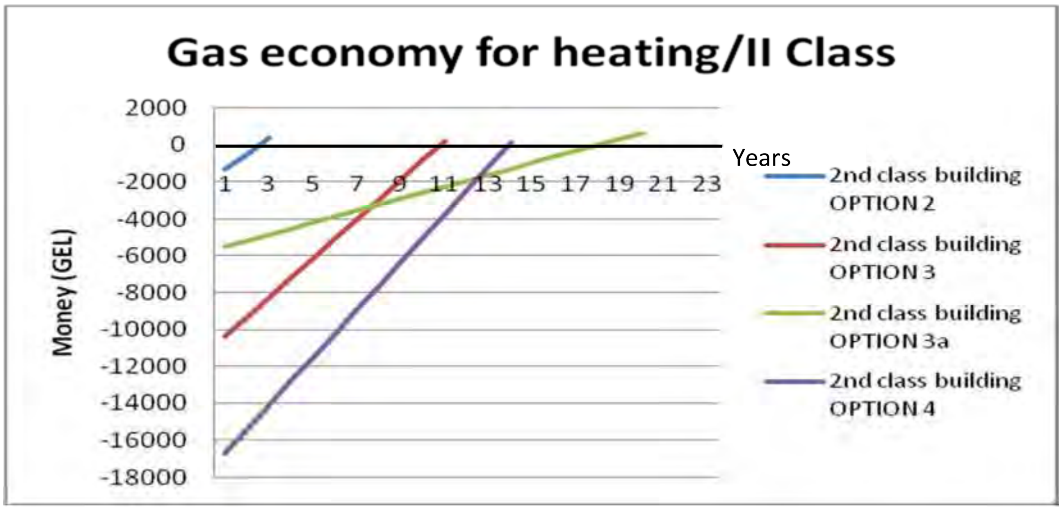


Figure 33: Gas Economy for Heating III Class Building

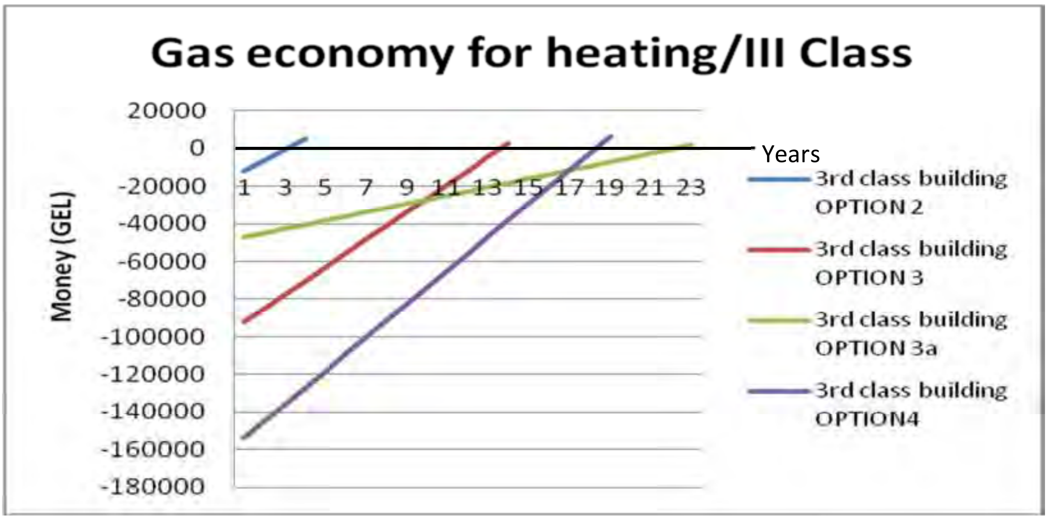
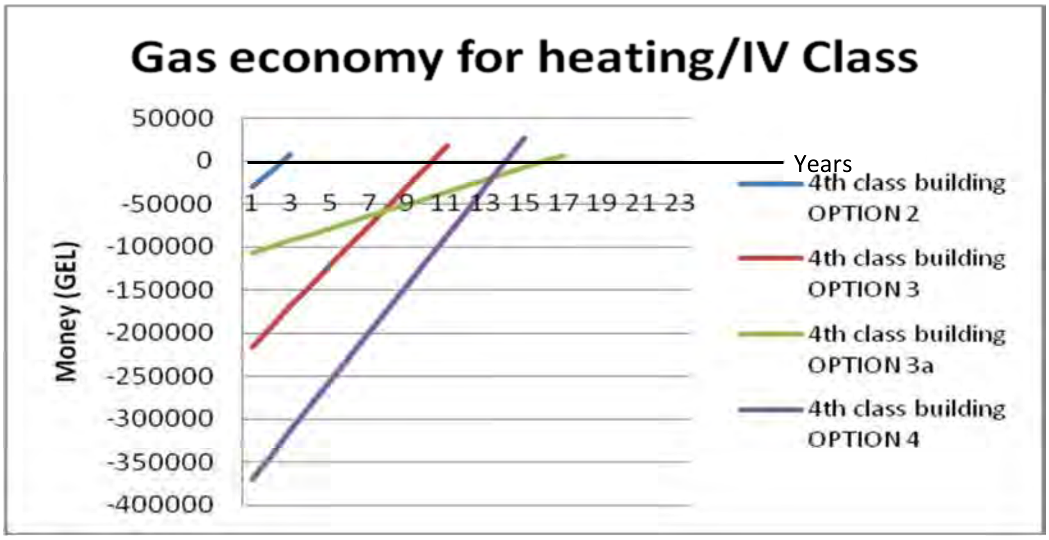


Figure 34: Gas Economy for Heating IV Class Building



From these figures, the least expensive and shortest payback period is with Option 2, using perlite blocks. In this case, the payback period is between one and two years, depending on the building class, even though its energy efficiency performance is inferior to Option 3. It should also be noted, that in the case of perlite blocks and plaster, the insulation of thermal bridges remains problematic.

Option 3 requires imported basalt insulation products and, as such, the payback period takes longer.

Option 4 is the most expensive, although it has the best thermal resistance qualities and the time period required to recoup investment is not significantly longer than with option 3.

CONSTRUCTION ECONOMY

In order to estimate material and financial savings in the skeleton of the building, a structural calculation was performed on each class of building, and with each wall filler type.

- Class II 2-storey building with dimensions 12.4m x 12.4m;
- Class III 8-storey building with dimensions 12.4m x 30.0m;
- Class IV 18-storey building with dimensions 18.4m x 42.4m;

All three buildings are rectangular, with a minimum 3.3m floor to ceiling height. From a structural viewpoint, all buildings are constructed in-situ with a reinforced-concrete skeleton.

