MSc Program
Wood Based Building Design for Sustainable Urban Development

Comparative study on economical feasibility of 4 storey wood-based residential building construction to conventional construction in Kosovo

A Master Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **Arta Januzi** hereby declare

1. that I am the sole author of the present Master Thesis, "Comparative study on economical feasibility of 4 storey wood-based residential building construction to conventional construction in Kosovo",
   <79> pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, ________________ ______________________________

Date Signature

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Abstract

The topic to be explicated came up due to latest study on the wood construction ability on multistory buildings and its great role on sustainable urban development, as well as personal interest on the possibility of this application in Kosovo.

Being part of the generations facing directly global environmental changes, which in a way is quite related to the manner of architectural solution as well, the wood-based further study offered an option on promissory impact on this serious issue.

This dissertation analyses the possibility of wood-based multistory construction application, still not practiced in Kosovo, comparing to conventional construction in residential sector. The comparison is focused on financial point of view. By designing a common four story residential for chosen typologies (concrete structure, massive cross lam panel system, timber skeleton and timber modular structure), the comparison is considered to be reliable as dealing with direct figure required for a clear financial overview.

Main aim of this study is cost flexibility of timber residential building construction as an alternative construction. Another issue which this dissertation could influence, is informing on the importance of wood-based application that beside having other options on regards of construction, could led to a more intelligent managing of the forestry of Kosovo as very important issue for the future.

This study is considered to be one of the first steps on this environmentally use of construction resources as well as on the consciousness on the importance of clever economical, environmental and social balance of the country.

1. Introduction

1.1 Motivation

Wood is widely considered to be one of the most used friendly materials all over the humankind. It has had a significant application from varieties of tools to a large range of products for construction. With coming of the industrial era, new construction materials, especially concrete and reinforced concrete came to the fore, as a tendency on enduring the necessity of habitation.

In our century, special attention has been paid toward wood manufacturing and large usage in construction as Konrad Wachsmann (1930) [1] indicated that 'wood or timber as a manufacturing material to be processed all the way through by machines, technically and economically is of the same importance as any other construction material. A new look will have to come into existence'.

Today the awareness of environmental concern is becoming more and more evident, rising up the notion of sustainability in a wide range of activities. Therefore a greater attentiveness is required on direct or indirect related actions to the environmental problems of the planet. 'An efficient handling of resources can therefore make an important contribution to sustainable development.' (Adolf Merl 2006, p.1075) [2].

'Several analyses have shown that woods renew ability, relatively low energy consumption during manufacture, carbon storage capability, and recyclability offers considerable potential long-term environmental advantages compared with other structural materials. Although aesthetic and economic considerations are usually the major factors influencing material selection, the environmental advantages of using wood may have an increasingly important effect on material selection.' (Moody Russell C. and Hernandez Roland, 1997, p.9) [3].

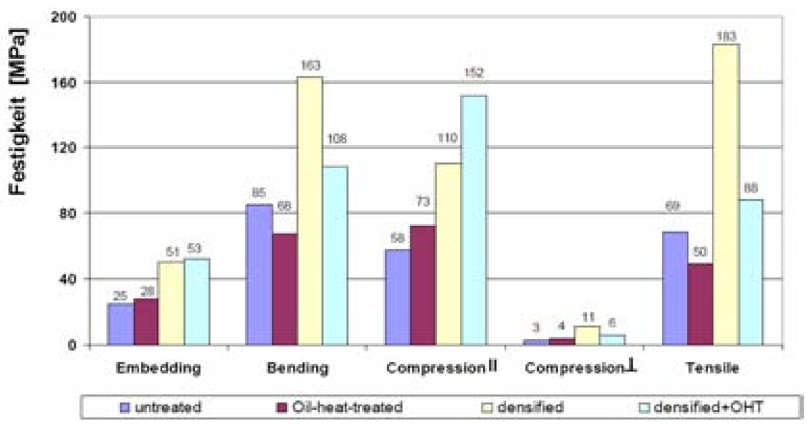
1.2 Global Economical / Ecological Aspects of Timber Use

Wood as the very old human-friendly material has had found its use in a large variety of application. Last decades bearing in consideration fundamentally environmental issues as well as sustainable use of planet resources, wood has proven itself to be a very interesting alternative material.

With the technology development, in combination with other construction materials, wood has found new manners of contemporary application in the field of construction.
Continuative studies of its anisotropic anatomic structure have enabled its application advancement through different methods of structure manipulation in order to get satisfying performance on specific applications. By processes such as like thermal treatment, mechanical, physical, chemical or biological treatment, significant improvement durability as well as better mechanical properties are achieved (Lecture of Prof. Peer Haller,2007) [4]

The Figure 1-1 show some possible technical performance improvements by densification and oil treatment of wood.

Table 1-1: Densification and oil treatment wood (Peer Haller, Rapp, 2001) [5]



In parallel to large-span execution by wood-based material, a significant development in residential sector is clearly evident. With rapid expansion of urbanized areas, especially those in developed countries, alternatives on efficient construction methods and material selections are required. At once time, this expansion visibly prepossesses higher construction material resources consumption. In this context, use of environmentally-friendly, low energy consumption as well as reusable materials are vital regarding economical, ecological and social balancing.

In residential sector, wood-based construction is continuously expanding its application on multi-storey buildings, proving its technical capability according to construction norms and regulations for such constructions. Therefore different structural and non-structural systems are being used and developed to reach the satisfactory solution. Following figure presents few already executed wood-based residential buildings.

Figure 1-1: Few already executed multi-storey wood-based residential buildings

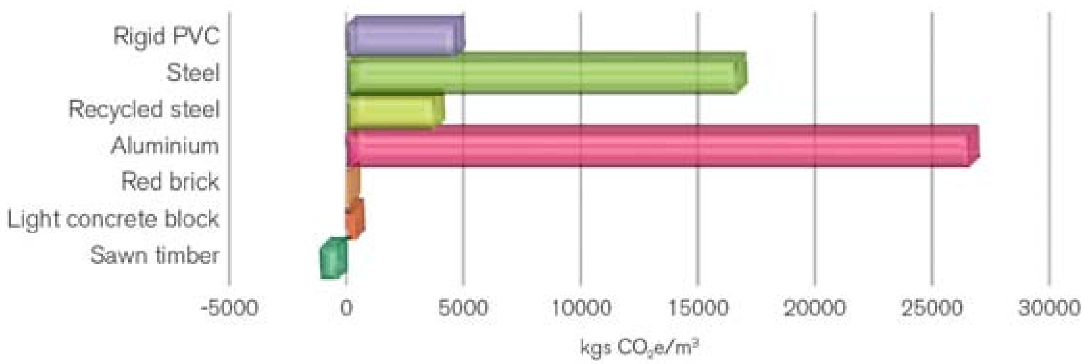
However wood-based application should be in accordance with the allowable consumption according to sustainability rights. Therefore an intelligent managerial approach to forests is strictly required in order to keep the balance of extracting and planting. ‘Today, at the beginning of the 21st century, again there exist different, new general conditions for design in individual and industrial production as well as for the possibilities to communicate with each other. In this situation of change and reform, energy resources, ecology, and sustainability gain new and increased importance- and in this context, this also applies to the timber construction and the entire value- added chain, beginning with the forest, to the utilization of timber.’ (Schulze Karl, 2006, pp.9)[6].

Some direct aspects regarding global benefit by using wood-based material in residential building construction could be listed as following:

- *Pace of construction* – wood-based construction time is significantly shorter in comparison to usual concrete constructions due to fast element erection and it is not that much related to the weather conditions…..
- *Lightweight structure* – enables lower cost for foundation leading to lower final selling cost per m².
- *Higher productivity* - due to construction speed, with less labour work in a shorter time period.
- *Photosynthesis process* enables absorbing of CO_2 from the atmosphere by storing the carbon during growth and releasing oxygen. According to Australian Forest and Wood Products Research and Development Corporation, to produce 1kg of wood, a tree absorbs 1.47 kg of CO_2 and releases 1.07 kg of oxygen to the atmosphere.
- *CO_2 impact* – According to “Roadmap 2010 for the European woodworking industries”, there are three broad areas to consider when assessing the relative CO_2 impact of different building materials:1) the energy used in the production of the material or product, 2) the ability of the product to save energy during the use of the building and 3) recycling and the final disposal of the materials or products.

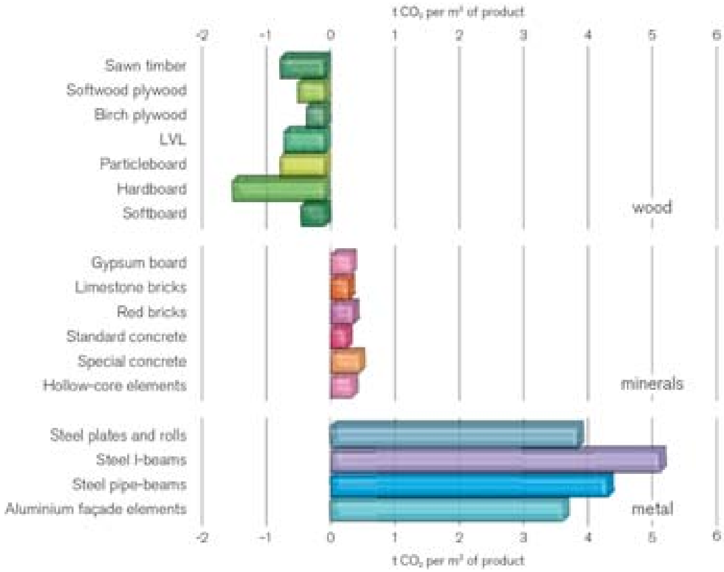
The production of CO_2 from different materials (including carbon sink effect) according to RTS (Environmental Reporting for Building Materials 1998-2001) can be observed as illustrated in Figure 1-4

Table 1-2: Nett emissions of CO_2 including Carbon sing effect (RTS. 1998-2001).[7].



The following Table show a report on CO_2 emissions of different construction materials where wood-based ones appear to be quite interesting in this point of view.

Table 1-3**:** Nett CO_2 emissions of selected construction materials during the whole lifecycle (RTS, Building Information Foundation) [8].



A very specialty of wood is its long live production cycling proving its great potential in different fields of use, as showed in following Figure.

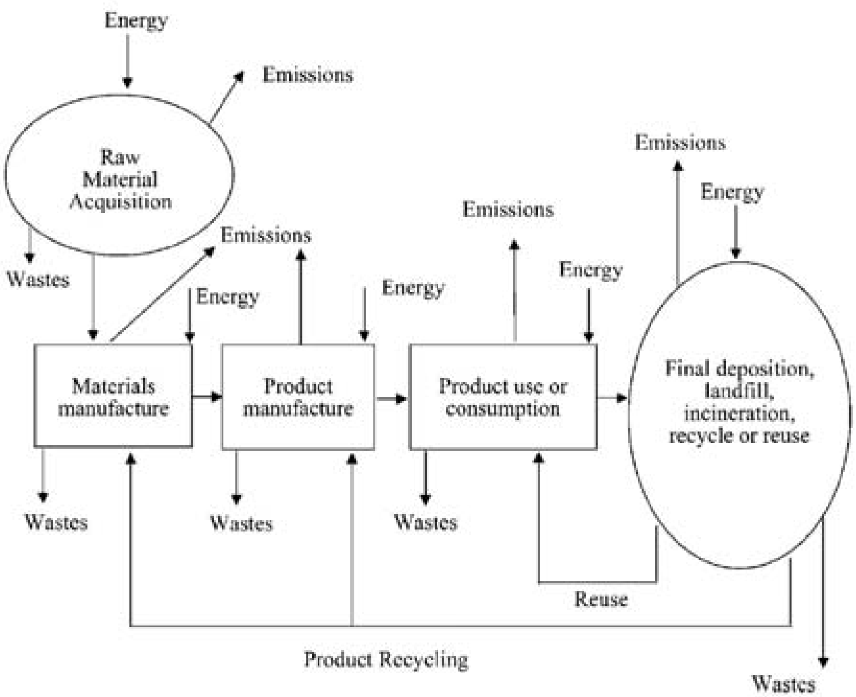


Figure 1-2: Product life cycling, LCA system (Franklin Associates 1990) [9]

In a case study performed in Atlanta for investigating of different building materials in single storey family houses showed considerable savings for wood construction in place of concrete in embodied energy as shown in Figure 1-7.

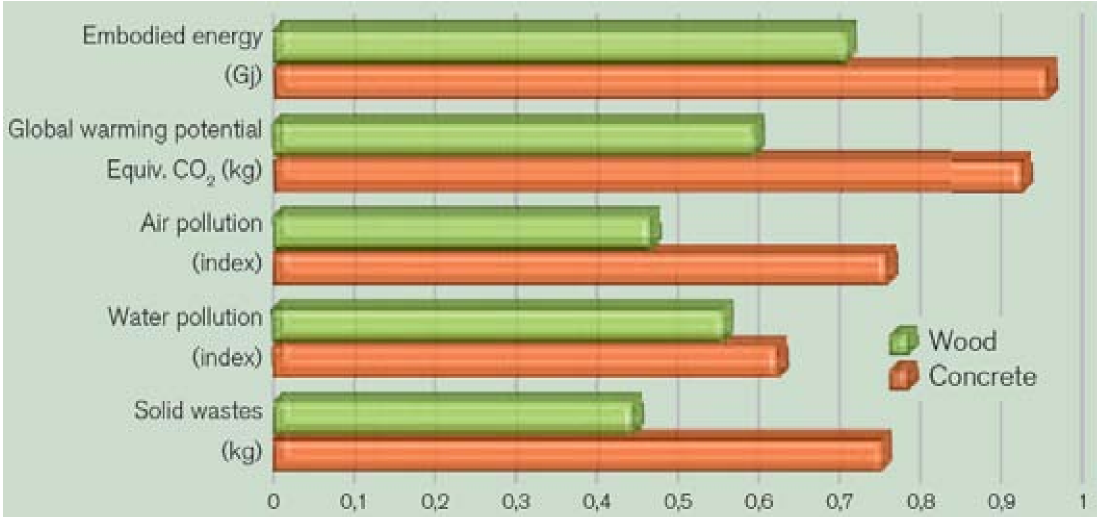


Figure 1-3: Preliminary environmental results for typical residential dwellings in wood and concrete (Athena Institute, Forintek, Canada) [10].

2. Objective

This study will analyze the possibility of wood-based multi-storey construction application, still not practiced in Kosovo, as compared to the conventional construction as well as stating the advantages and the short comings of each, from the economical point of view.

The purpose is to present other possible typological construction to incite design/construction alternatives, which might be profitable and efficient in terms of cost, and use of renewable material.

Main objectives of this research are:

- To survey private design/construction and trade companies and investigate their:
    - present construction material supply, construction work & pricelist
    - future interest on multi-storey buildings
    - opinion on timber construction (advantages, disadvantages, suspects, suggestions)
    - possibility of wood-based construction application

- To survey people on how do they conceive living in a timber flat

- To inspect Kosovo state of:
    - forestry, sawmills, companies producing timber products

- To analyze the cost efficiency of wood-based multi-storey construction

3. Pre-research Study

3.1. General Data on Kosovo

Geographical coordinates (SOK) [11]:

North	43º 16’	East	21 º 16’
South	41 º 53’	West	19 º 59’

Figure 3-1: Kosovo Map

‘Kosovo is a territory in centre of Balkan Peninsula, with no naval access. Kosovo borders with Serbia in Northeast, Macedonia (FYROM) in South, Albania in Southwest and Montenegro in Northwest. The gross area of Kosovo is 10.9081 km². The climate is classified as continental with warm summers reaching up to 36 °C and cold winter dropping down to -10 °C. Kosovo is densely populated with about 193 persons per km², and divided into 30 municipalities. The capital is Pristine.(Statistical Office of Kosovo) [12].

3.2. Background

The cultural and material tradition inheritance in the Albanian inhabited areas is distinguished also by the people's architecture, architectural building construction, respectively Kulla (which in Albanian means tower), as a fortified existential Albanian residence, being a special neo-classical type and style, which with its plane geometry, shape, compositional scheme and double function appeared and evolutionary developed in the turning of the 18th century to the 19th century and till the first ten years of 20th century (Fejaz Drancolli, 2001) [13]. Its design, which is unique to this part of the region, is influenced by the social and cultural needs of the people, climate and locally available building materials (Sahar Rassam, 2001) [14].

Kullas are composed by two or tree floors in a rectangular plan, where the ground floor serves for animals and the rest for residing. The exterior walls are of almost up to one meter of stone thickness of stones providing comfort thermal conditions for the climate of Kosovo. The floors are constructed by wooden beams, while ceilings are fully decorated by wood. Windows are constructed by stone or brick, and some of the openings, called Frengi used for defence purpose as the Kulla typology itself. In some cases Kullas are also composed also by wooden cantilever so called Çardak. Bellow Figures show some examples of such construction.

Figure 3-2: Restorated Kulla and inner structure of another Kulla in Kosovo

Figure 3-3: Kullas in Kosovo

During the period of 1900-1912 the last Kullas were constructed. ‘New buildings from this period are mostly residential and administrative. This architecture is characterized by wooden structure retrieval’ (Arch. Xhelal Lloncari 2004)[15].

The ground floor is constructed by the thick walls of clay bricks and plastered by clay and straw called Cerpic and reinforced with wooden beams. The floor is executed by wooden beams offering the architectural spatial and functional layout of the first story. Construction system of the second story, so called Bondruk, is made of a skeleton wooden system of vertical wooden struts and base and top beams, reinforced by diagonals. The fillings between are layered with clay bricks plastered and painted with limestone.