Figure 35: Class II Building Skeleton

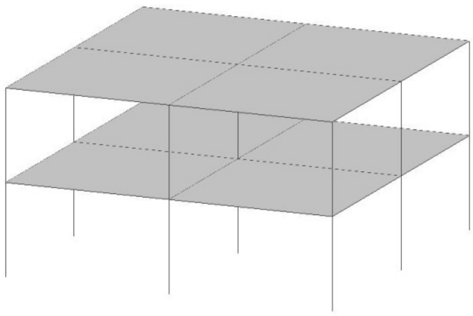


Figure 36: Class III Building Skeleton

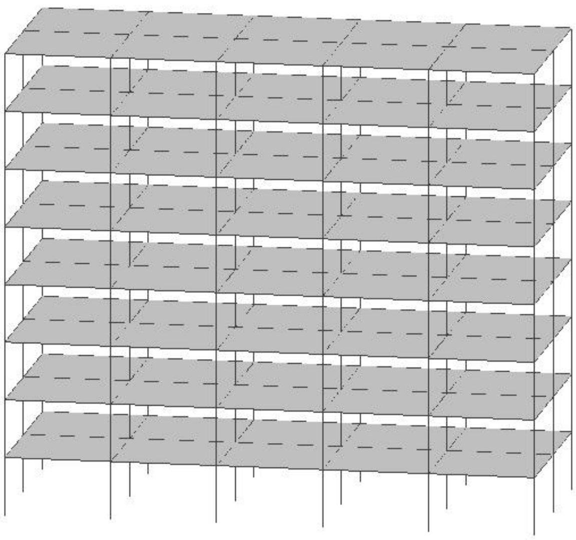
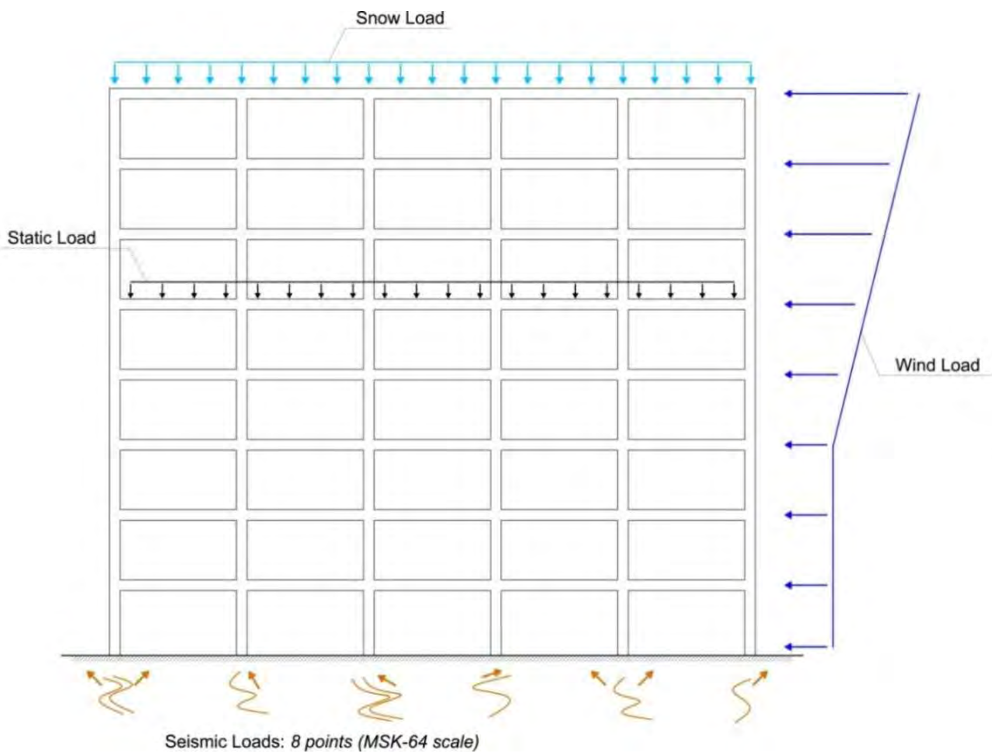


Figure 37: Class IV Building Skeleton

The contemporary estimation of static and dynamic loads for Class II, III, and IV buildings is calculated according to current Georgian construction normative documentation. Generally, the building influences static and dynamic loads, which in their part are grouped into live, dead, and special type loads. Dead loads include the weight of the building's immovable parts such as load-bearing elements of the skeleton, external walls, internal partitions, and finishing, among others. Live loads include snow and wind, as well as the weight of light equipment and those parts of the building that seldom change, including temporary partitions, and fixed equipment among others, while special loads are those caused by seismic fluctuations. These types of loads are displayed below in Figure 38.

Figure 38: Scheme of Static and Dynamic Loads on Building



As this survey estimated savings based upon the weight reduction of external filler in buildings, the calculation diagrams were undertaken in order to simplify analysis of the final results. The skeleton for similar class buildings and cross sections of load-bearing elements in the diagrams below are maintained. Only the volume of loads, according to wall type, varies.

Figure 39: Structural Parameters of Wall Components in Option 1

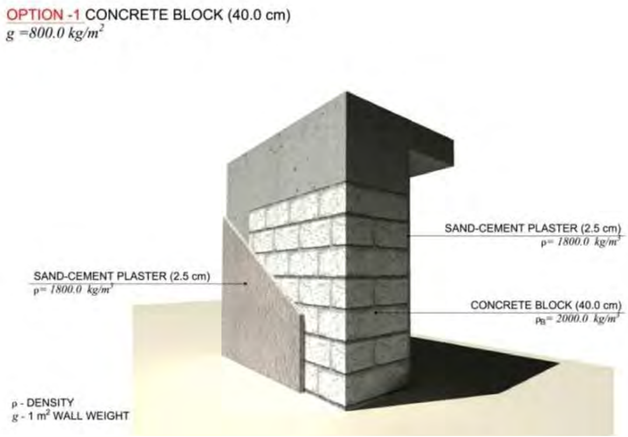


Figure 40: Structural Parameters of Wall Components in Option 2

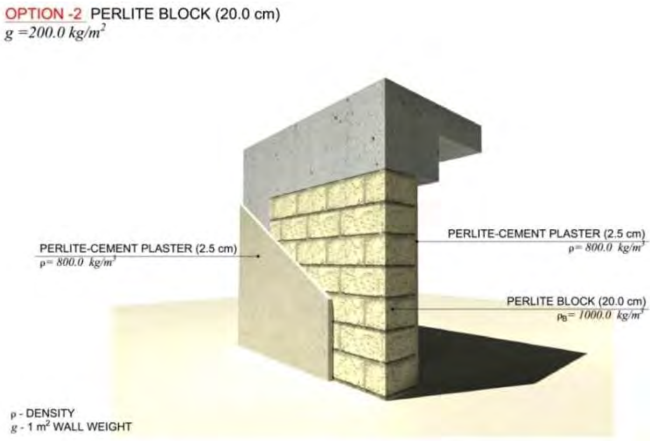


Figure 41: Structural Parameters of Wall Components in Option 3

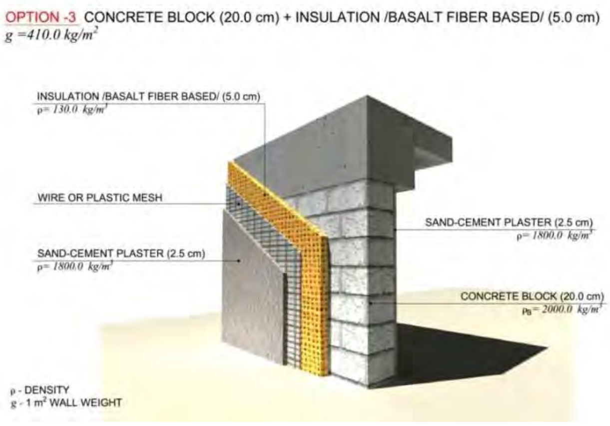


Figure 42: Structural Parameters of Wall Components in Option 3a

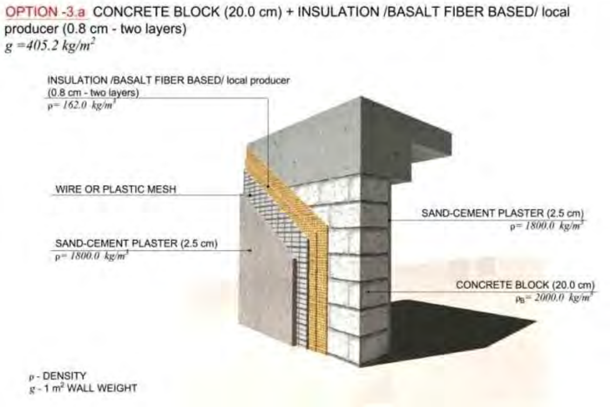
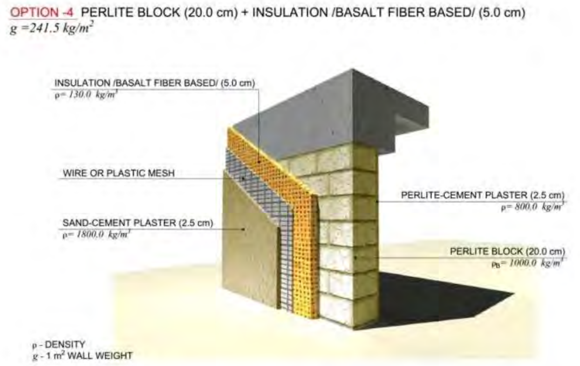


Figure 43: Structural Parameters of Wall Components in Option 4



Figures 44, 45, 46, and 47 show the percentage of the external filler's weight in ratio to the total weight of the building with class III, or 8-storey buildings, being used as a case study.