‘As a characteristically architectural element in these houses is the enclosed balcony "çardak" which is characterized as an enclosed volume protruding from the volume of the house and is in harmony with the type of wooden forming structure-formation and creates a bold structure of several layers of wooden beams placed above each other the tip of which is engraved with symbols with floral motives” (Flamur Doli, 2000)[16].

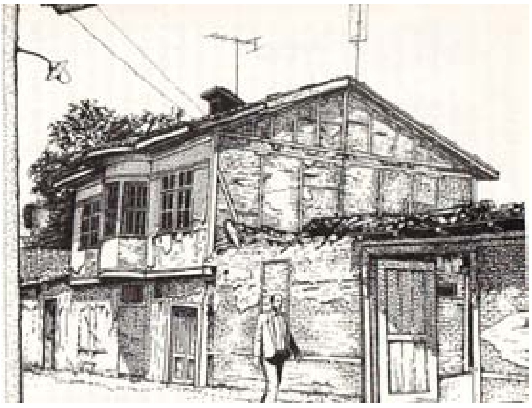



Figure 3-4: Private house in Kosovo

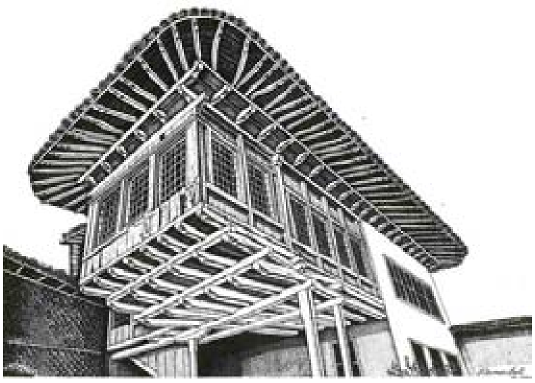
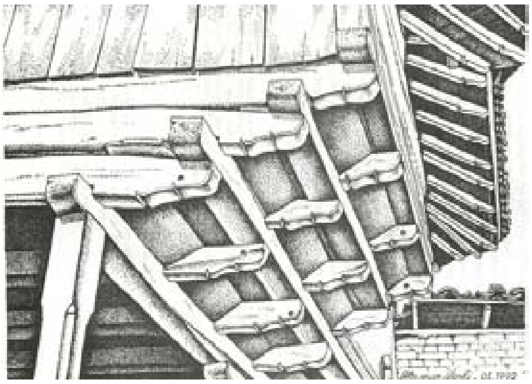



Figure 3-5: Great Medresa in Gjakova, built in 1794 (Flamur Doli 2000) [17]

From the 40's a lot of conquerors have passed by Kosovo leaving a lot of damages and burnings. Multi-storey residential buildings started constructions even though in contradiction to theretofore way of living. On behalf of "new" architecture, new treatment with background political purpose of urbanisation, especially of the architectural proportion took place.

Masonry structure is retrieved. These buildings are composed by the basement level serving as inhabitants' cellar, the ground floor for commercial or residential purpose and two or three residential floor covered by the pitched or flat roof. The primary structural walls are up to 50 cm of thickness done by bricks, secondary walls 20 cm and non-structural walls 12 cm thick constructed by bricks as well. Usual floor height is three meter mostly composed of lightweight semi-montage structures.

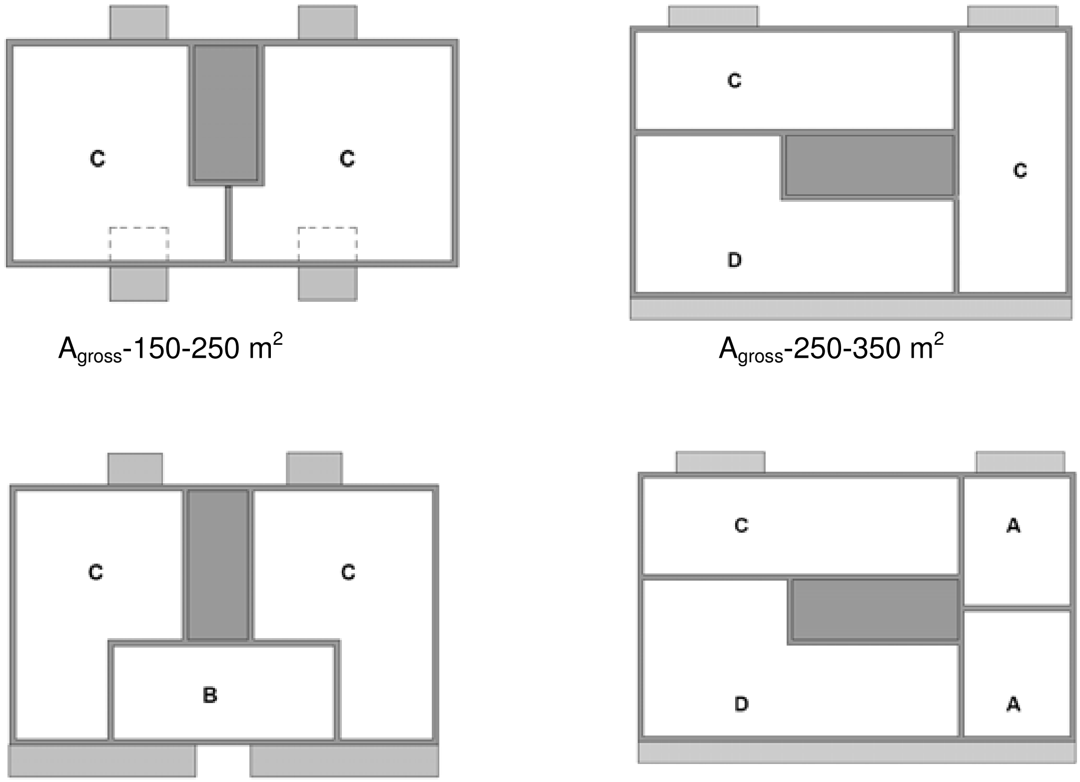


Figure 3-6: Usual masonry residential layouts

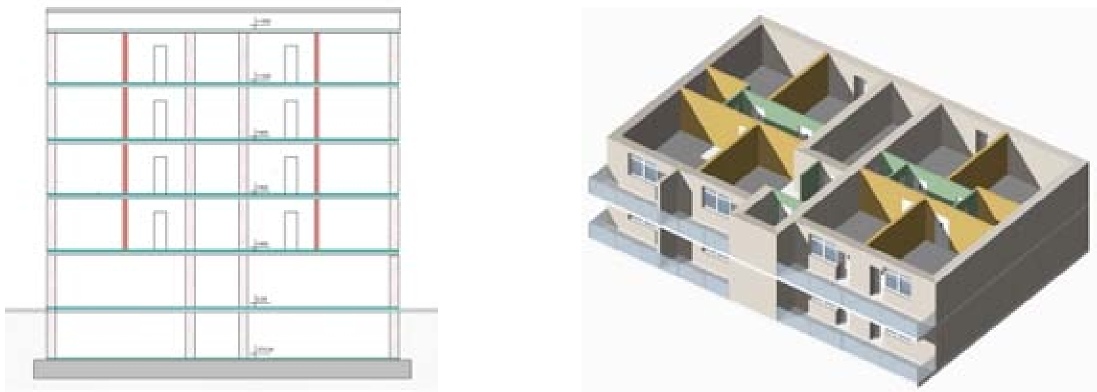


Figure 3-7: Usual section and structural axonometric

After the ‘60’s middle-high-rise residential buildings were constructed by skeleton reinforced concrete with almost the same composition and layout as the prior masonry buildings. The skeleton is executed by reinforced concrete. The outer walls are composed by 25 cm thick cement mortar bound hollow clay blocks, inner walls of 20 or 12 cm blocks. Flooring is constructed by lightweight structure or reinforced slab with hidden beams within the volume of slab.

Figure 3-8: Skeleton reinforcement structure approved

Figure 3-9: Existing skeleton residential buildings

After about two decades of decline in urban development caused by political-economical-social grounds, with the rapid increase of demographic density in urban areas and expansion of urban spaces, the need of living space became evident.

During the last war occurrence in Kosovo (1999), beside a lot of heritage buildings, most of the houses were burned, damaged or ravished. With the returning of Kosovo population from the neighbouring countries, housing as shelter was the most important issue to consider. A large number of tents were erected for the temporary accommodation. With coming of UNMIK (United Nation Mission in Kosovo), various GO`s (International Governmental Organization) and NGO's (International Non Governmental Organization), number of houses were constructed or repaired as provided with basic construction materials.

During few following years, due to lack of appropriate urban and execution law by UNMIK, multi-storey buildings were not allowed to be constructed which led to a possibility of great illegal housing and multi-storey construction was executed on state or private property. Unfortunately this "event" is still present at some level, without serious consideration of human accommodation requirements set by law. According to Daniel (2003), "The key to the illegal housing can be caused by a number of factors: lack of knowledge, frustration with bureaucratic obstacles, general negligence in following the law etc." (cited by Islami,2007) [18]. It is incited also by the lack of municipality approved developed urban planning. Developed Urban Planning is multi-sector plan, which sets long-term objectives for developing and managing of urban areas, for a period of at least five years. This plan covers the area within the commune (Binak Becaj, 2007) [19].
Only 40 % of the municipalities have approved for drafting developed urban planning (Binak Becaj, 2007) [20]. The lack of urban planning for the municipalities is due to low budget. Most of them still use the old urban planning.

According to Statistical Office of Kosovo, there are around 360,000 housing units, whereof 93% belong to individual housing and only 7% to collective one.

Currently a considerable number of objects from the overall construction lies in residential construction, which is totally executed in skeleton reinforced concrete structural system as quite common construction typology. Most of the construction aforementioned reaches 4-5 stories, owing to lower building cost.

Regarding multi-storey residential buildings, final construction cost is up to 300 - 315€/m^2, whereas 450-900 €/m^2 for the final selling cost. This amount is very high considering economical standard in Kosovo, with mean salary of 150-200 €/month (SOK, 2007) [21].

3.3. Current State of Forestry

Figure 3-10; Current State of Forestry

According to an EU funded project managed by the European Agency for Reconstruction regarding Sustainable Forest Management in Kosovo (2007) [22], the official state of Kosovo Forestry can be summarized as following:

The Kosovo estimated forest area is 464,800 ha or 42% of the land area. Some 278,880 ha are public forestlands and under the control of the Kosovo Forest Agency (KFA) which is organized into six geographic regions. The KFA has a regulatory function in relation to the 185,920 ha of private forestlands. Broadleaved forest, created through natural seeding accounts more than 90% of the forest area with the main species being oak and beech. Coniferous forest, covering 7% of the total forest area, is dominated by *Abies alba*, *Picea abies* and *Pinus* species.

Afforestation in Kosovo has averaged around 240 ha per annum in recent years and is mainly of coniferous species. The annual allowable cut of 900 000 m^3 gross corresponding to 77% of the calculated increment on areas surveyed is estimated. Official harvesting is currently some 200,000 m^3 per annum.

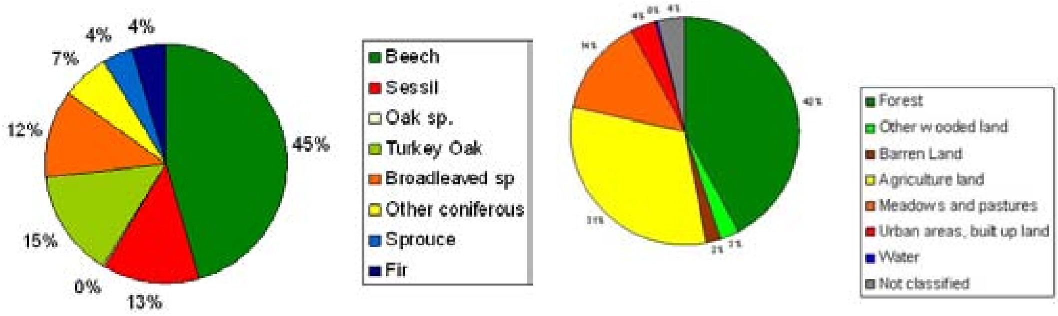
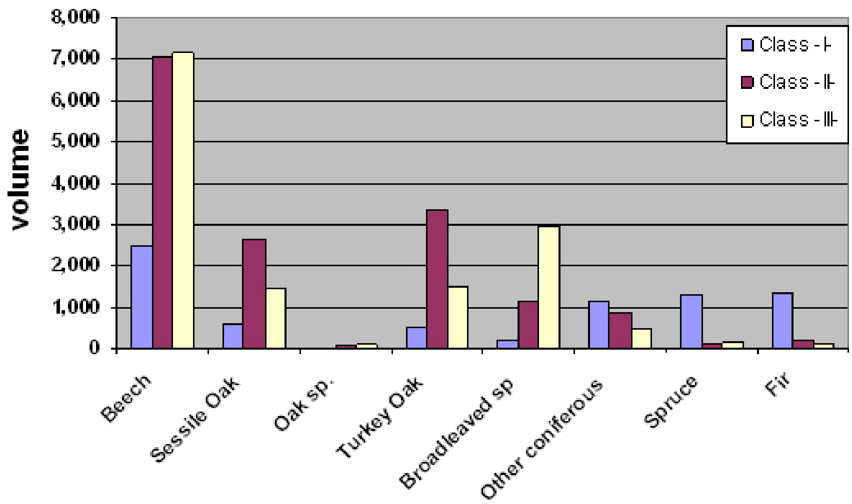


Figure 3-11: Wood species ratio and land use in Kosovo

Table 3-1: Volume by species and quality classes ('000m^3)



Since post-war period, electricity supply in Kosovo is quite unstable and low. The electricity and wood burning are the main heating resources during winter, which means that a great amount of trees are being fallen annually for this purpose. Also due to lack of appropriate commission and forest managing, illegal felling in Kosovo Forestry is evident. A wise management in accordance to Sustainable Forest Management is indispensable in order to benefit from the forestry and meet the EU environmental recommendations.

3.4 Interview and Survey

In order to get an overview on the advantaged / disputable aspects for the wood-based multi-storey construction four Architectural Offices were interviewed. They were informed generally on this application and several executed wood-based multi-storey residential buildings in Europe and the interest on researching for such a possibility in Kosovo. Also an opinion of their interest for such application was taken. Certain disputability has been observed on issues like financial, quality proof of timber and fire protection.

Regarding quality proof of timber in Kosovo there's still no certification for the timber products set by the law. It is an issue being in process and to bet set in the near future. Inquired on the advantages on applying such a construction they were declared for the benefits on labour cost due to simpler way of construction and lightweight of wood-based structure and shorter building time. Regarding the more adequate cases for such application, cases like social houses has been considered. Kosovo faces high necessity for social accommodation, especially on post-war period the need for social accommodation has aroused in the villages which were mostly damaged during the late 90-ties and currently 100 % of residing belongs to individual residing. Such construction could evidently reduce the cost for residing as well as property occupancy.

Whether they would apply such typology in the next future, the following report has been observed.

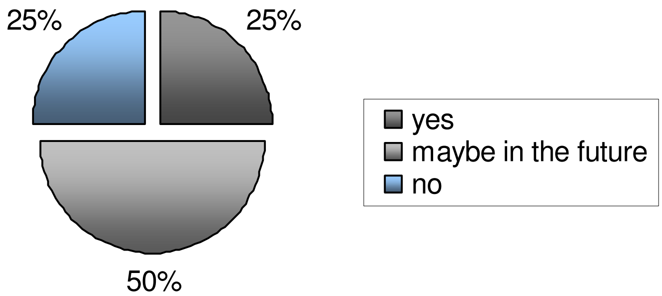


Figure 3-12: : The report on the willingness of wood-based application

Considering that multi-storey wood-based application is yet not present in Kosovo in residential sector, a survey on the conceiving the livingness in such building, appeared to be interesting. Therefore 35 occasional people were surveyed.

Regarding safety and comfort on wood-based with same technically proved performances as conventional construction, 45.7% declared for safe/comfort, 31.4% for mid-safe/mid-comfort and 22.8% not safe/not comfort.
Whether they would live in such flat, 51.4% declared as yes, 25.7% for perhaps/don't know and 22.8% declared no. From the most disputable aspects, construction stability, fire safety and durability were mentioned. An interesting observation was on the age of surveyed peoples. Most elders considered as safe declaring they use to live in wood houses in former times while, those of middle age and young had more suspects on aforementioned aspects.

4. Approach

In order to achieve a realistic overview on the economical efficiency of wood-based multi-storey residential construction, a comparison method has been approved. The comparison is conducted between four different structural typologies: (1) skeleton reinforced concrete, as conventional typology present in Kosovo, (2) massive panel wood-based typology, (3) skeleton wood-based structure and (4) skeleton modular system (structural system which is developed by PhD. Elif Somer (2008) [23] on her dissertation). For the four aforementioned typologies, detail research on structural composition, element material supply, processing and price has been carried out.

4.1. Current state of building typology

Current residential middle-rise buildings are constructed in skeleton reinforced concrete. Usually the skeleton is composed of columns of 20x60 cm or larger (depending on statics), hidden beams within the slab volume or exposed and reinforced slab of around 20 cm of thickness. The envelope (25 cm thick) is executed by cement mortar bound hollow clay blocks of 19 x 19 x 25cm with usually 5 or 8 cm of Styrofoam insulation and façade. The inner walls are constructed by 19 x 19 x 25cm clay blocks, 20 cm thick or in some case of 12 cm thick walls, 12 x 19 x19 blocks are used. Roofs are usually pitched hidden by the attic. Windows and doors are mainly made of plastic frames and the wooden ones depend on the investor will.