Figure 44: Option 1 - Concrete Blocks (40cm thick) used as filler

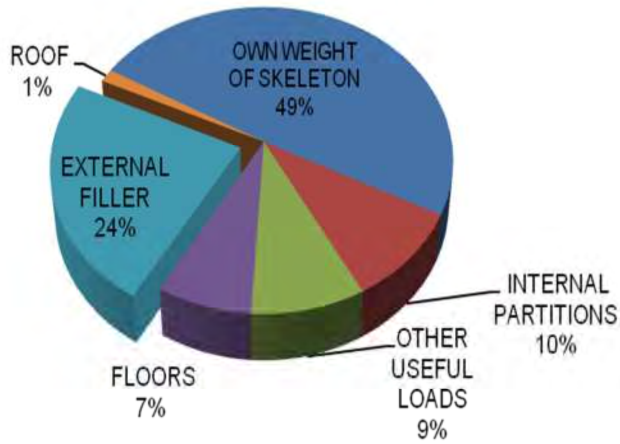


Figure 45: Option 2 - Perlite Blocks (20cm thick) used as filler

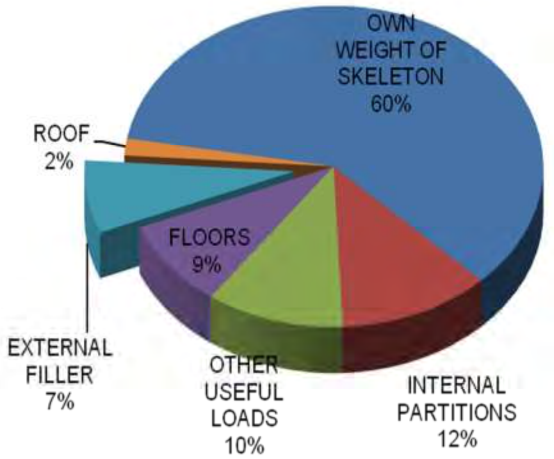


Figure 46: Options 3 and 3a - Concrete Blocks (20cm thick) using External Insulating Layer

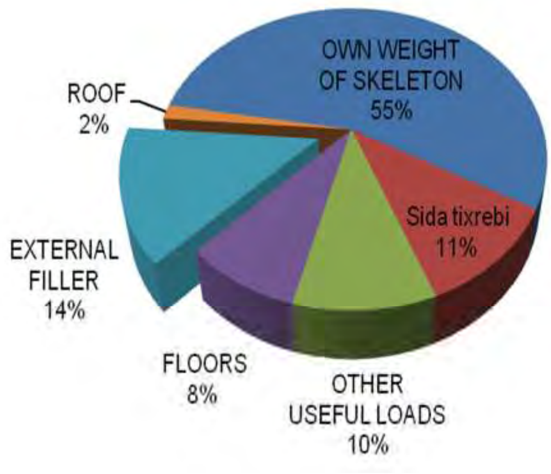
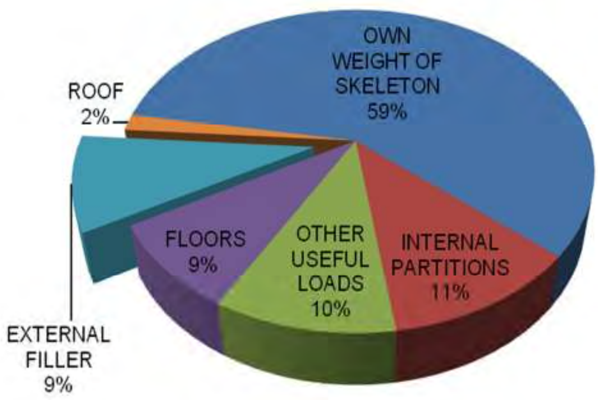


Figure 47: Option 4 - Perlite Blocks (20cm thick) using External Insulating Layer



The figures below illustrate the percentage difference in amount of reinforcement used in the same class of building when different external fillers are utilized.

The results conclude that the use of reinforcement in class II buildings does not depend on the type of external filler as the expenditure on $1m^2$ in all three cases is the same or very close to each other. In class III and IV buildings, the percentage of reinforcement used, such as the armature, depends on the external filler and is less than Option 1 by as much as 5.8%.

Figure 48: Difference in Reinforcement Usage for all Options in Class II Building

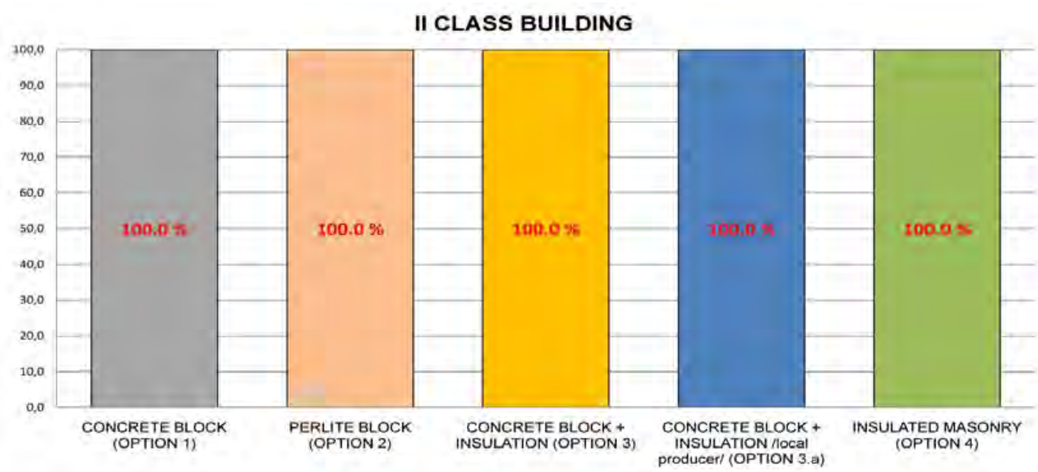


Figure 49: Difference in Reinforcement Usage for all Options in Class III Building