Figure 4-1: Reinforced concrete structure of residential buildings

4.2. Collection of Data

In order to perform the material and cost calculation of the four models appropriated for comparison as realistically as possible, a detailed study on material supply and required structural elements provision has been carried out. Therefore, the requisite data have been granted by directly visiting of respective providers.

4.2.1. Timber supply

Five Sawmills in different parts of Kosovo have been visited. All of them were local sawmills in peripheral part of cities, so usual distance to the centre of the cities varied around 10-20 km, which simplifies the transport of material. They were declared that partially they are supplied by Kosovo logs and partly importing from Slovenia, Bosnia or Montenegro.

The cost didn't vary much between sawmills, probably due to relative small area of the country. The market price offered per m^3 includes the material transportation to the site. The average production of timber to these sawmills varies from 600-1000 m^3 / month or 30-50 m^3 /day. For the section dimensions of around 12x10cm and 12x14cm the price of 180 euro/m^3 is approved while for the larger section dimensions like 20x20, 20x25cm or more, the price comes up to 250 euro/m^3.

4.2.2. Wood based modelled structural elements supply

Three companies selling and producing timber elements have been visited. They were asked on the possibility of producing specific structural elements with certain dimensions. The elements needed for this research have been provided and explained to the companies. Consequently the cost offered varied according to level of complexity of elements requested. The optimal price offered for the elements needed for the models adopted for comparison varies as following:

timber price [€/m^3] **+** 30-100% of the timber price **=** ordered element [€/elem.]

Factually, the price of timber is summed up with 30-100% of its value considered for working acquiring the final price per specific structural element.

One foreign company producing cross-laminated panels was succeeded to reach in order to get prices per m^2 for the required thickness approved in one typology. The prices offered were dedicated to south-east Europe (for Kosovo as well).

4.2.3. Additional construction material supply

Five companies selling construction material have been visited to get the pricelist of materials used for performing the cost calculation. These companies were also chosen from different parts of Kosovo and the price-list approved considers the mean cost even though the prices were very similar. Some of construction materials are being produced in Kosovo, while others imported mostly from Macedonia, Serbia and Slovenia.

The bellow material price-list table per specific unit according to cost pre-evaluation approved is considered.

Table 4-1: Construction material price-list

	material	unit	price [€]
1	Natural gravel	m³	6
2	Sand fraction 1 for masonry	m³	20
3	Sand fraction 1 for plastering (first layer)	m³	20
4	Fine sand for layer)	m³	25
5	Mixed concrete Mb-15	m³	65
6	Mixed concrete Mb-30	m³	70
7	Reinforcement steel	kg	1.1
9	Binding wire for steel (0.2032 per kg)	kg	1
8	Clay blocks 19x19x25 cm	element	0.45
10	Clay blocks 12x19x25 cm	element	0.4
11	Chimney and ventilation plastering "Schunt"	element	1.5
12	Chimney caps	element	45
13	Plastering cement	sack	5
14	Lining lime 25 kg/sack	sack	3.5
15	Cement for separating walls and floor levelling	sack	5
16	Bitulit A	kg	0.6
17	Kondor 4 (7.5m²/rrolle)	rolled	17
18	Timber for roof structure	m²	195
19	Roof lath 3.5x5.0cm	m'	0.35
20	Roof lath 1.5.x3.0cm	m'	0.25
21	Ter Paper	rolled	7
22	Metal tile	m²	7
23	Dandified Styrofoam for facade t=5 cm	m²	3.2
24	Glass wool t=5 cm	m²	4
25	Stone wool t=5 cm	m²	4.5
27	Mesh for façade	m²	0.15
29	Elements for fixing the Styrofoam	element	0.1
30	Stirokoll glue	kg	0.5
31	Rofiks façade	kg	1.3
32	Façade colour fasadeks	kg	2.8
44	Plaster board 12.5 mm	m²	6
45	Hydro-resistant Plaster Board	m²	8
47	Wind barrier folie	m²	1.4
48	Timber	m³	180-250
50	OSB 15 mm	m²	7
51	Plywood 6 mm	m²	5
52	Plywood 10 mm	m²	6
53	Plywood 16 mm	m²	9

4.2.4. Labour and work calculation

Two construction companies were visited. They provided information on the price per labour work which varies around 18 €/ m². The process of construction for the reinforced concrete typology has been provided in order to perform the cost calculation for this typology. The below table shows the work cost.

Table 4-2: Work process cost for reinforced skeleton system

no.	work	unit	price [€]
I	**ground work**		
1	Construction site clean-up, transporting to the nearest dump site. Cleaning depth t=20 cm	m³	2.5
2	Ground excavating with machinery and by hand for building foundation & transport to the nearest dump side	m³	2.5
3	Lying of gravel below the foundations. layer depth t=30 cm in compact form.	m³	10
4	Filling the space surrounding the foundations and basement outer walls with earth and compacting in 20-30 cm layer 70.4x2.4=	m³	6
II	**wall work**		
1	Wall work with clay blocks 19x19x25cm in mortar lime bonding 1:3:9; thick t=20 cm	m³	75
3	Inner wall work with clay blocks 12 x 19 x 25 in mortar lime bonding p=1:3	m²	22
4	Lining in the inner walls and ceiling	m²	5.5

no.	work	unit	price [€]
III	**concrete and reinforced concrete work**		
1	concrete pouring of levelling layer below the foundation with light concrete Mb-15 thickness 2x5 cm	m³	70
2	Cementing of the foundation slab slab with reinforced concrete. concrete Mb-30 depth t=60 cm.	m³	70
3	Cementing of basement outer walls with reinforced concrete Mb-30 wall thickness t=25 cm	m³	120
4	Cementing of basement, columns with reinforcement concrete Mb-30.	m³	95
5	Cementing of beams with concrete Mb-30	m³	100
6	Cementing of floors with concrete Mb-30	m³	95
7	Cementing of stairs complete with stair flights and stair walls in reinforced concrete concrete Mb-30, thickness t=20cm, tread dimensions 17/29 cm.	m³	120
IV	**steel work**		
1	Supplying and processing of		
	reinforcement ribbed steel	kg	1.1
V	**roof work**		
1	Roof works with required material	m²	37
VI	**floor work**		
1	Supplying with required material and work of		
	the flooring	m²	12
VII	**façade work**		
1	Supplying with required material and work of		
	façade		
	Styrofoam glue		
	Styrofoam 100 mm		
	Styrofoam glue		
	Plastic mesh		
	Styrofoam glue		
	Lining		
	Façade color	m²	21

5. Design of four story residential building

To figure out whether wood-based multi-storey would be possible in terms of material supply as well as cost, the comparison between four different typologies is adopted. For a more reliable overview, a four story residential building is designed which does correspond entirely to the conventional construction of such destination in Kosovo considering function, organization layout and structural plan. At the same time, this design is quite in compliance to the three other wood-based typologies. Each type of architectural/structural/construction application is characterized by its peculiarities which should be considered for achieving a greater overall efficiency. However, such a design in compliance to existing construction in Kosovo has been designed to prove the probability to the competent party in Kosovo, that the same or almost the same solution could be achieved also by other alternatives which could assure benefits on certain aspects.

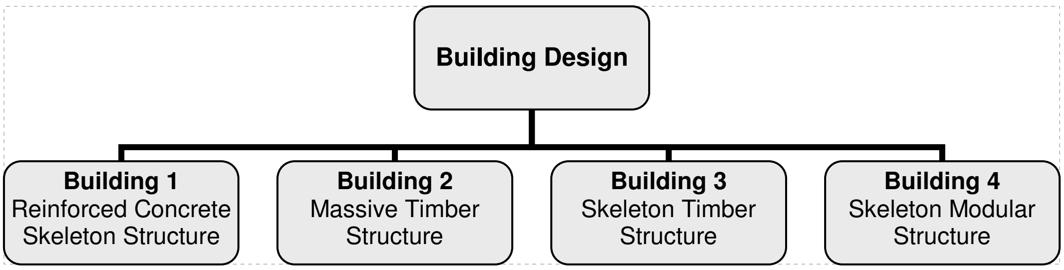


Figure 5-1: Models adopted for study

The model adopted for collation is divided in two main parts:

1) the common part consisted of the basement and the core of the building which is mutual for the four buildings, and

2) the separated four structures and envelopes for the four typologies. Material and cost calculation of the common part will be apart from the structure and envelope of each of them.

Figure 5-2: Perspective view of the model

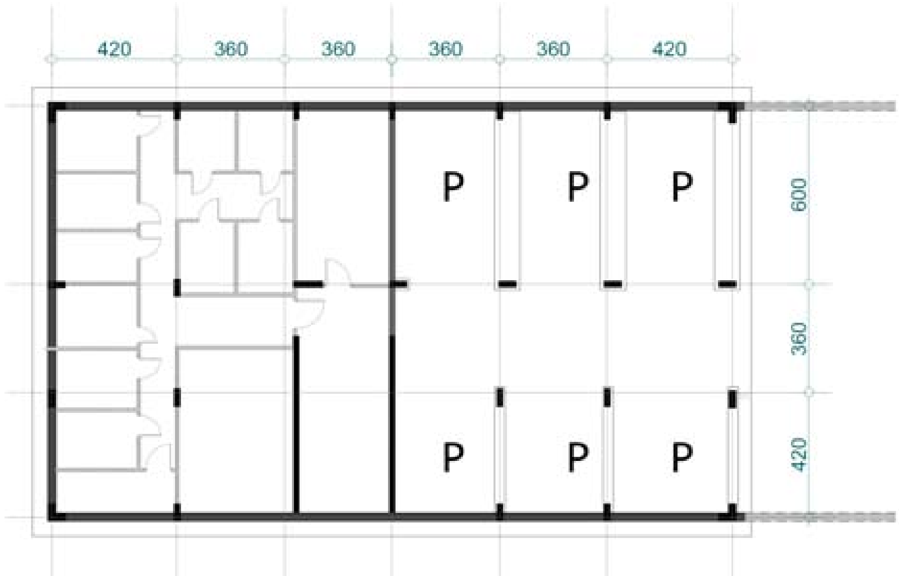


Figure 5-3: Basement of the model

The grid and layouts are the same for the all floors with dimensions of 320cm, 360cm, 400cm, 420cm and 600cm.

Table 5-1: Floor & Dwelling area of the model

1. Basement	320 m²		
2. Ground floor	350 m²	3. Three floors	346 m²
Dwelling 1	73 m²	Dwelling 1	71 m²
Dwelling 2	83 m²	Dwelling 2	83 m²
Dwelling 3	83 m²	Dwelling 3	83 m²
Dwelling 4	94 m²	Dwelling 4	90 m²

(1)

(2)

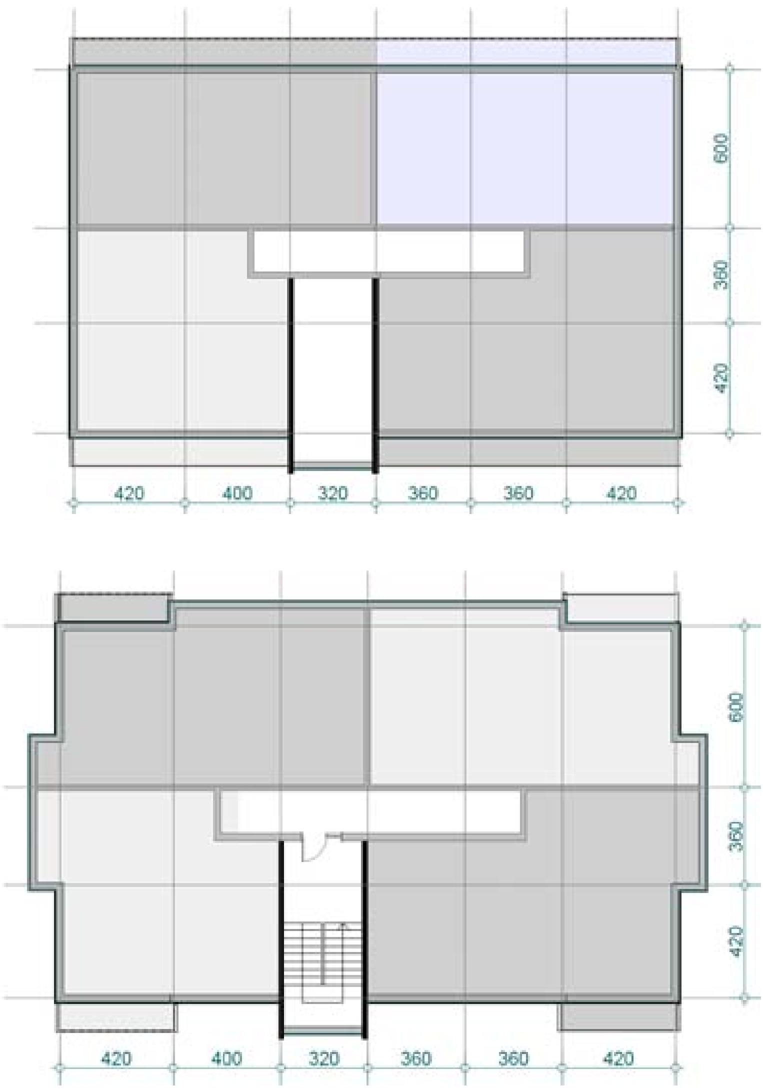


Figure 5-4: Ground floor (1) and three other floors (2)

5.1 Design of Building 1- Reinforced Concrete Structure

5.1.1 Structure of Building 1

The first building is defined by its skeleton structure. It is composed of the reinforced concrete columns with dimension 20x60 cm and 25x60 cm, the hidden beams into the slab 20x60 cm and peripheral beams encompassing the building with height of 40 cm as well as the slab comprised of reinforced concrete with height of 20 cm. The height of the building is 290 cm including the thickness of slab. The whole construction is executed on site by preparing the frames of elements, fitting up the reinforcement steel and pouring the already mixed concrete into the frames.

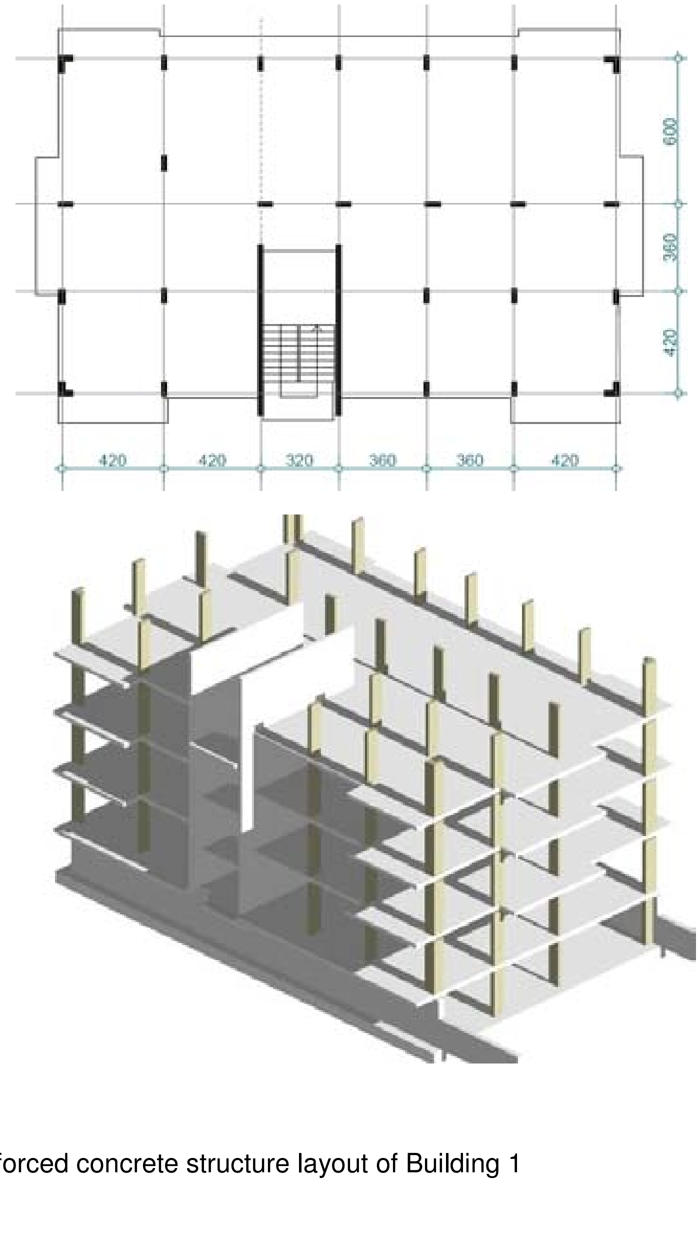
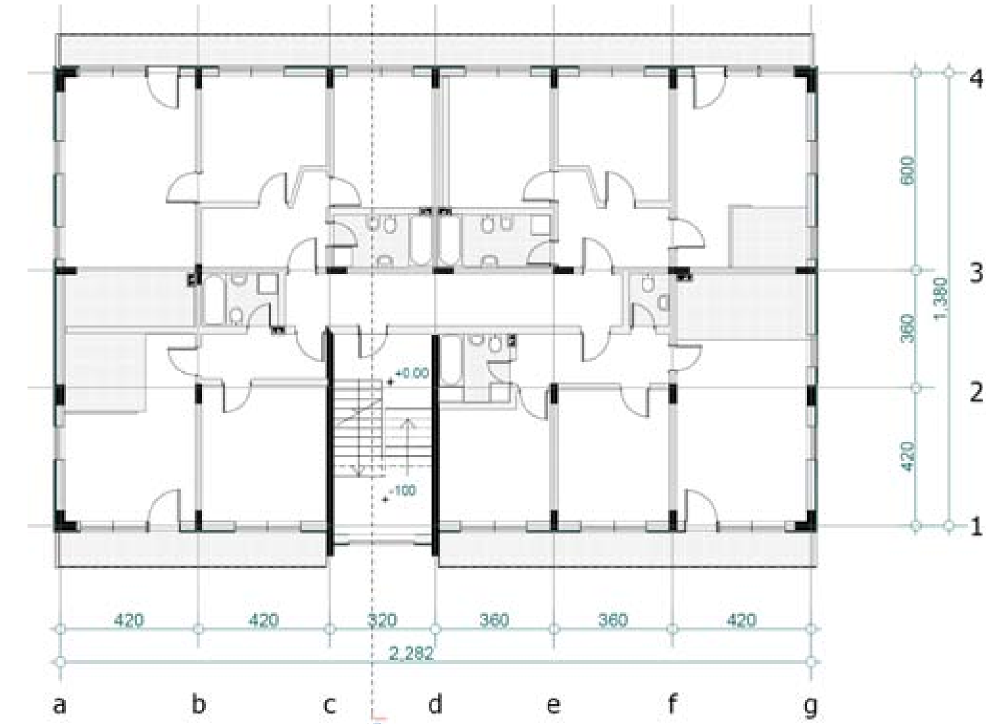


Figure 5-5: Reinforced concrete structure layout of Building 1

5.1.2 Layout of Building 1

The following pictures show the layout of the dwellings within the Building 1 of the ground floor and the tree other floors applying skeleton reinforced concrete system.

(1)



(2)

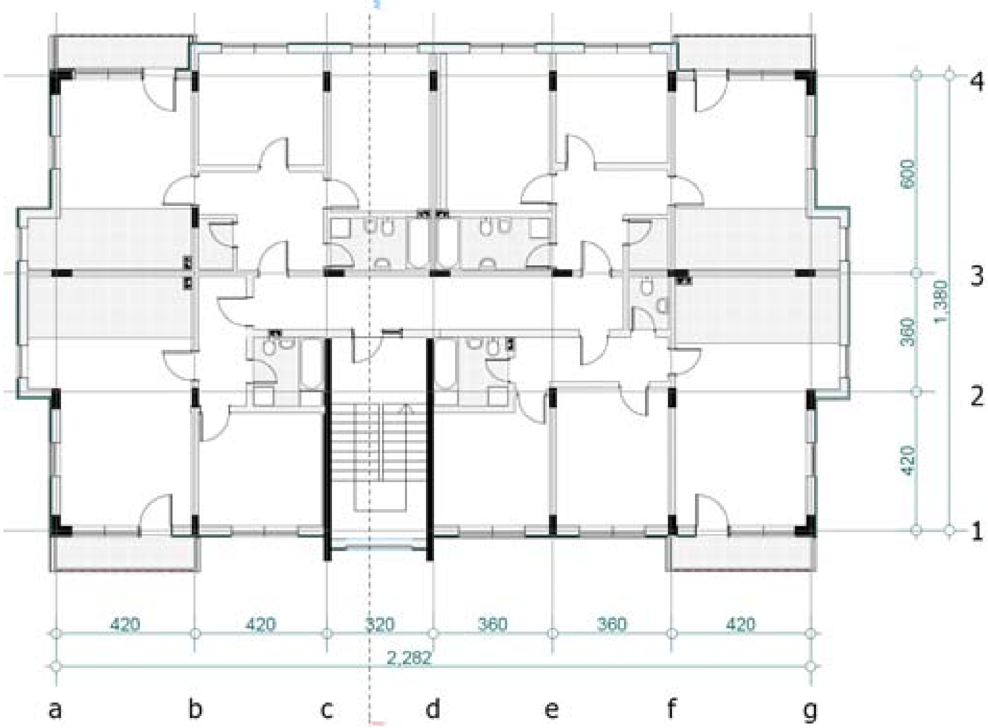


Figure 5-6: Ground floor (1) and characteristic floor (2) layout plan of Building 1

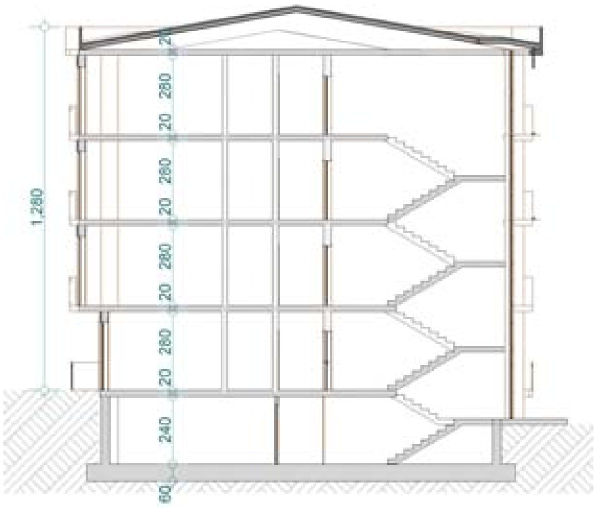
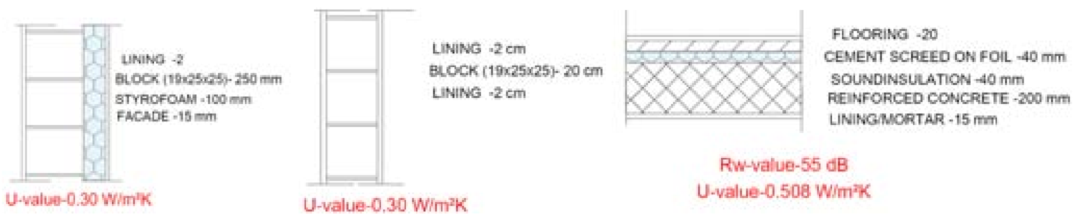


Figure 5-7: Section of Building 1

5.1.3 Envelope of Building 1

The Building 1 is considered to be covered by external walls composed of clay blocks 25 cm of thickness, plastered 2 cm from inside and outside covered by 10 cm of Styrofoam and the façade. Inner walls designed of 20 cm thick clay blocks plastered both sides. The slab is composed of reinforced concrete of 20 cm, 4 cm of sound insulation, cement screed on foil and respective flooring as they are executed in residential buildings. The below figure shows the section of enveloping.



(a) (b) (c)

Figure 5-8: Outer (a), inner (b) wall and floor (c) composition of Building 1

5.2 Design of Building 2- Massive Timber Panel Structure

5.2.1 Structure of Building 2

The structure of Building 2 is defined by its massive wood-based panel layout with wall and floor panels serving as envelope as well. External walls as well as inner ones are designed of 3 cross laminated wooden panels of 3 layers-94 mm, while flooring is designed by those of 5 layers-140 mm thick. As the wall panels adopted for this model are produced of 272 cm of height, the overall floor elevation is almost 290 cm. The panels required are considered to be imported from providers and erected directly on site.

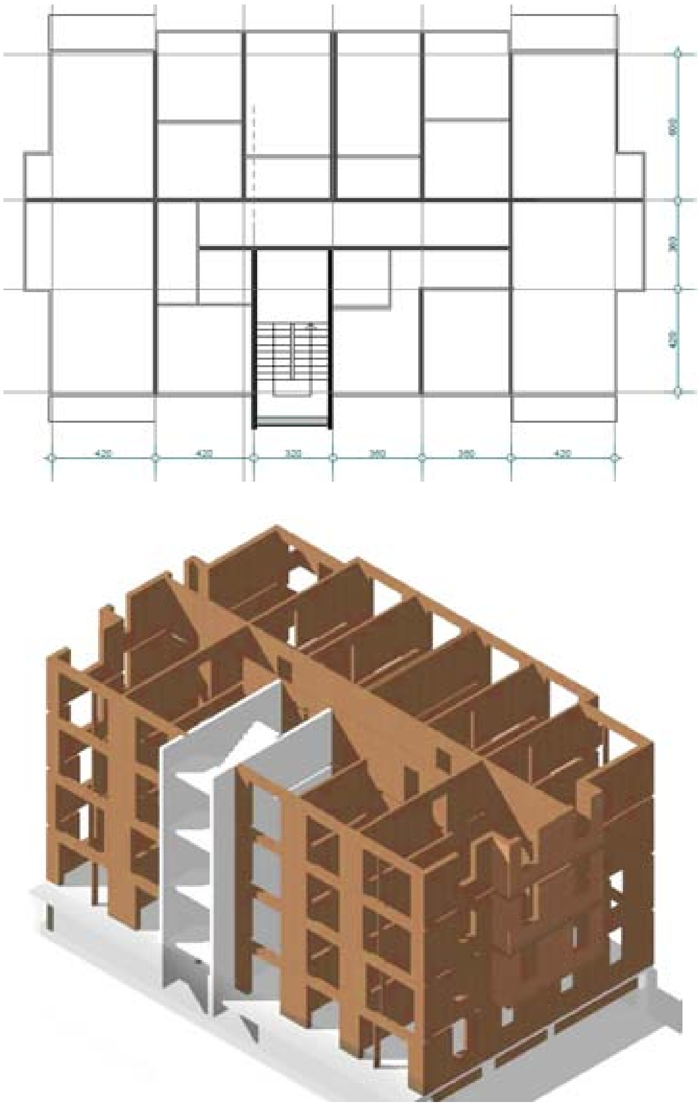


Figure 5-9: Massive cross laminated wooden structure layout of Building 2

5.2.2 Layout of Building 2

The following pictures show the layout of the dwellings within the Building 2 of the ground floor and the tree other floors applying massive wooden panel structure.

(1)

(2)

Figure 5-10: Ground floor (1) and characteristic floor (2) layout plan of Building 2

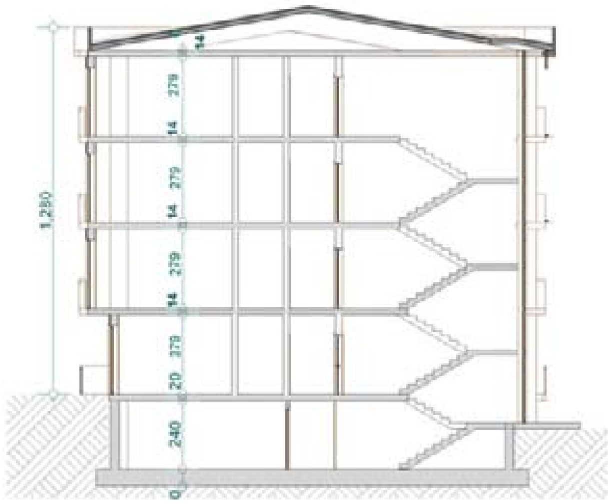


Figure 5-11: Section of Building 2

5.2.3 Envelope of Building 2

Outer walls are constructed by cross lam panels of 9.4 cm covered by plasterboard form inside while from the outside insulated by 10 cm of stone wool and the additional layers of façade. Inner walls are designed by the same panels covered on both sides by plaster boards. Floors are designed of 12 cm cross lam panels, 7 cm bottoming gravel, sound insulation of 4 cm, cement screed of 4 cm and the flooring, as shown in below figure.

(a) (b) (c)

Figure 5-12: Outer (a), inner (b) wall and floor composition of Building 2

Design of Building 3- Skeleton Timber Structure

5.2.4 Structure of Building 3

Skeleton Timber structure is adopted for the third typology considering the possibility of using the local resources. It is composed of timber columns with dimension 26x26 cm for the first and second floor and 20x20 cm for the third and the fourth. They're connected to each other and to the beams by metal frame. The beams of 10x20 cm are one-direction oriented as they're supported by panels of walls lying under them. Floors are considered of 14 cm thickness of planks supported on beams by metal plates.

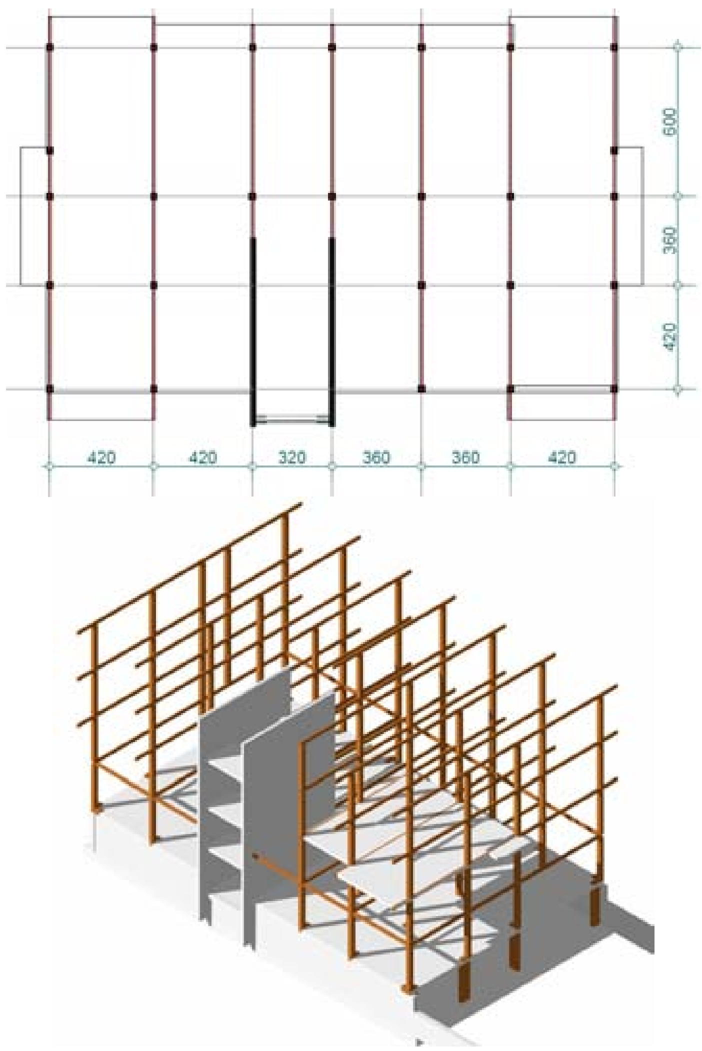


Figure 5-13: Skeleton timber structure layout of Building 3

5.2.5 Layout of Building 3

The following pictures show the layout of the dwellings within the Building 3 of the ground floor and the tree other floors applying skeleton timber structure.

(1)

(2)

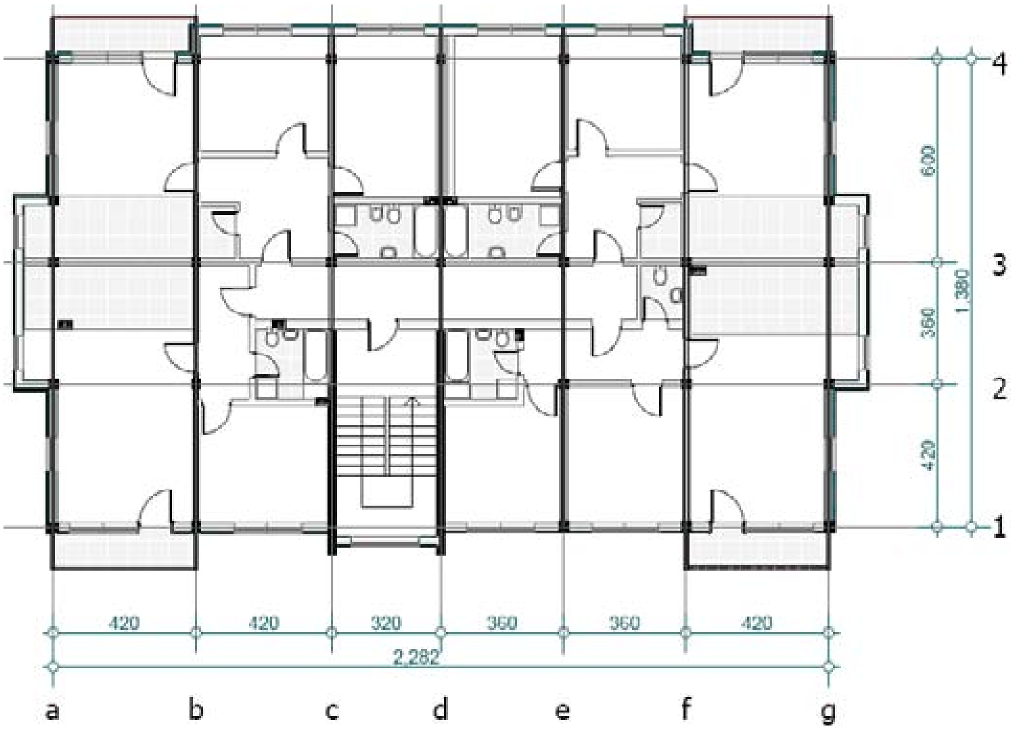


Figure 5-14: Ground floor (1) and characteristic floor (2) layout plan of Building 3