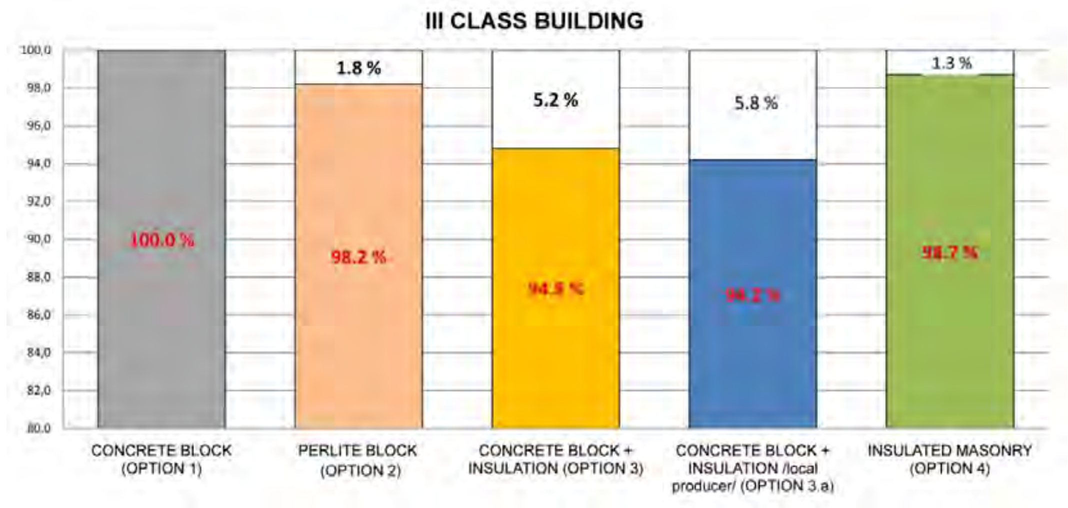
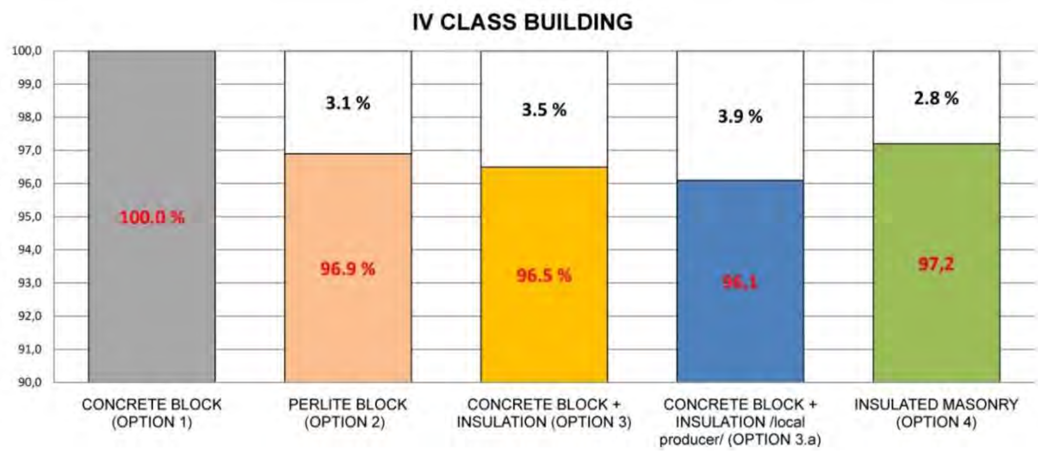


Figure 50: Difference in Reinforcement Usage for all Options in Class IV Building



CAPITAL INVESTMENT RECOVERY PERIOD DIAGRAMS

The results of the analysis demonstrate the capital investment payback periods for each Option, enabling further evaluation of the various Options.

Figure 51:

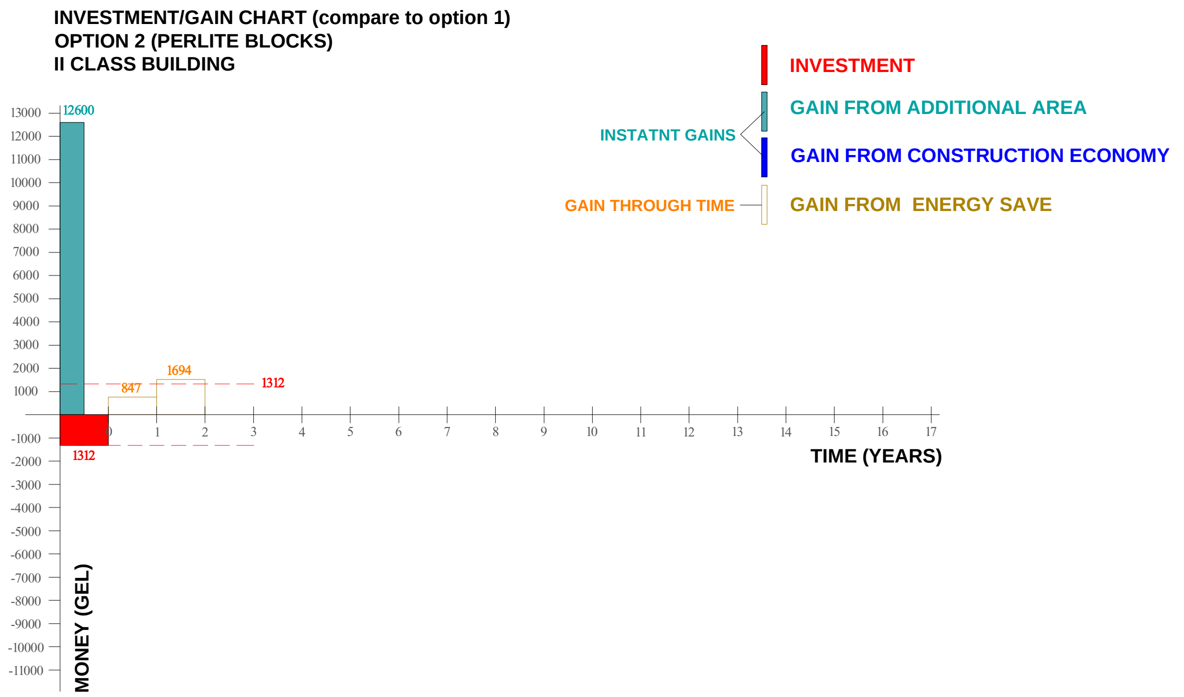


Figure 52:

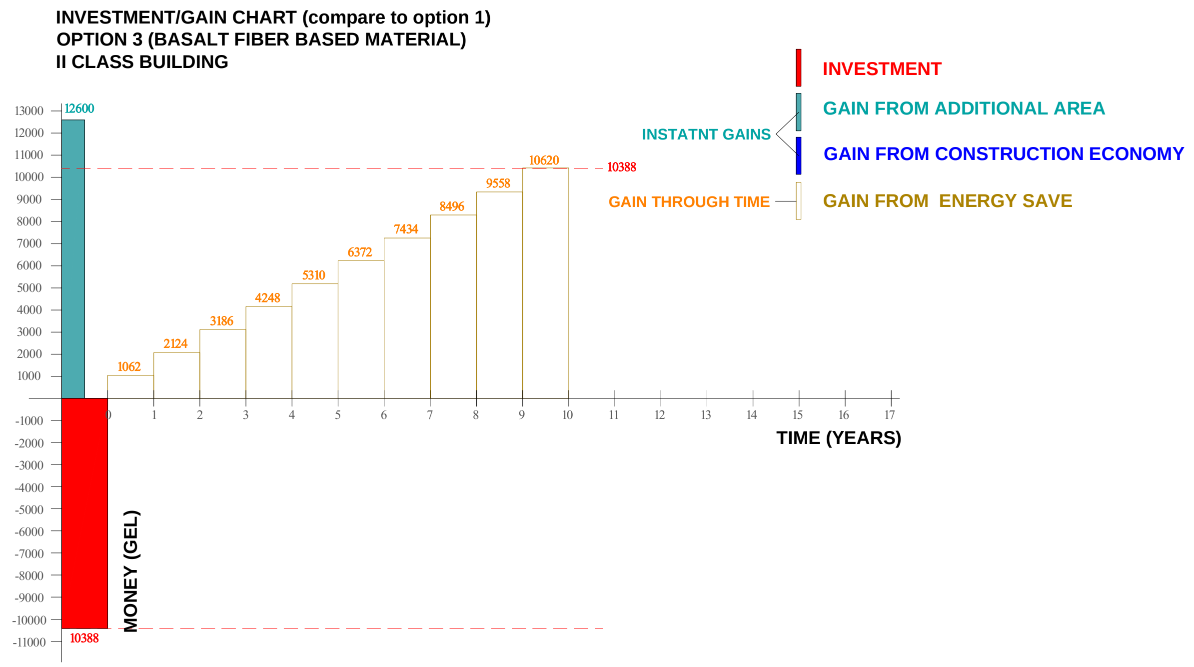


Figure 53

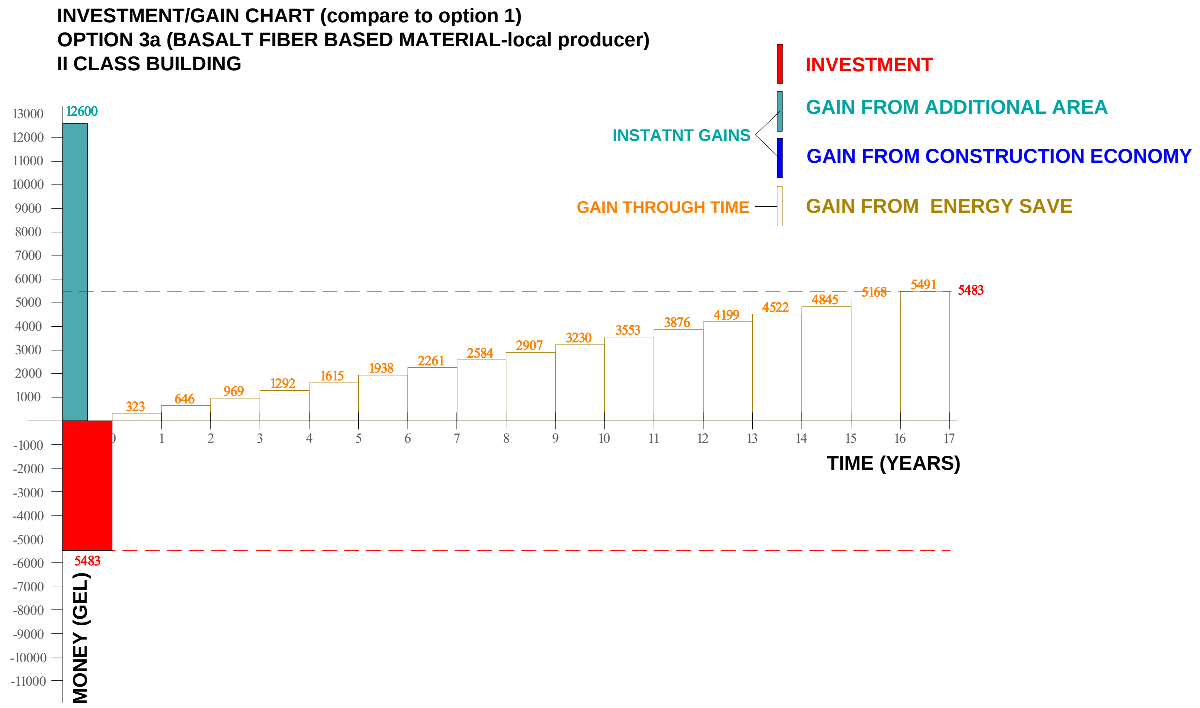


Figure 54:

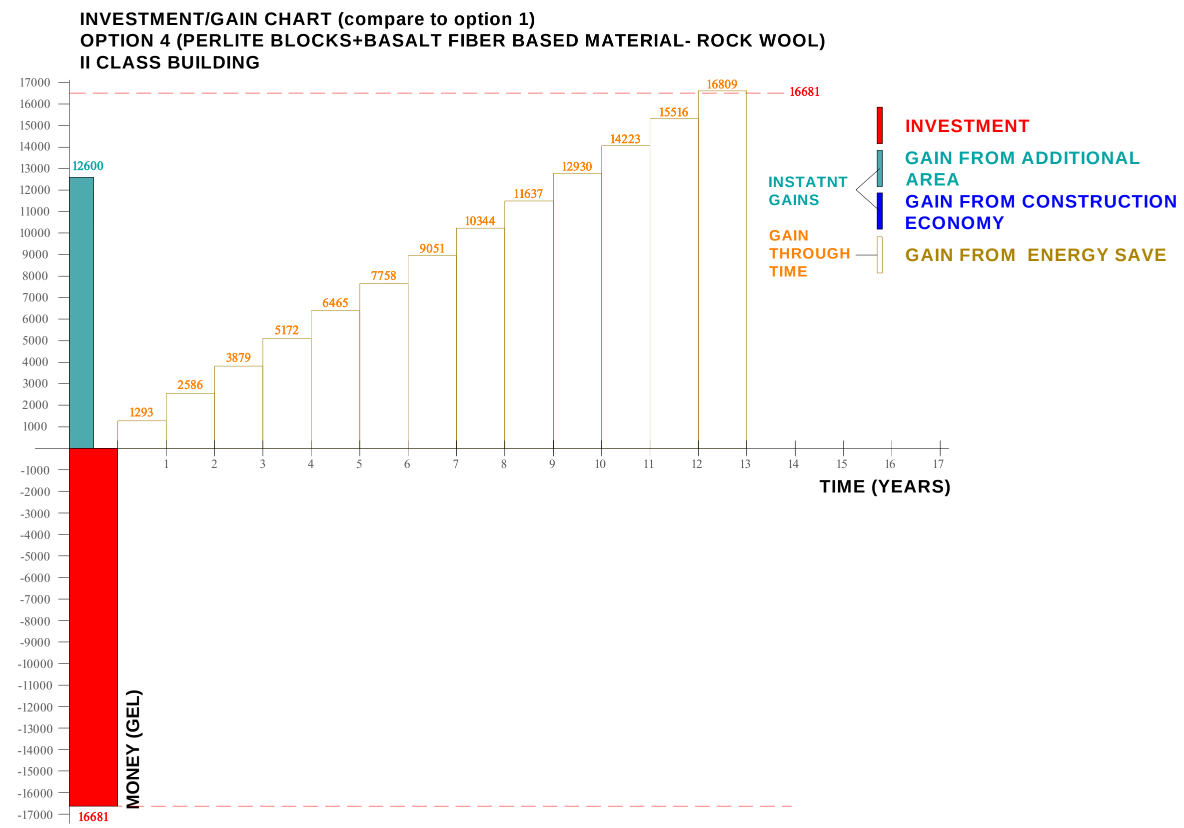


Figure 55:

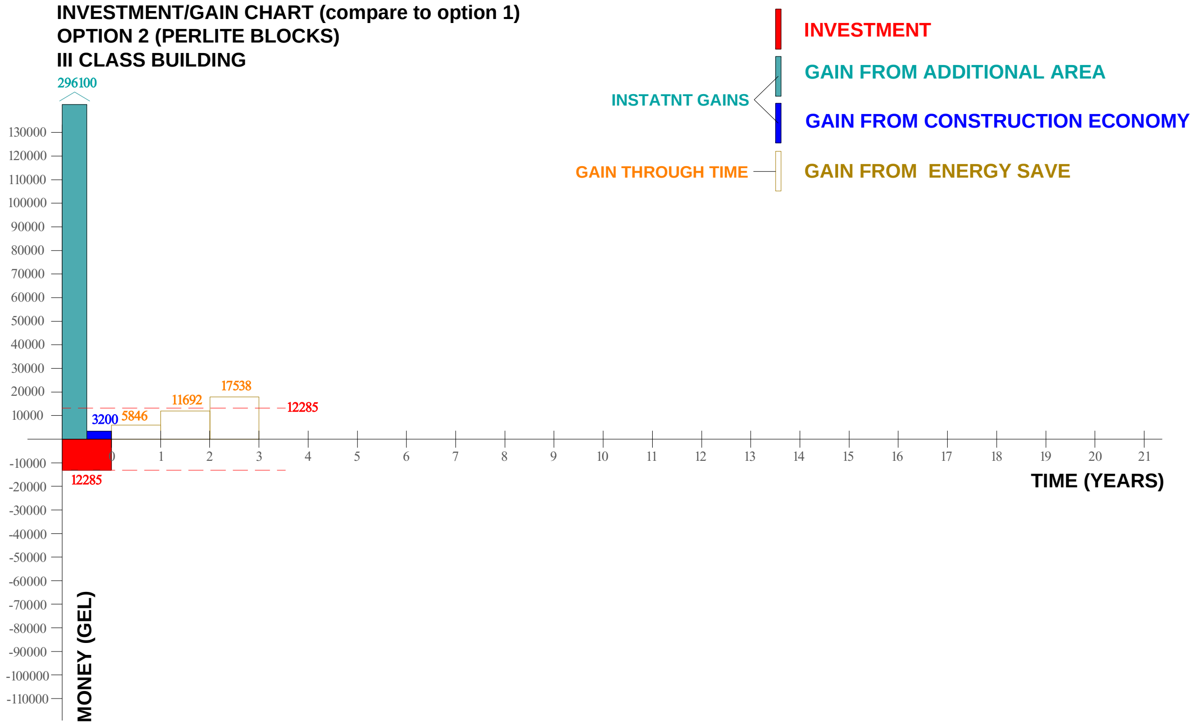


Figure 56:

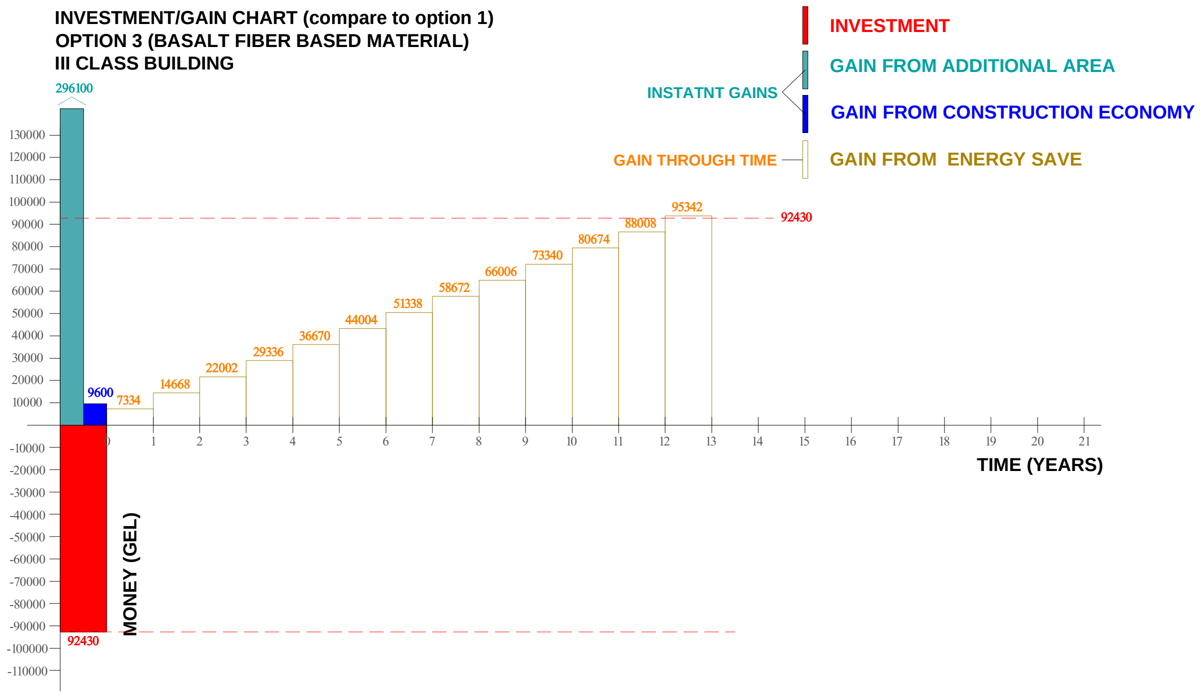


Figure 57:

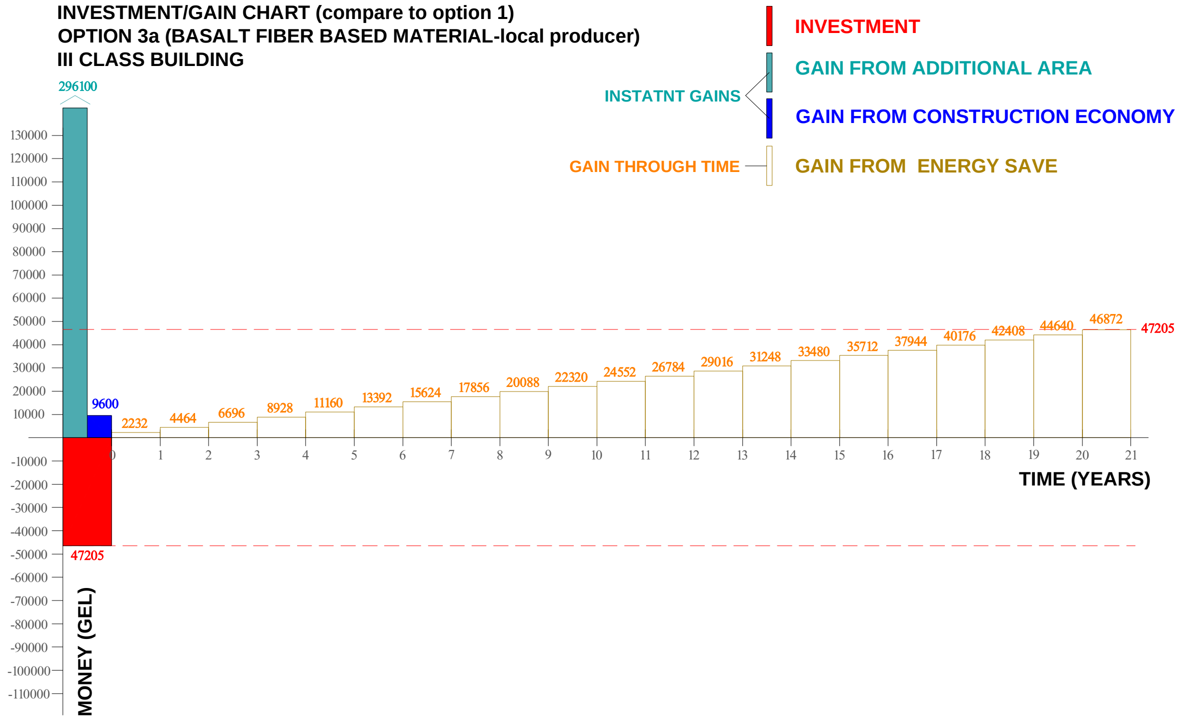


Figure 58:

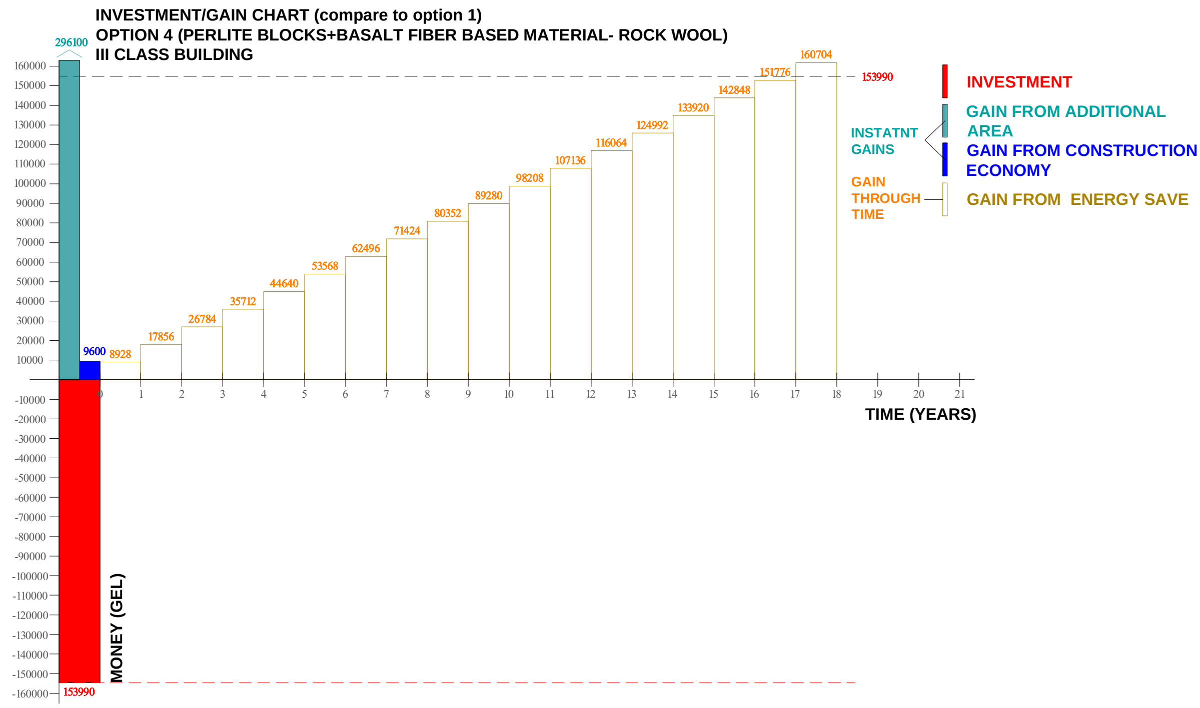


Figure 59:

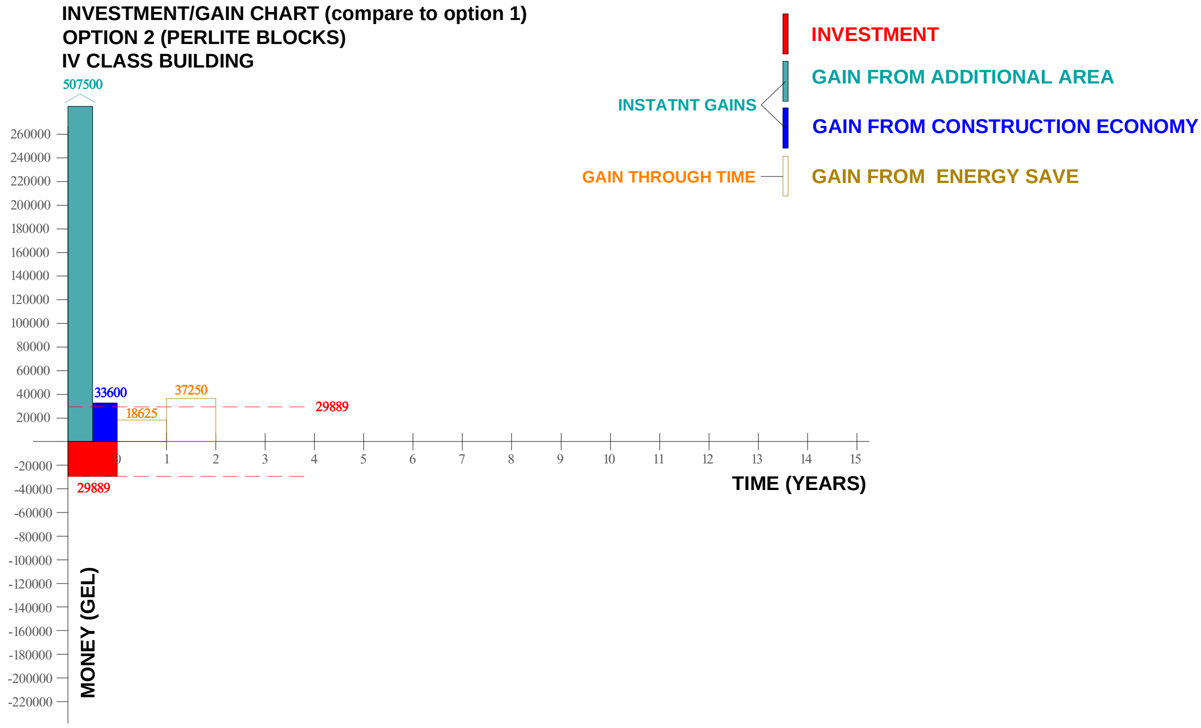


Figure 60:

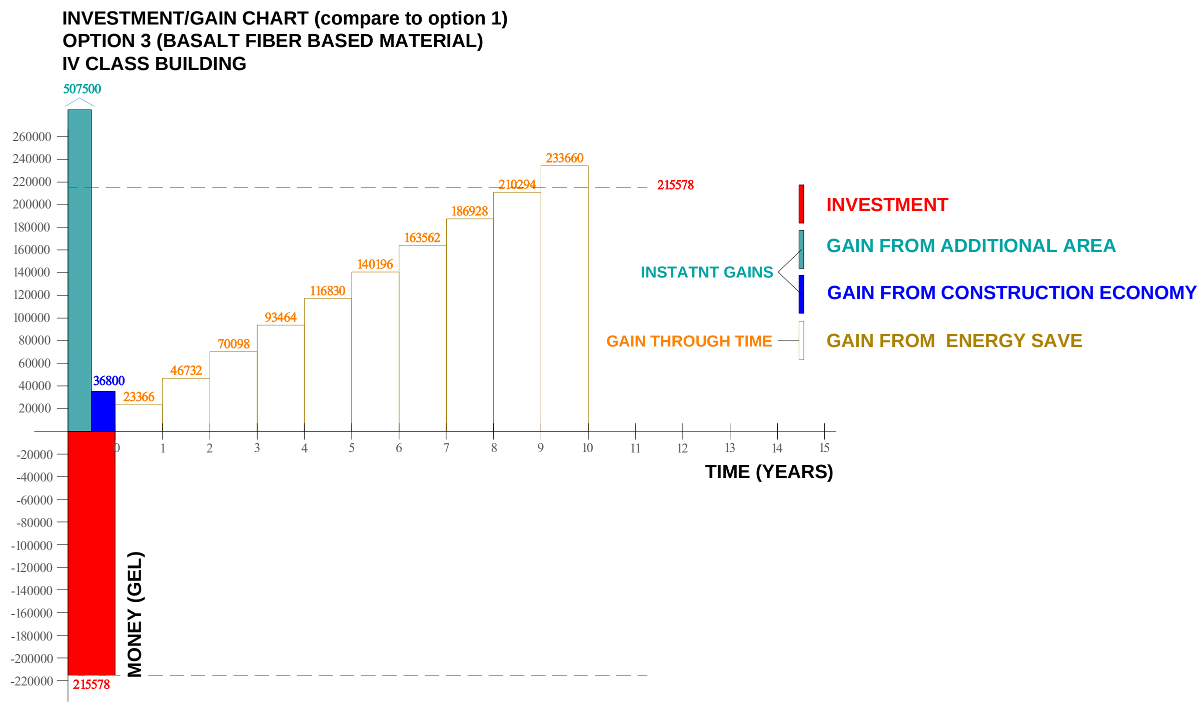


Figure 61:

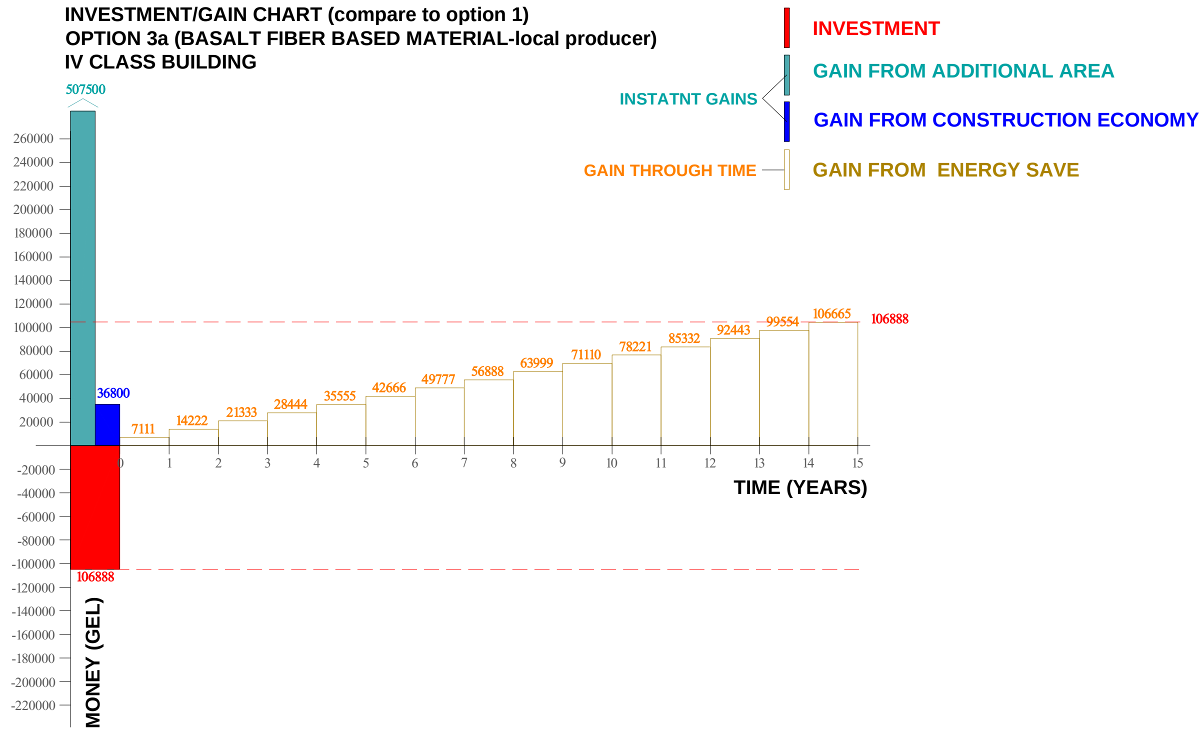
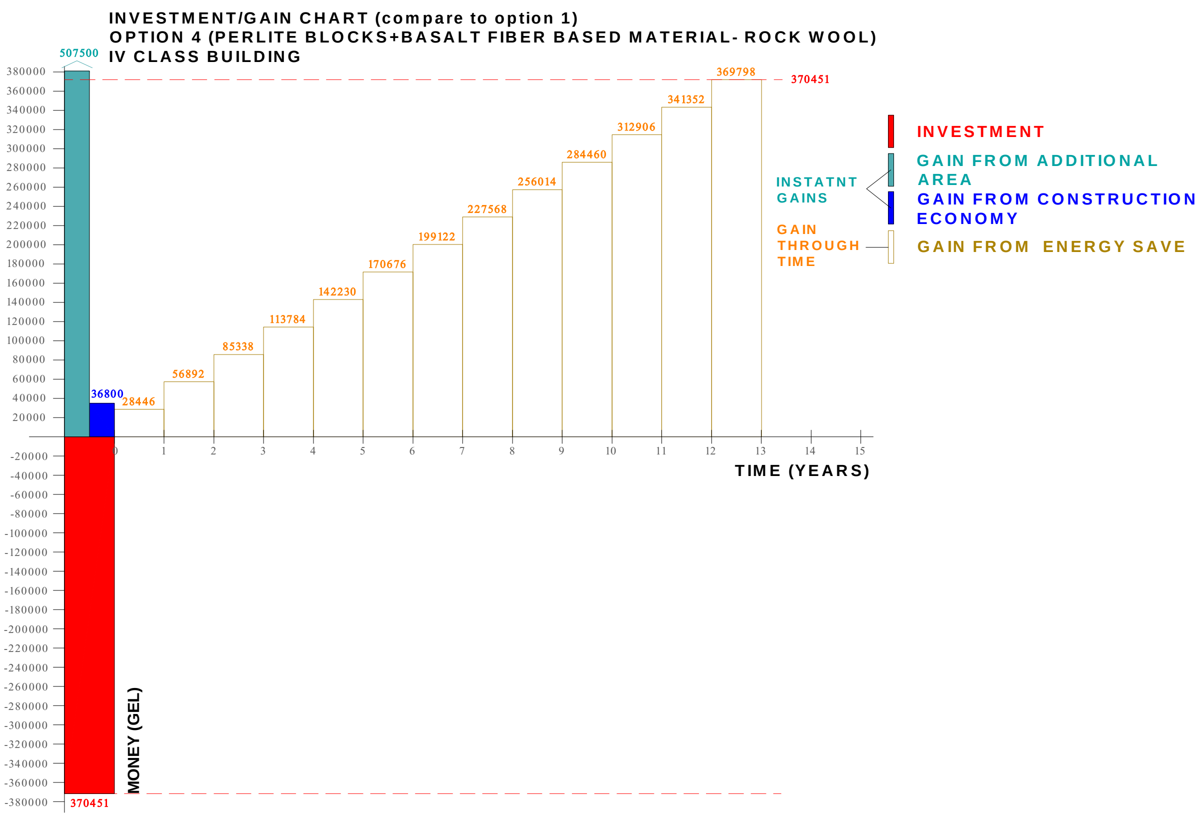


Figure 62:



As the above analysis demonstrates, the type of insulation material used in construction can be quite profitable for investors. Even if it is not in the investor's direct commercial interest to save energy, profits gained due to increased space may exceed investment. In the end, an energy efficient building is the best advertisement to sell real estate and create a customer base.

ADVANTAGES AND DISADVANTAGES OF WALL TYPES

OPTION 1

Advantage(s):

- Cheap in comparison with other Options

Disadvantage(s):

- Ideal interior temperature cannot be achieved without high energy consumption

OPTION 2

Advantage(s):

- Ecologically clean raw materials
- Good thermal characteristics
- Acceptable price with a short time period to recoup capital investment
- Possibility for interior space gain
- Possibility to economize on materials, such as reinforcements, by 2-3%

Disadvantage(s):

- Problems with thermal bridges
- Necessity of permanent quality control as the thermal efficiency of material greatly depends on perlite-concrete ratio, and block density, among others.

OPTION 3

Advantage(s):

- Ecologically clean raw materials
- Good thermal characteristics
- Easy to completely insulate the building, including thermal bridges
- Possibility for interior space gain
- Possibility to economize on materials, such as reinforcements, by 4-5%

Disadvantage(s):

- Comparatively high cost
- Lack of appropriate skilled specialists (mounters) in Georgia

OPTION 3A

Advantage(s):

- Ecologically clean raw materials
- Local manufacturing capacity
- Possibility for interior space gain
- Possibility to economize on materials, such as reinforcements, by 4-5%

Disadvantage(s):

- Insufficient heat characteristics due to thickness of manufactured product (not the raw materials)
- High cost in comparison with quality (the longest period to recoup investment)

OPTION 4

Advantage(s):

- Ecologically clean raw materials
- Best thermal characteristics among all Options
- Easy to completely insulate the building, including thermal bridges
- Possibility for interior space gain
- Possibility to economize on materials, such as reinforcements, by 2-3%

Disadvantage(s):

- Highest cost among these Options
- Lack of appropriate skilled specialists (mounters) in Georgia

CONCLUSIONS AND RECOMMENDATIONS

Energy efficient buildings maintain a comfortable temperature in a building throughout the year with minimal energy consumption and without expensive power supply systems.

However, most residential, office, and commercial constructions utilize 40 cm thick external filler using concrete blocks without adding additional insulation, which is not energy efficient and cannot attain a comfortable internal temperature without high-energy consumption.

Existing buildings, constructed with concrete block masonry, meet only minimal requirements.

When a 20 cm solid perlite block with a desirable ratio of perlite and concrete is used as external filler, the consumption of energy for heating decreases by 33-43%, in comparison with a concrete block. This Option also offers the quickest payback period as the cost for perlite and concrete blocks and the amounts used in the stonework balance each other. For instance, 20 cm perlite block masonry successfully replaces 40 cm concrete block masonry with better heat indices and with a cost difference of only 6- 7%.

If the thickness of a perlite block is increased, its potential heat efficiency will increase. For example, increasing perlite wall thickness by 30 cm will create energy savings of 55%, in comparison to a concrete block wall, while it requires only 30% more investment.

Imported rock wool, Option 3, has the best heat index in comparison to all other Options discussed, though the capital investment payback period is extensive due to the high material costs. In addition, one of the key components of rock wool, basalt felt, is manufactured in Georgia but is of poor quality and cannot compete with the other Options. In general, the Georgian basalt felt has a low-density structure and is of insufficient thickness at 0.8cm. In the study, two layers were used for better effect, thus creating 1.6cm of basalt felt.

Saving on materials in the load-bearing structure of the building saves 20-25% of the investment on average, except for class II buildings (individual residential houses) for which there are no savings.

Even with the most modest gains in additional space from decreased thickness in the external filler, profits exceed capital investment several times. Perlite filler is especially cost effective.

Georgian construction legislation is currently under reform and attention should be paid to ensure the creation of both energy saving regulations as well as new standards for thermal resistance figures. The Georgian construction and development community should support and encourage energy saving and high-tech construction activities.

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