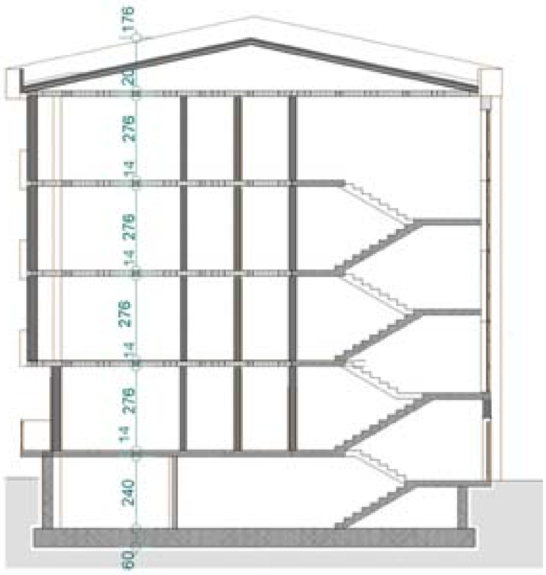
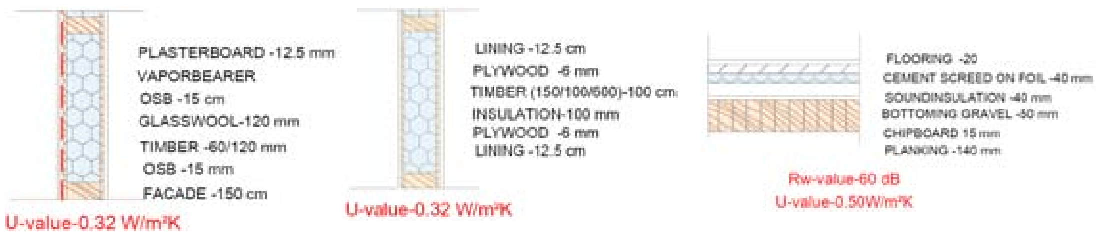


Figure 5-15: Section of Building 3

5.3.3 Envelope of Building 3

The outer walls are composed of the timber elements of 12x6 cm cross section each 60 cm filled with glass wool insulation, covered inside by OSB boards, vapour bearer and plaster board, while OSB boards and facade from the outside. The inner walls are designed by timbers of 10x5 cm in distance of 60 cm filled with insulation and covered both sides by plywood 0.6 cm and lining. Almost every structural beam is lying on such walls which do also serve as supporters. Floors are considered by solid ply wood of 18 cm, with additional layers of chipboard, 5 cm gravel, sound insulation 4 cm, cement screed of 4 cm and flooring



(a) (b) (c)

Figure 5-16: Outer (a), inner (b) wall and floor (c) composition of Building 3

5.4 Design of Building 4- Skeleton Modular Timber Structure

5.4.1 Structure of Building 4

The adopted structure for the Building 4 is a typology developed by PhD. Elif Somer. The system is considered as being possible for application as it doesn't require an advanced technology for element production, which is the case of Kosovo. By timber elements, different variations of columns for encompassing the structural module are provided, according to the need of the project. Compound elements required for columns and beams are of 3x10x300 cm for the panel and 10x10 cm for the pillars. Flooring is designed by 3x14 cm planking supported to the beams by metal plates. The following figures show the composition of each structural element.

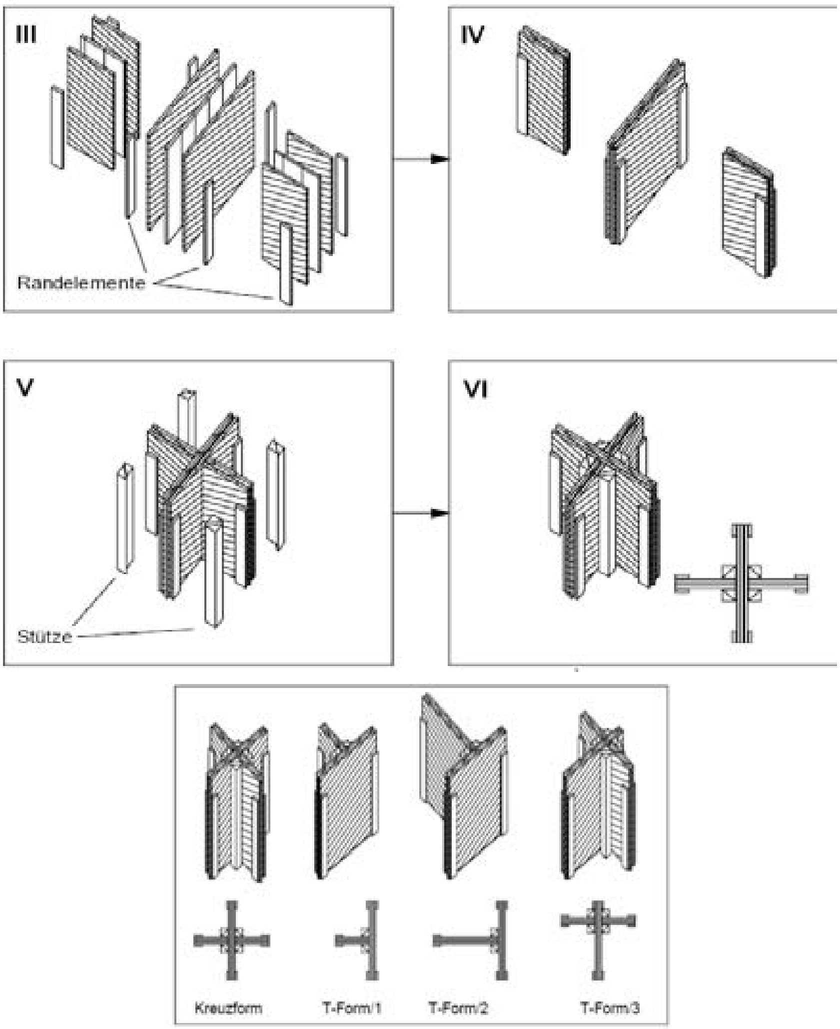


Figure 5-17: Composition of columns (Elif Somer, 2008) [24]

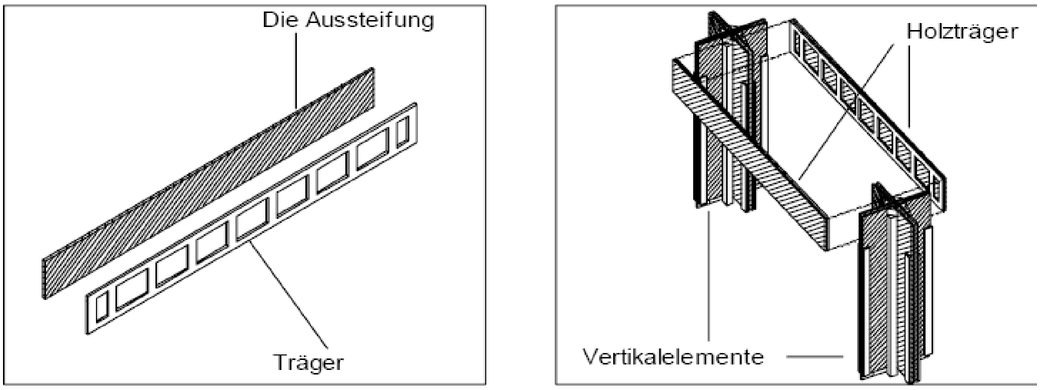


Figure 5-18: Composition of beams (Elif Somer, 2008) [25]

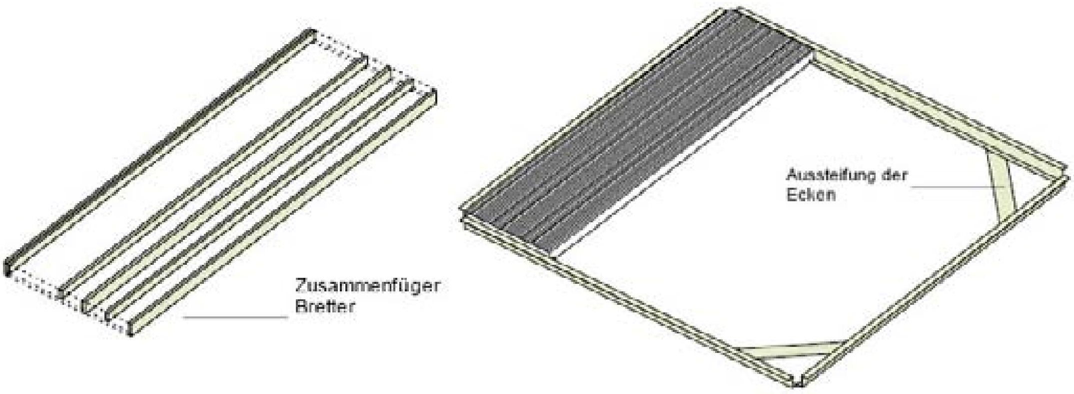


Figure 5-19: Composition of flooring (Elif Somer, 2008) [25]

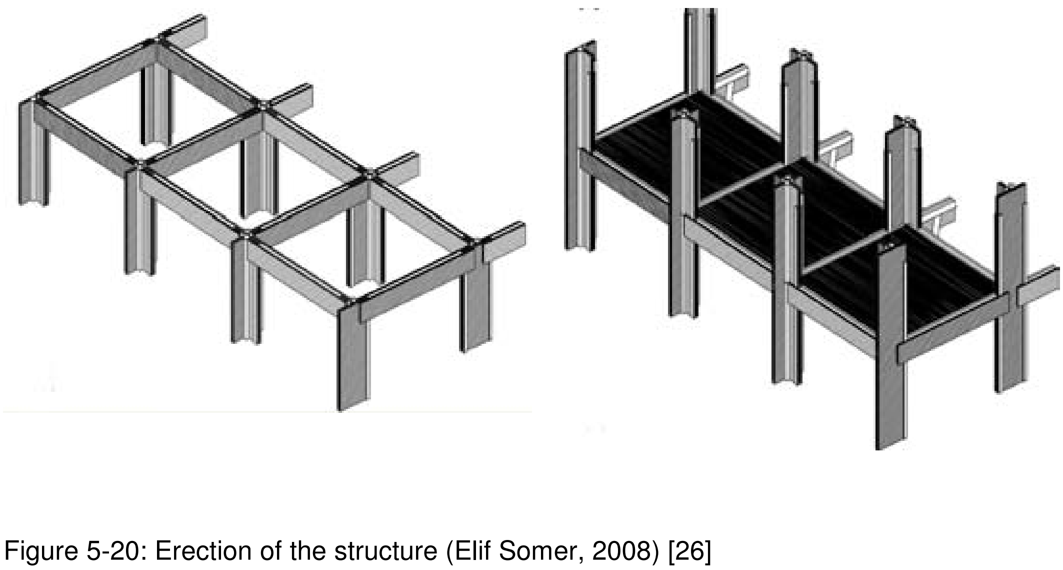


Figure 5-20: Erection of the structure (Elif Somer, 2008) [26]

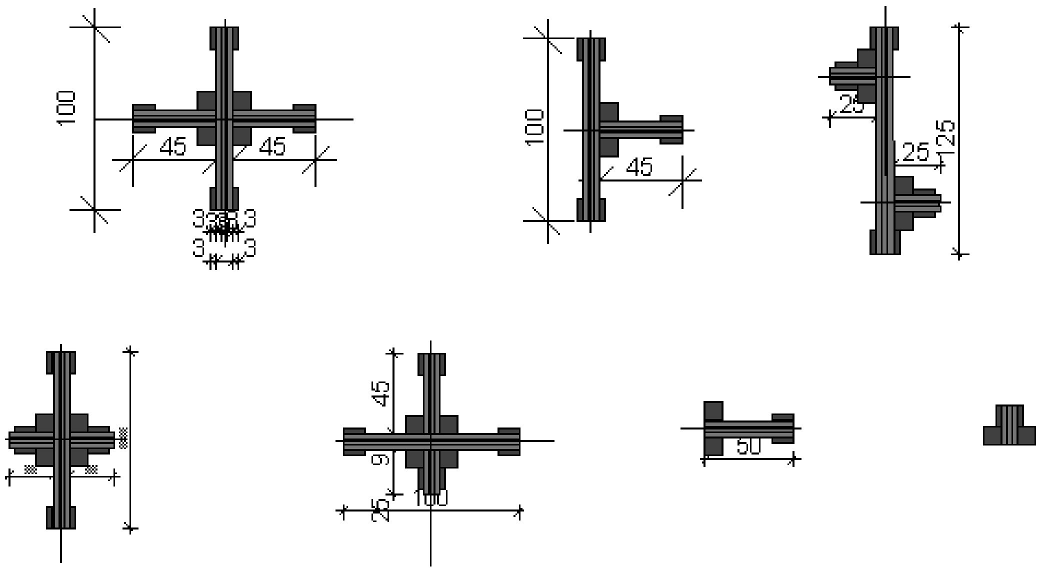


Figure 5-21: models of columns adopted for Building 4

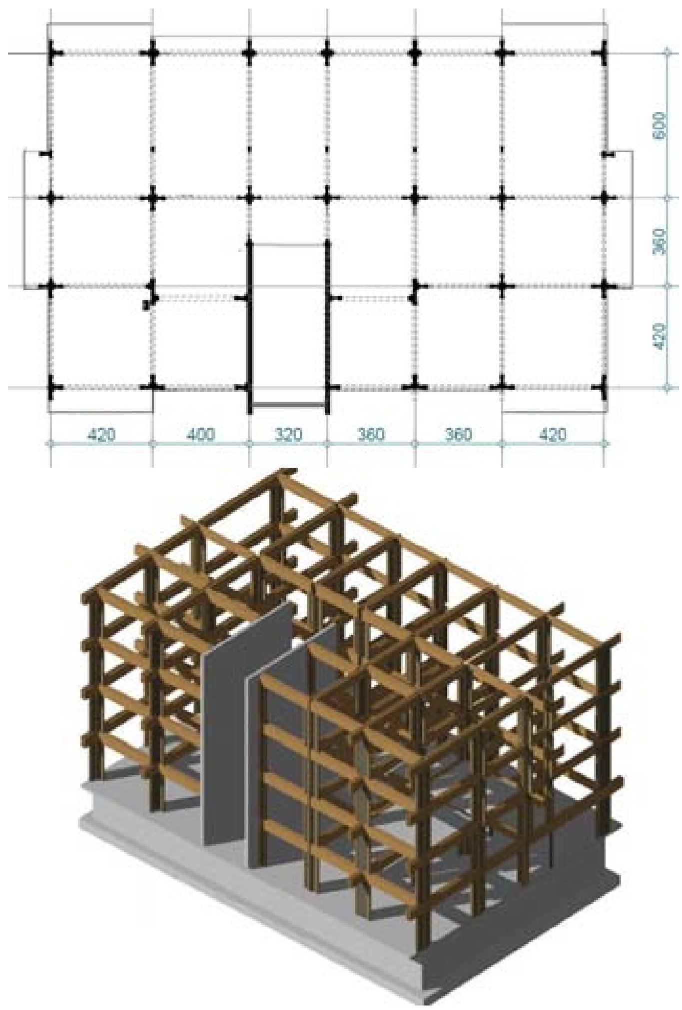


Figure 5-22: Modular skeleton timber structure layout of Building 4

5.4.2 Layout of Building 4

The following pictures show the layout of the dwellings within the Building 4 of the ground floor and the tree other floors applying modular skeleton timber structure.

(1)

(2)

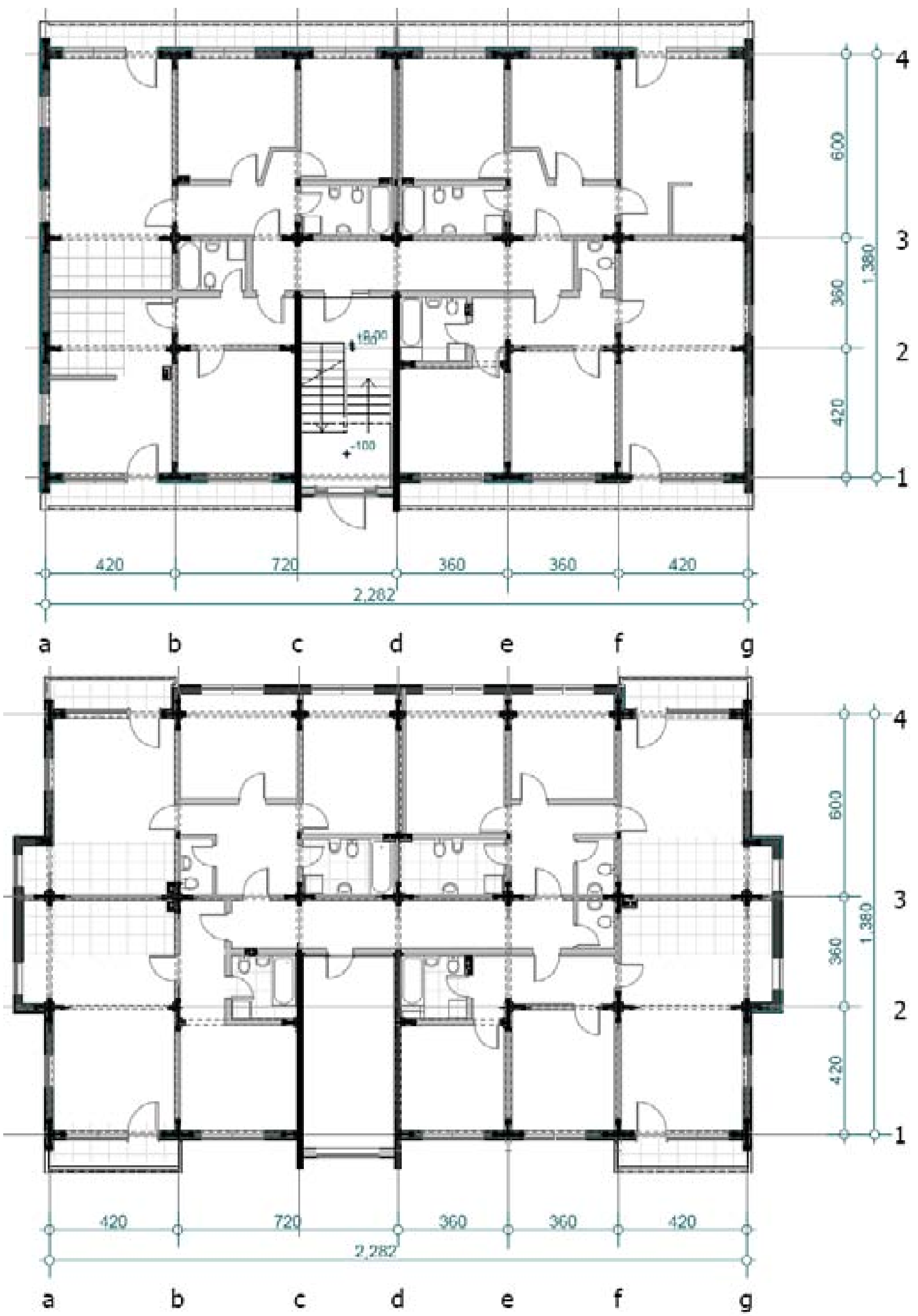


Figure 5-23: Ground floor (1) and characteristic floor (2) layout plan of Building 4

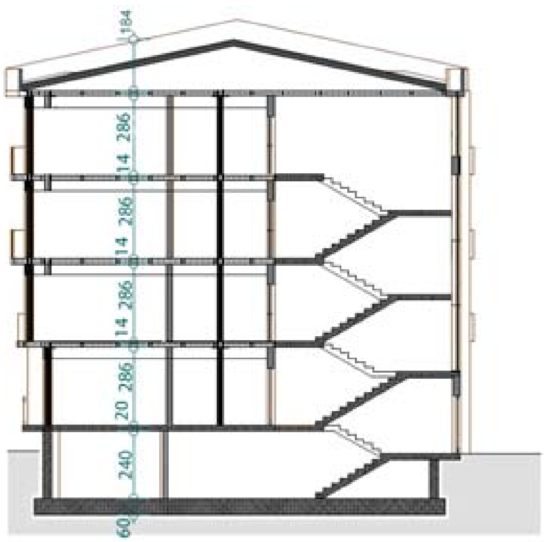


Figure 5-24: Section of Building 4

5.4.3 Envelope of Building 4

The envelope of the Building 4 is designed by the same composition as the floor of the Building 3. The solely difference is the thickness of the plywood which in this case is 14 cm enabled by this structure. The price difference is considered for the Building 4.

6. Cost & Material pre-evaluation

To contrast the four typologies presented in previous chapter in terms of cost, parted calculation of the common part (basement, stairway and roof) and structure with envelope for each Model has been conducted. On this occasion, the cost of common part designed in reinforced concrete comprises all required works and material rate, whereas for the four Models cost calculation is carried out separately for the structure and the envelope, respectively the external and inner walls.

Due to the fact that wood-based multistory construction is still not present in Kosovo, it was impossible to estimate the cost of labor work for assembling the structures. Apropos, only the structure material of the typologies is computed and compared while regarding the walls, material as well as working cost has been evaluated.

The following calculation has been conducted for the model area as presented in below table.

Table 6-1: The composition and areas of the Model for comparison

Model floor	area [m²]
Basement	320
Ground floor	350
First, second and third floor	3 x 346
Total area	1708
Total useful area	1388

6.1 Cost & Material for the common part

The below table shows the cost of each work required for constructing the basement, stairway and roof, including material. The values have been obtained from construction companies interviewed. Final cost gained for the common part is 114,103.40 €.

Table 6-2: Construction works and cost of the common part of typologies

pre-evaluation and cost estimation for the construction work of the basement, stairs and roof

Ground works	**Unit**	**Quantity**	**Cost/unit [€]**	**Amount [€]**
• Construction site clean-up, transporting to the nearest dump site. Cleaning depth t=20 cm 450.4 x0.2	m^3	98	2.5	245
• Ground excavating with machinery and by hand for building foundation & transport to the nearest dump side 362 x 2.3	m^3	832.6	2.5	2,081.50
• Laying of gravel below the foundations. layer depth t=30 cm in compact form. 350x0,3	m^3	105	10	1,050
•Filling the space surrounding the foundations and basement outer walls with earth and compacting in 20-30 cm layer 70.4x2.4=	m^3	168.96	6	1,013.80
			total	**4,390.30**

Concrete works	**Unit**	**Quantity**	**Cost/unit [€]**	**Amount [€]**
•Concrete pouring of leveling layer below the foundation with light concrete Mb-15 thickness 2x5 cm 362 x 0.10	m^3	36.2	75	2,715
•Cementing of the foundation slab with reinforced concrete. concrete Mb-30 depth t=60 cm. 362 x 0.6	m^3	217.2	85	18,462
•Cementing of basement outer walls with reinforced concrete Mb-30 wall thickness t=25 cm 66.5x0.25x2,4	m^3	39.9	95	3,791
•Cementing of basement, columns with reinforcement concrete Mb-30.	m^3	9.6	100	960

•Cementing of the ground floor slab with reinforced concrete Mb-30	m^3	70	85	5,950.00
•Cementing of stairs complete with stair flights and stair walls in reinforced concrete concrete Mb-30, thickness t=20cm, tread dimensions 17/29 cm.	m^3	46.07	120	5,528
•Cementing of attic wall with reinforced concrete Mb-30 88.96 x 0.15 x 0.8	m^3	10.67	120	1,281.00
		429.64		**38,687**

Steel works	Unit	Quantity	Cost/unit [€]	Amount [€]
•Supplying and processing of reinforcement ribbed steel 429.64 x 110	kg	47260.4	1.1	51,986.44
			total	**51,986.44**

Hydro-insulation works	Unit	Quantity	Cost/unit [€]	Amount [€]
•Required material and work of hidroinsul. under the foundation of the building bitulit A and a layer of "Kondor 4"	m^2	362	4.5	1630
•Required material and work of vertical hidroinsul. of the basement walls bitulit A and a layer of "Kondor 4"	m^2	362	5	1810
			total	**3,440**

Roof works	Unit	Quantity	Cost/unit [€]	Amount [€]
•Roof works with required material	m^2	390	40	**15,600**

Total cost [€]	**114,103.40**

6.2 Cost & Material for the Building 1

Structural elements of the first building are presented in m³ as the material as well as working is calculated by the same unit. Walls are presented by m³ as the blocks required are being sold in m³ and by m² for calculating the m² of the wall cost with additional material like insulation and plastering.

The following table show the pre-evaluated amount of structural and nonstructural material required for the Building 1.

Table 6-3: Pre-evaluation amount of structural and non-structural materials for the Building 1

Element	Unit	Gr. Floor	1 Floor	2 Floor	3 Floor	Roof
Column	m³	11.2	11.2	11.2	11.2	/
Peripheral Beam	m³	32.76	32.76	32.76	32.76	/
Slab/Foundation	m³	/	69.2	69.2	69.2	78
Slab/Foundation	m²	/	346	346	346	390
Inner Wall (20 cm)	m²	251.2	267.53	267.53	267.53	/
Outer Wall (25 cm)	m²	91.3	105	105	105	/
Inner Wall (20 cm)	m³	50.22	53.5	53.5	53.5	/
Outer Wall (25 cm)	m³	22.06	23.4	23.4	23.4	/

0

The cost of material required for forming the structure is achieved by the price of 81€/ m³ for mixed concrete including transportation to the site and the price of 110 kg of reinforced steel which is 1.1 €/ kg equaling 1 m³ of reinforced concrete. This is the price adopted by the architectural offices for pre-evaluating of the structural cost and the final cost is achieve after calculating the static of the building structure.

Table 6-4: Cost of structural elements of Building 1

Element	Unit	Amount	Cost/unit [€/m³]	Total cost [€]
Column	m³	44.8	191	8,556.80
Peripheral Beam	m³	131.04	191	25,028.65
Slab	m³	285.6	191	54,549.60
				88,135.05

The cost of the building structure is divided to the cost of material and the cost of work. The below table show the pricelist of the works regarding reinforced concrete construction in Kosovo adopted for work calculation of the Building 1 as well.

Table 6-5: Construction work and cost for Building 1

no.	work	unit	price [€]
I	**ground work**		
1	Construction site clean-up, transporting to the nearest dump site. Cleaning depth t=20 cm	m^3	2.5
2	Ground excavating with machinery and by hand for building foundation & transport to the nearest dump side	m^3	2.5
3	Laying of gravel below the foundations. layer depth t=30 cm in compact form.	m^3	10
4	Filling the space surrounding the foundations and basement outer walls with earth and compacting in 20-30 cm layer 70.4x2.4=	m^3	6
II	**wall work**		
1	Wall work with clay blocks 19x19x25cm in mortar lime bonding 1:3:9; thick t=20 cm	m^3	75
2	Inner wall work with clay blocks 12 x 19 x 25 in mortar lime bonding p=1:3	m^2	22
3	Lining in the inner walls and ceiling	m^2	5.5
III	**concrete and reinforced concrete work**		
1	concrete pouring of leveling layer below the foundation with light concrete Mb-15 thickness 2x5 cm	m^3	70
2	Cementing of the foundation slab slab with reinforced concrete. concrete Mb-30 depth t=60 cm.	m^3	70
3	Cementing of basement outer walls with reinforced concrete Mb-30 wall thickness t=25 cm	m^3	120
4	Cementing of basement, columns with reinforcement concrete Mb-30.	m^3	95

5	Cementing of beams with concrete Mb-30	m^3	100
6	Cementing of floors with concrete Mb-30	m^3	95
7	Cementing of stairs complete with stair		
	flights and stair walls in reinforced concrete concrete Mb-30, thickness t=20cm, tread dimensions 17/29 cm.	m^3	120
IV	**steel work**		
1	Supplying and processing of reinforcement ribbed steel	kg	1.1
V	**roof work**		
1	Roof works with required material	m^2	37
VI	**floor work**		
1	Supplying with required material and work of the flooring	m^2	12
VII	**façade work**		
1	Supplying with required material and work of façade Styrofoam glue Styrofoam 100 mm Styrofoam glue Plastic mesh Styrofoam glue Lining Façade color	m^2	21

Inner and outer walls cost comprises the cost of material and the cost of working. Inner walls of 20 cm thickness are composed of hollow clay blocks of 20x20x25cm bounded by cement mortar and both side lining of mortar. Outer walls are composed of hollow clay blocks of 20x20x25cm bounded by cement mortar. Inner side is lined with mortar and on the outer side it is covered by 10 cm of Styrofoam and 1.5 cm of façade layers. Outer walls with this composition achieve U-value of 0.30 W/m^2K. Following table shows the cost of total amount of inner and outer walls, considering the work for execution for the building 1.

Table 6-6: the amount and cost of the inner and outer walls for the Building 1

Element	Unit	Amount	Cost/unit [€/m²]	Total cost [€]
Inner Wall (20 cm)	m²	1,053	44	46,332.00
Outer Wall (25 cm)	m²	406.3	64.5	26,206.35
				72,538.35

Considering the total useful are of the Building 1 of 1388 m^2, final cost of structure, envelope and the common part per useful area comes up to 197.97 €, as shown on the Table 6-7.

Table 6-7: Material and work cost for the Building 1

		concrete		cost [€]
common part	&	work		114,103.40
structure				88,135.05
walls	&	work		72,538.35
		total cost		**274,776.80**
		cost/useful	**area[€/m²]**	**197.97**

6.3 Cost & Material for the Building 2

The Building 2 is formed by massive cross laminated panels, which should be imported from abroad as such production is not present in Kosovo. From a company contacted for supplying east Europe (Kosovo as well), prices per m^2 of panels are achieved. The below table show the pre-evaluated amount of panels required for the Building 2.

Table 6-8: Pre-evaluation of panels for Building 2

Element	Unit	Gr. Floor	1 Floor	2 Floor	3 Floor	Roof
Inner Wall	m²	268	303	303	303	/
Outer Wall	m²	120.23	133.83	133.83	133.83	/
Floor	m²	/	346	346	346	390

Cross laminated panels used for inner and outer walls are of 94mm 3s-3layers of the type NSi (Non-visual load bearing panels).NSi is chosen as the panel are not consider to be visual in any side as used for domestic. As the panels have to be imported the amount of 15% for VAT, 10% for custom services, and 3% for the transport has to be added to the primary price as well as trimming of the panel price. Therefore the final price for such panel comes up to 77.3 €/m².

The ceiling panels are of 120 mm, 5s-5 layer of the type NSi. Adding the mentioned amount for VAT, costume services and transport the price of 97.4 €/m² is achieved.

The panels ordered are considered to be delivered within 4-8 weeks.

The below table shows the amount of panels without covering required for the B

Table 6-9: Material cost for building 2

Element	Unit	Amount	Cost/unit [€/m²]	Total cost [€]
Inner Wall	m²	1,177	77.3	90,982.10
Outer Wall	m²	521.72	77.3	40,329.00
Floor	m²	1,428	97.4	139,087.20
			total cost [€]	**270,398.30**

Inner walls are formed by 3layer cross lam panel covered by plasterboard of 15mm on both sides. The outer walls are composed by cross lam panes from the inside covered by plasterboards of 12.5 mm and stone wool of 100mm and façade of 15 mm. Such a composition of outer wall achieves the U-value of 0.32 W/m^2 K.

Floor is composed of 120mm panels, protection against flowing of gravel, 70 mm of bottoming gravel, sound insulation of 40 mm, cement screed on foil of 40 mm and the flooring. This composition reaches thermal transmittance U-value of 0.50 W/m^{2}K and sound insulation Rw-value of 60 dB.

The following table shows the amount & cost of wall and floor panel with additional material layers for the Building 2.

Table 6-10: the amount & cost of wall and floor panel with additional material layers for the Building 2.

Element	Unit	Amount	Cost/unit [€/m²]	Total cost [€]
Inner Wall	m²	1,177	97.3	114,552.00
Outer Wall	m²	521.72	117.3	61,197.75
Floor	m²	1,428	97.4	139,087.20
			total cost [€]	**314,836.95**

The final cost of the Building including wall, floor panel and that of the common part per useful area of 1338 m^2 comes up to 330.65 € per useful area.

Table 6-11: Material and work cost for the Building 2

		massive timber		**cost [€]**
common part	&	work		114,103.40
floors				139,087.20
walls	&	work		175,749.75
		total cost		**428,940.35**
		cost/useful	**area [€/m²]**	**309.04**

6.4 Cost & Material for the Building 3

The Building 3 is formed by skeleton timber structure, considering the use of local material in Kosovo. The delivery time for timber is considered around 3-5 weeks according to the amount required.

The table below shows the amount of structural components presented in m³ and m' as they are calculated, steel elements in quantity and m' as well as wall panels in m² for the Building 3.

Table 6-12: Pre-evaluation amount of structural and non-structural materials for Building 3

Element	Unit	Gr. Floor	1 Floor	2 Floor	3 Floor	Roof
Column	m³	4.38	4.38	2.6	2.6	/
Beam	m'	142.8	142.8	142.8	144.8	/
Floor	m²	/	337.8	337.8	337.8	382
Steel elem/column	Quant.	/	24	24	24	/
Steel plate/flooring	m'					
Inner Wal	m²	256	273	283	283	/
Outer Wall	m²	105	120	120	120	/

Columns of the building 3 are of 26x26 cm and 20x20 cm of the section and the final price for m3 is 270€. Beams with 10x20 cm of section is calculated with price of 250€/m^3, respectively 5€ per m'. Flooring with thickness of 18 cm is calculated with price of 180 €/m^3 +30% of 180 for the final selling cost. With additional layers: chipboard 15mm, bottoming gravel 50 mm, sound insulation 40mm, cement screed on foil 40mm and flooring, it reaches the U-value of 0.5 W/m^{2}K and Rw-value 60 dB. Steel elements prices come from 0.55 €/kg. Inner and outer walls are considered to be prefabricated and erected in site. The price comes of walls as well as other elements are adopted from the consulting with the interviewed companies selling timber elements and are showed in following tables.

Table 6-13: Cost of structural elements for Building 3

element	beam
m³/m'	0.02
Cost /m' [€]	5
element	**floor**
m³/m²	0.18
Cost /m² [€]	42.12
element	**steel elem./column**
kg/element	34
[€/m']	18.7
element	**steel plate/flooring**
kg/m'	36
[€/m']	19.8

Table 6-14: the amount and cost of the inner and outer walls for the Building 3

Element	Unit	Amount	Cost/unit [€]	Total cost [€/m³]
Column	m³	13.96	270	3,769.20
Beam	m'	573.2	5	2,866.00
Floor	m²	1395.4	42.12	58,774.25
Steel elem./column	Quant.	72	18.7	1,346.40
Steel plate/flooring	m'	634.24	19.8	12,557.95
				79,313.80
Inner Wal	m²	1095	41.25	45,168.75
Outer Wall	m²	465	58,45	27,179.25
				72,348.00

The final cost of the Building including structure, enveloping and the common part per useful area of 1338 m^2 comes up to 330.65 € per useful area.

Table 6-15: Material and work cost for the Building 3

		skeleton timber		**cost [€]**
common part	&	work		114,103.40
structure	&	work		79,313.00
walls	&	work		72,348.00
		total cost		**265,764.40**
		Cost/useful	**area [€/m²]**	**191.48**

6.5 Cost & Material for the Building 4

The Building 4 is composed of skeleton modular structure, which as well is considered possible to be provided using local resources in Kosovo.

The figure and table below show the types of columns used for the Building 4 as well as the amount of all structural elements and panels for this typology.

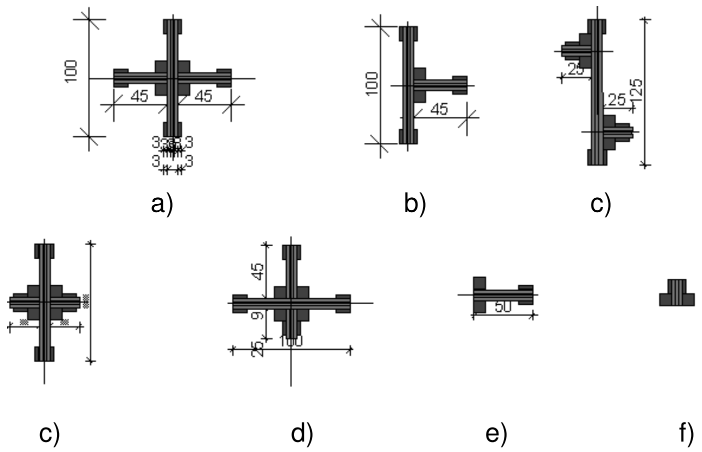


Figure 6-1: Column models adopted for Building 4

Table 6-16: Pre-evaluation of structural and non-structural elements for Building 4

Element	Unit	Gr. Floor	1 Floor	2 Floor	3 Floor	Roof
A	Quant.	3	3	3	3	/
B		16	7	7	7	/
C	/	1	2	2	2	/
D	/	/	5	5	5	/
E	/	4	7	7	7	/
F	/	4	4	4	4	/
G	/	2	2	2	2	/

Beam	m'	164.5	172.5	172.5	172.5	/
Floor /Planking	m²	/	321	321	321	332
Steel plates	m'	/	253	253	253	253

Inner wall	m²	224	229.6	229.6	229.6	/
Outer wall	m²	56.7	69.2	69.2	69.2	/

The price offered for producing the columns and beam elements is of 180 €/m^3 +90% of the prices of element. Therefore each type of column and beam is specified by the amount of timber used in m^3.

Ex. For the element A

0.733 m^3 x180 € = 131.94€

131.94€ + 131.94 x 0.9 = 250.69 €

The floors are calculated by 180 € adding 30% for the preparation.

Table 6-17: Cost calculation of structural and nonstructural elements for Building 4

Element	A	B	C	D	E	F	G
m³/elem.	0.733	0.527	0.687	0.613	0.67	0.21	0.14
Cost /elem. [€]	250.69	180.24	234.96	210.25	229.14	71.82	47.88

Element	Beam
m³/m'	0.065
Cost /m' [€]	22.23

Element	Floor
m³/m²	0.14
Cost /m² [€]	32.76
Element	Steel
kg/m'	30
Cost [€]/m'	15

Element	Inner Wall
Cost /m² [€]	41.25
Element	Outer Wall
Cost /m² [€]	58,45

Table 6-18: the amount and cost of the inner and outer walls for the Building 4

Element	unit	Amount	Cost/Unit [€]	Total cost [€]
A	Quant.	12	250.69	3008.28
B		37	180.24	6668.88
C	/	7	234.96	1644.72
D	/	15	210.25	3153.75
E	/	25	229.14	5728.5
F	/	16	71.82	1149.12
G	/	8	47.88	383.04
	Total cost of column elements			**21,736.29**
Beam	m'	682	22.23	**15,160.86**
Floor /Planking	m²	1295	32.76	**42,424.20**
Steel plates	m'	1020	15	**15,300**
		Total cost of Structure		**94,621.35 €**
Inner wall	m²	912.8	48.25	44,043
Outer wall	m²	264.3	62,45	15,881.04
				59,924

The final cost of the Building 4 including structure, enveloping and the common part per useful area of 1338 m^2 comes up to 268,468.80€ per useful area.

Table 6-19: Material and work cost for the Building 4

		modular timber		cost [€]
common part	&	work		114,103.40
structure	&	work		94,621.00
walls	&	work		59,924
		total cost		**268,648.40**
		Cost/useful	**Area[€/m²]**	**193.55**

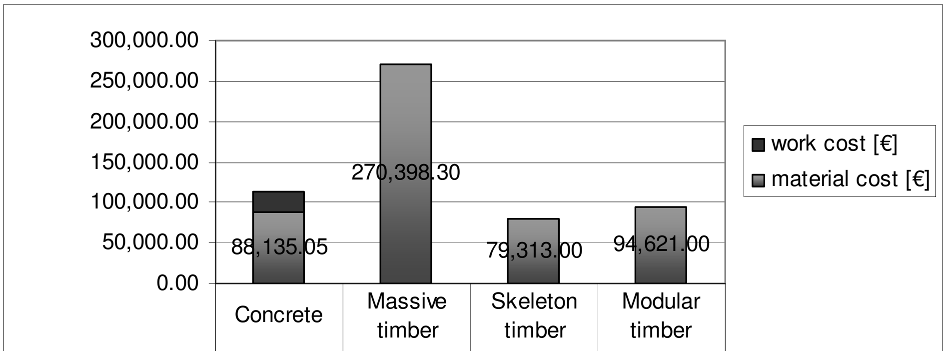
7. Discussion of Data

7.1 Material / Work cost

The cost of material is separated of the cost of working in case of Building 1-Concrete one, as for the rest typologies it was not possible performing the working cost. As showed in the table below, the structure cost of skeleton timber and modular one do not differ a lot to the concrete building. Assuming that work cost of wood-based building wouldn't exceed the price of labor work of concrete building considering that an amount of elements are already prefabricated and need only erection to the site, while in case of concrete building everything is prepared to the site, it can be accounted on wood-based skeleton application.

As regards the Building 2-Timber Massive panel system, appears to be quite more expensive even though the comparison presented applies to the structures of typologies, while Massive typology comprises enveloping within structure. The importing of panels for massive application from abroad, as well as high amount of wood used for enveloping influences the high price.

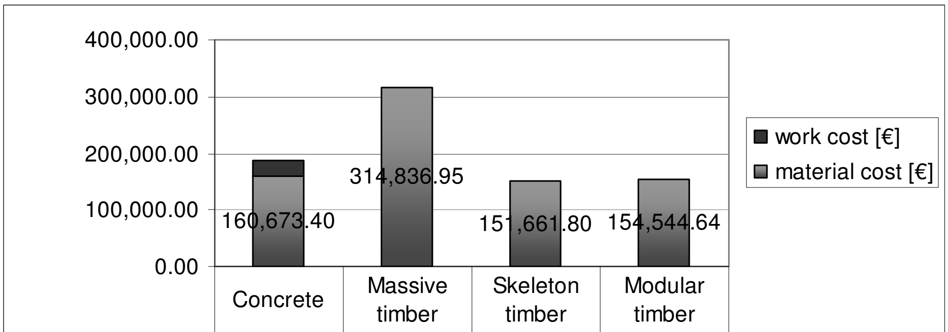
Table 7-1: Structural Material / Work Cost for the four Buildings



	Concrete	Massive timber	Skeleton timber	Modular timber
work cost [€]	25,709.60			
material cost [€]	88,135.05	270,398.30	79,313.00	94,621.00

When considering the enveloping, respectively inner and outer walls, Building 1, 3 and 4 don't differ a lot in terms of cost. The massive one-Building 2 appears to be almost 195% more expensive in comparison to Building 1 which excludes the possibility of being interesting in financial context. The table 7-2 shows the ratio of structural and non-structural between four models adopted.

Table 7-2: Structural & Enveloping Material / Work Cost for the four Buildings

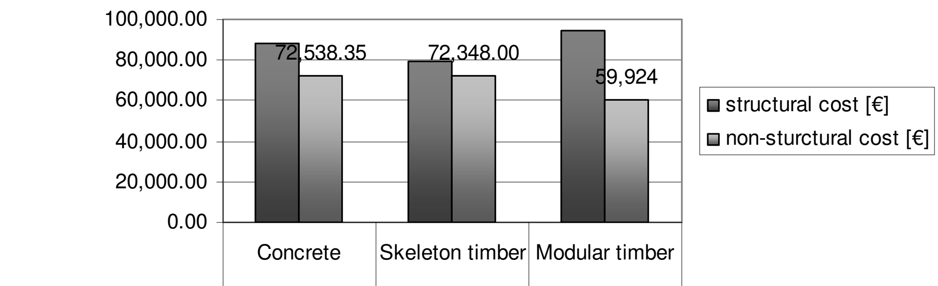


	Concrete	Massive timber	Skeleton timber	Modular timber
work cost [€]	25,709.60			
material cost [€]	160,673.40	314,836.95	151,661.80	154,544.64

7.2 Structural / non-structural cost ratio

As Buildings 1, 3 and 4 can be separated to structure and non-structure part. The ratio between these two states showed in below table denotes the similarity to a great level between Building 1 and 3. The structure of the fourth typology-modular one seems to be more expensive due to larger amount and complexity of structure elements.

Table 7-3; Comparison of structural and non-structural costs for Building 1, 3 & 4



	Concrete	Skeleton timber	Modular timber
structural cost [€]	88,135.05	79,313.00	94,621.00
non-sturctural cost [€]	72,538.35	72,348.00	59,924

The percentage ratio of structural and non-structural cost of the Building 1, 3 and 4 is displayed in below charts, where the modular structure takes part with 61% of the overall cost while the concrete and skeleton timber with 55% and 52%.

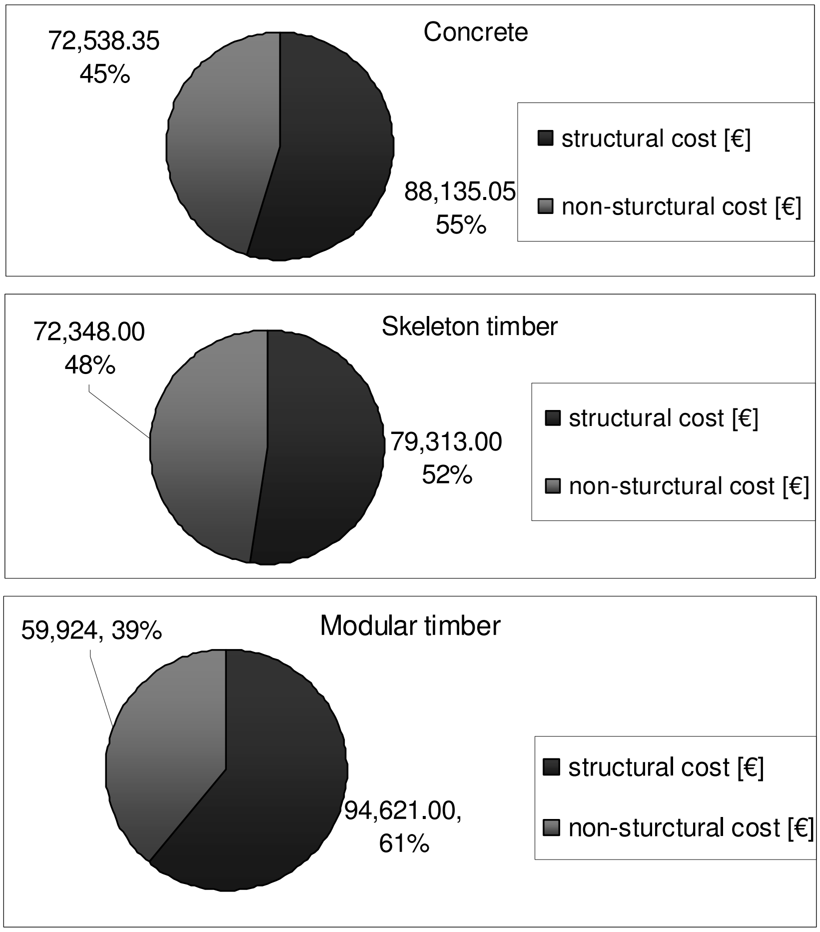


Figure 7-1: Structural and non-structural cost for Building 1, 3 & 4

The ratio between structural elements is interesting for the future focus on finding better alternatives. Also it can give ideas on combining different structural typologies for better financial results. Flooring takes the most part, respectively from 62% to concrete typology, 51% to massive timber, 61% to modular timber and the extreme case is the skeleton timber floor taking 90% of the overall structural cost. Alternatives like lightweight flooring requiring less solid material could be an interesting financial solution.

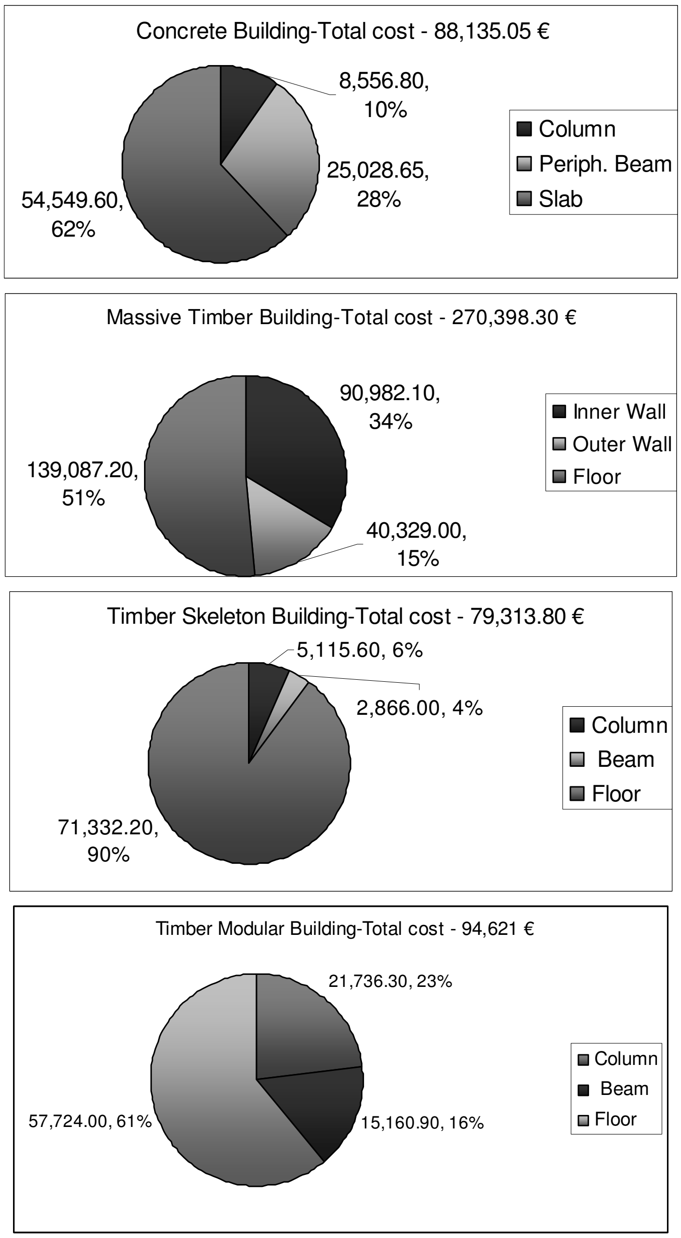


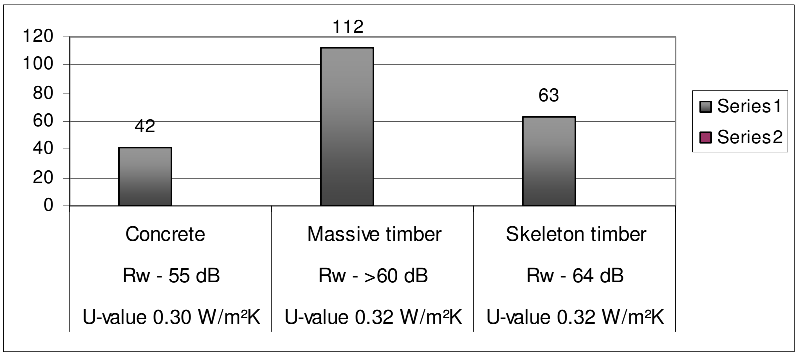
Figure 7-2: Ratio between structural elements costs for four Buildings

7.3 Envelope cost

The four Buildings comprise tree types of flooring which in terms of thermal transmittance have almost the same performance- U-value 0.50 W/m^{2}K for the composition as showed in below figure. But regarding cost, a difference is noticed, especially massive flooring.

Table 7-4: Comparison of flooring costs for four Buildings

	Concrete [€/m^2]	Massive timber [€/m^2]	Skeleton timber [€/m^2
Floor	42	112	63



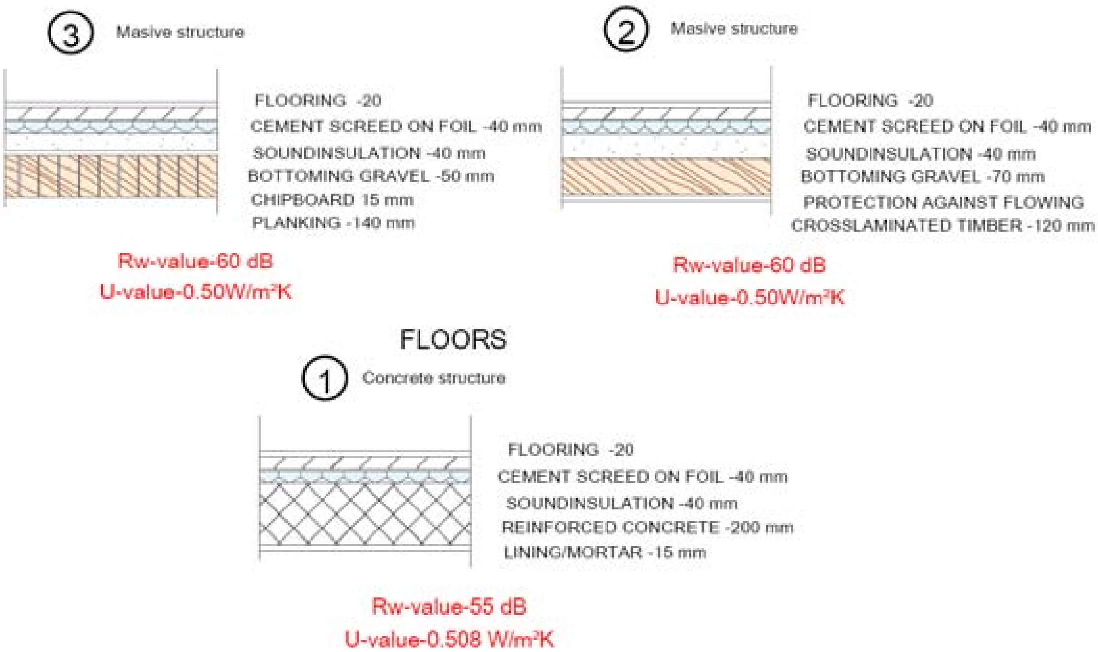


Figure 7-3: Composition of the floors for the four Buildings

Three types of enveloping showed in below figures have U-value of 0.32 W/m^{2}K, but a cost difference is specially walls of second building typology.

Table 7-5: Comparison of inner &outer wall costs for four Buildings

	Concrete [€/m^2]	Massive timber [€/m^2]	Skeleton timber [€/m^2
Inner wall	44	97.3	41.25
Outer wall	64.5	117.3	58.45

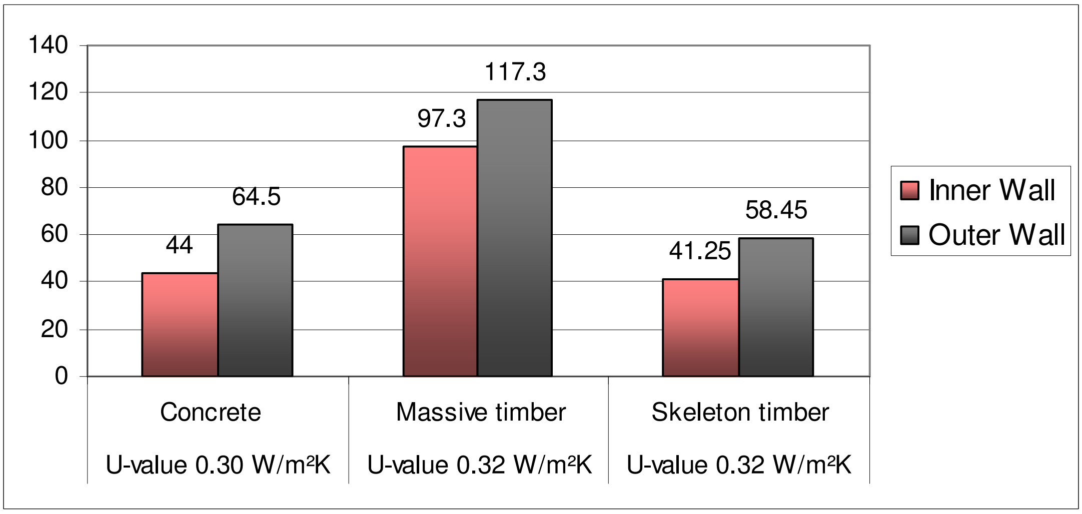
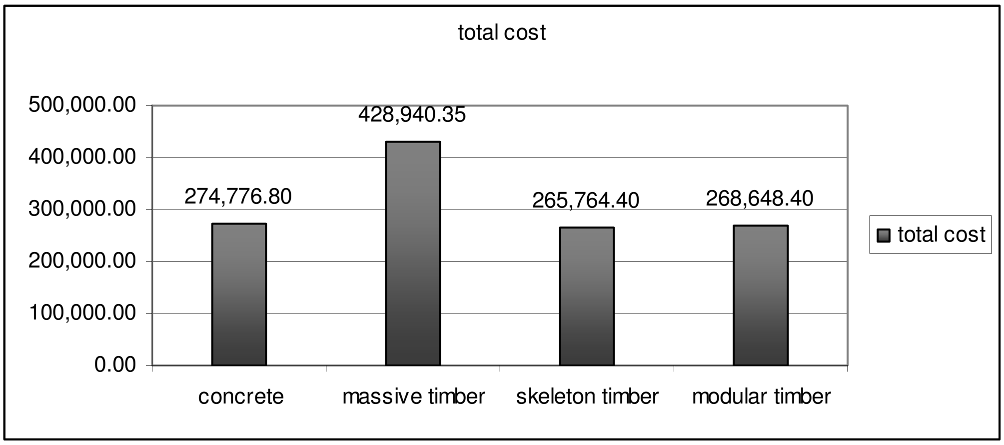


Figure 7-4: Composition of outer walls for the four Buildings

The cost ratio between four typologies including the cost of common part is shown on the table below. The difference between Building 1, 3 and 4 is around 10 000 €.

Table 7-6: Total cost including the common part cost for the four Buildings

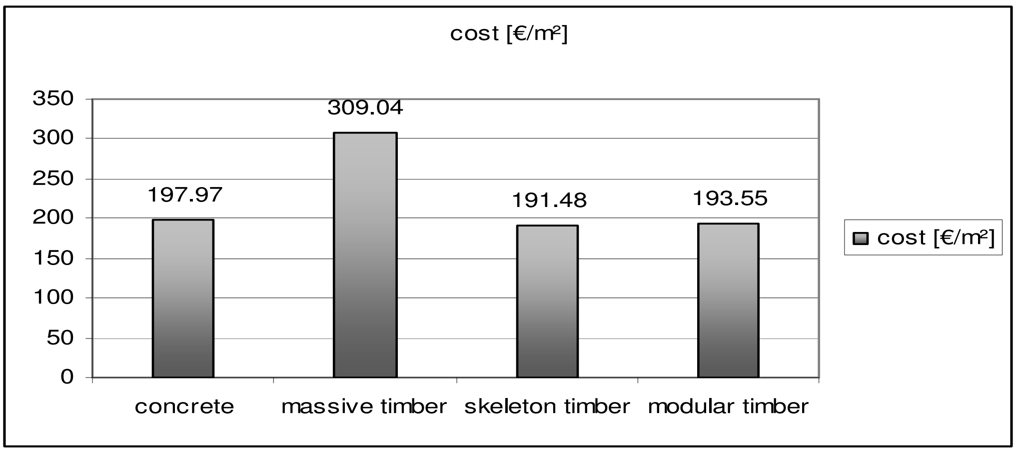
	concrete	massive timber	skeleton timber	modular timber
total cost	274,776.80	428,940.35	265,764.40	268,648.40



On the table 7-7 prices per m^2 of the useful area are showed.

Table 7-7: prices per m^2 of the useful area for the four Buildings

	concrete	massive timber	skeleton timber	modular timber
cost [€/m²]	197.97	371.64	191.48	193.55



As regarding the Building 1, it was possible accessing on all required data relating to the cost of material as well as labor work cost. Therefore, final price of the structure, envelope and the common considering the labor cost has been calculated as shown in the below table.

Table 7-8:Total material and work price for the Building 1

		concrete	cost [€]
common part	&	work	114,103.40
structure	&	work	113,844.65
walls	&	work	72,538.35
		total cost	**300,486.40**
		cost [€/m²]	**216.5**

A very interesting indicator is the ratio between the basement complete cost and the rest (structure and non-structure) cost including the work. It shows the partaking of the basement cost within the overall cost. Apropos, the basement cost comprises 33% of the overall cost of the building 1, which leads to the interest on calculating the weight of the building structures that could influence the cost of the common part.

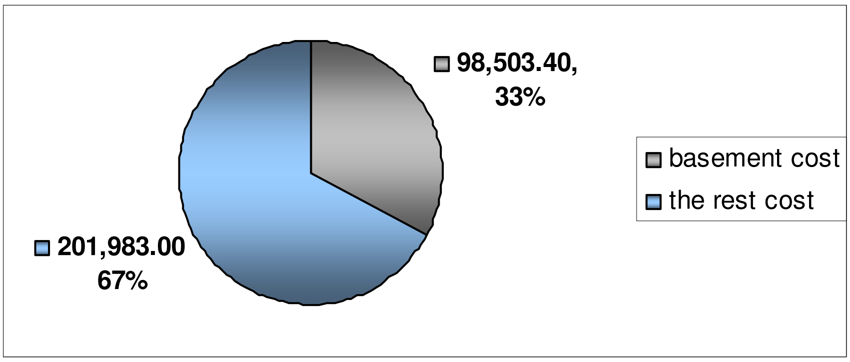


Figure 7-5: Ratio between common part & rest cost for Building 1

7.4 Weight of the buildings

The weight of the structure for the four typologies has been calculated in order to get an overview on the possibility of reducing the cost of the basement. At this point, the following data shown below have been achieved.

Table 7-9: Weight of the four Buildings

	Concrete	Massive Timber	Skeleton Timber	Modular Timber
Total weight [t]	330.2	427.74	121.31	117.04
weight [t/m²]	1.032	1.34	0.38	0.37
weight [Pa]	10.12	13.11	3.72	3.59

The ratio of the weigh presented in tone per m^2 of the basement and tone per m^2 of the useful area of the building for the four typologies are showed in the tables below. Comparing the skeleton timber and modular timber to the concrete building, around 30% of the weight of concrete building equals the wood-based ones. This is a very optimistic indicator regarding the cost reduction of the overall building in case of wood-based application.

Table 7-10: Weight in tone/ m^2 of the basement for the four Buildings

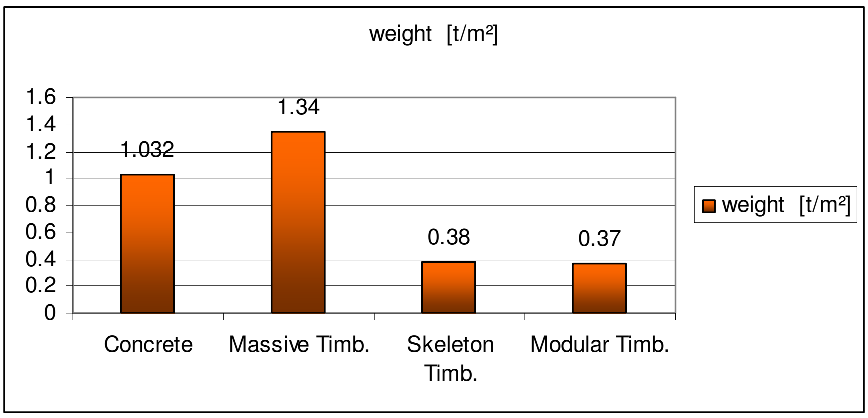


Table 7-: Weight in tone/ m^2 of the useful area of the four buildings

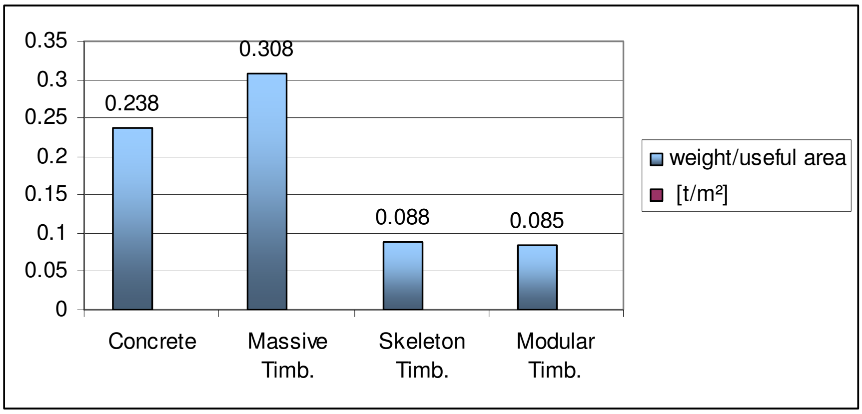
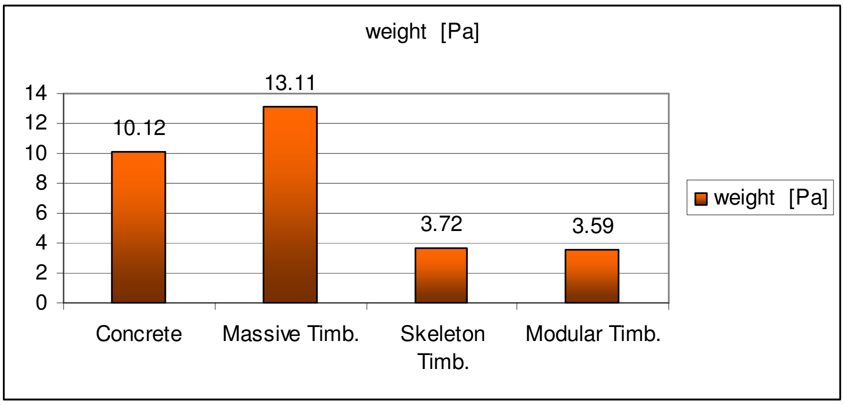


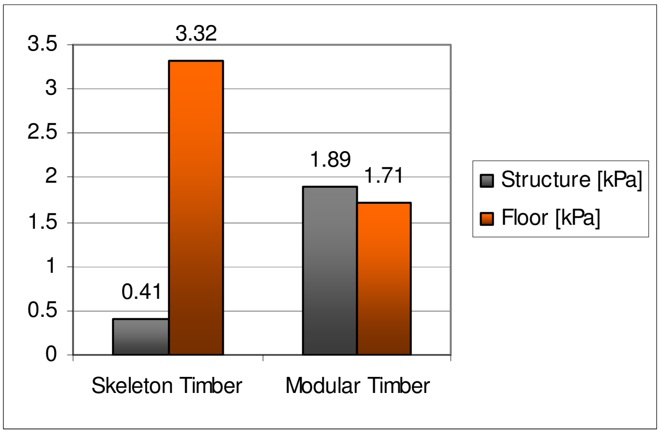
Table 7-11: Weight in Pa for the four builidngs

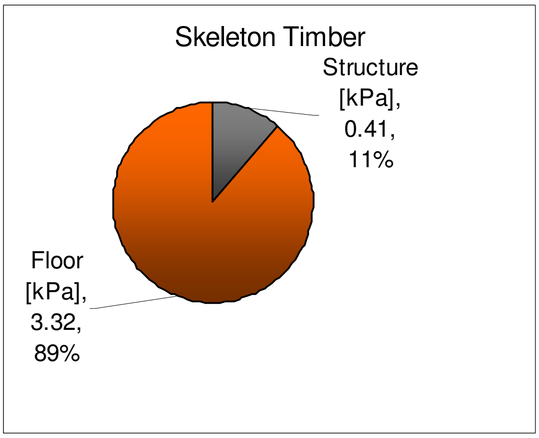


A ratio between the structure and the floor of the two skeleton systems regarding the weight could serve as interesting indicator. Regarding modular system, flooring comprises 48% of the weight of the total weight of building, whereas in case of skeleton system, the flooring takes up to 89% of the overall weight of the building which leads to important further study on alternatives for getting lighter flooring system. Following tables show the ratio of the weight of these two typologies.

Table 7-12: Ratio between flooring and structural weight

	Skeleton Timber	Modular Timber
Structure [kPa]	0.41	1.89
Floor [kPa]	3.32	1.71





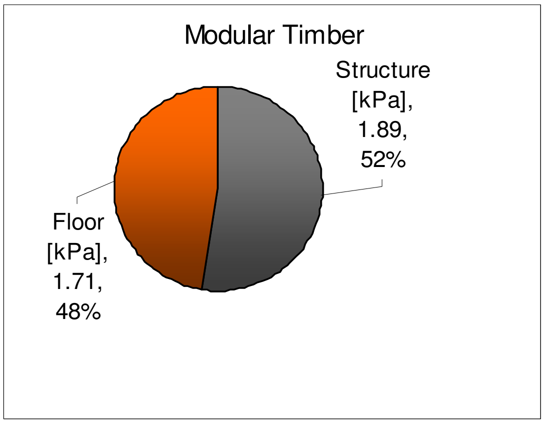


Figure 7-6: Ratio between flooring and structural weight

8. Conclusion

Studies on finding other options regarding building construction can lead on benefiting in terms of cost as one of the most direct indicator when approving certain typology. In respect of the middle-rise residential building construction, it is the most construction typology applied in Kosovo concerning the high range of habiting necessity. Residential typologies in comparison to other destination buildings are characteristic due to the fact of its iterant application on the structural as well as non-structural point of view. Therefore, new alternatives on this sector of construction can have a direct positive impact in financial terms.

At the same time considering the specialties of the wood-based material application as the only renewable construction material gives an impressing prospect on better use of resources used in construction as well as interesting impact from the ecology point of view.

The study performed showed clearly the possibility on cost efficiency issue. Comparisons conducted on the four typologies evidences on the probability of wood-based application, especially of skeleton structural system.

Further study required to complete this explicated topic is researching on further wood-based construction system in order to get a complete overview regarding the time, labor, therefore cost of work for such systems.

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