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ROTES
ENHANCING THE RELEVANCE OF VOCATIONAL TRAINING FOR ROOFERS

MODULE 1

Essentials for roof construction, maintenance, renovation & demolition

OPEN EDUCATIONAL RESOURCES

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1. Lecture notes

- **Unit 1: 3D modelling/design tools**

Global warming, heat islands, the greenhouse effect - these are terms that enter our homes every day. There are many solutions, more or less drastic, that try to marginalize these problems.

These include the so-called green roofs, a horizontal roof system cultivated with vegetation. These systems alone will not be able to save the entire planet Earth in the short term, but they are certainly capable, if properly distributed in the urban system and incentivised, of improving the quality of life within cities. Currently, there is no uniform law providing for the redevelopment of buildings by means of green roofs and walls. However, there are various regulations, often local, that favour and incentivise their installation.

1. Why a green roof?: In addition to its aesthetic appeal, a green roof provides undeniable ecological and economic advantages, provided it is built correctly! In fact, a green roof:
   - Improves the microclimate
   - Absorbs dust and harmful substances
   - Retains water
   - Improves sound insulation
   - Reduces energy costs
   - Extends the life of the roof
   - It offers a natural habitat
   - Create new spaces

2. European regulations: There is still no uniform law providing for the rehabilitation of buildings, but there are regulations and directives that lead to their regulation among them are:

   - Directive 2002/91/EC = energy performance of buildings.
   - Directive 2010/31/EU = 'nearly zero-energy' building.
   - Directive 2012/27/EU = building renovation strategy.
   - COM (2013)249 =Green Infrastructure - Strengthening Natural Capital in Europe.
   - Directive2018/844/EU = New Energy Efficiency in Buildings Directive.

3. European Initiatives: Following the adoption of the European Climate and Energy Package in 2008, the European Commission launched the Covenant of Mayors to endorse and support the efforts of local authorities in implementing sustainable energy policies. Indeed, local governments play a decisive role in mitigating the effects of climate change, especially considering that 80% of energy consumption and CO2 emissions are associated with urban activities. Due to its unique characteristics - being the only movement of its kind to mobilise local and regional actors in pursuit of European objectives - the Covenant of Mayors is considered by European institutions as an outstanding model of multilevel governance

- **Unit 2: Roofing Tools and Equipment**

  Green roofs are an alternative solution to traditional roofs and offer advantages in terms of comfort, energy efficiency and environmental sustainability. Their popularity has increased in connection with the growing interest in sustainable architecture and green building. Green roofs can be intensive or extensive; a classification that depends on several factors: the amount of land, maintenance, weight and accessibility. For sure, green roofs bring social, economic and environmental benefits: mitigation of microclimate, energy saving, reduction of air and noise pollution, reduction of water runoff velocity, growth of biodiversity, better performance of photovoltaic panels on the roof.

1. Types of green roofs: There are two basic types of green roofs: extensive and intensive, with many variations in layout and stratigraphy (simple intensive green roofs).

   - Extensive green roofs are an environmentally friendly alternative to conventional surface protection such as gravel. They are lightweight and their thickness is reduced. For this type of system, we use proven plant communities adapted to the environmental conditions (sun, wind, humidity, etc.) prevailing on the roof in question. Once implemented, the extensive green roof requires very little care. As a rule, maintenance is limited to one or two operations per year.
   - Intensive green roofs can easily be compared to building a Dachgarten on a roof. They are usually multifunctional and usable. They weigh more and their structure is deeper. Maintenance must be regular and depends on the layout, as well as the plants chosen. Depending on the thickness of the substrate, any solution is possible: lawn, perennials, shrubs, trees and other options such as ponds, basins, pergolas and terraces.

2. Types of green roofs (intensive): this section deals with the main elements for laying a roof:
   - Methods for connecting the membrane to the laying surface: Flaming of the roll compound must affect both the membrane and the substrate at the same time, with the roll prevailing.
   - Vertical parts: Vertical parts must also be waterproofed. First of all, all reliefs must be painted with bituminous adhesion primer. The perimeter wall will be covered with a layer of waterproofing membrane that will be turned up at least 10 cm onto the flat part. The second layer will be made with a root-proof waterproofing membrane, the sheets will be unrolled parallel to the first and straddle the overlaps of the same and will be torch-bonded to it.
   - Preparation of the laying surface: On the suitably clean and wet roofing slab, a sloping screed (1÷5%) will be laid, well adhered and smoothed with a trowel, made up of concrete prepared with 200÷250 kg of cement per m3 of mixture; for areas where a thickness of less than 3 cm is envisaged, the screed will be made from a mortar prepared with 350 kg of cement per m3 of sand. The screed may consist of concrete with light mineral granules prepared with 250 kg of cement per m3 of mixture. The sloping screed may also be made of cellular cement or concrete lightened with non-mineral granules provided it is sufficiently cohesive to allow the membranes to adhere.

3. Installation details and warnings (intensive):
   - for gardens larger than 100 m2: A sterile area at least 40 cm wide will be provided near the vertical parts of the roof at the flap of the waterproof covering, which can be created in accordance with the two examples shown below.
   - For gardens of less than 100 m2: In the vicinity of the vertical parts of the roof at the turn-up of the waterproofing membrane, the sterile zone can be created by draining polystyrene panels at least 3.5 cm thick or by a composite draining and filtering geotextile at least 2 cm thick under load.

4. Installation details and warnings (intensive):
   - Embankments: If the roof of a terrace is partly buried or in any case in contact with an embankment, in addition to the normal waterproofing, a strip of protective plastic film must be laid around the perimeter of the roof

in contact with the ground, with a vertical waterproofing lap of at least one metre.

- Tree pits: In the case of gardening work of a certain degree of commitment, where the planting of stem plants of a certain height is envisaged, tree pits of sufficient size and height must be provided, which will provide deep burying for normal root growth. These tubs will be placed on the drainage layer, having
  take care to separate them with a weight-distributing layer.
  The tank itself will have a drainage layer inside with drains and a separating filter.

5. Laying details and warnings (extensive): this section contains the elements that characterise the laying of an extensive green roof in the vicinity of a drain and in the vicinity of a rainwater collection channel

6. Laying details and warnings (extensive): the figure shows an example of an extensive green roof on a slope and highlights the special type of laying of the construction elements

- **Unit 3: Roofing Tools and Equipment**

Technological solutions for green roofs involve the layering of different elements. The positioning of the various layers is decisive for the green roof to function properly and be maintained over time. All green roofs include at least the following layers: waterproofing (one or more layers), drainage and planting media. For the various layers to remain intact over time, they must also possess mechanical strength characteristics. One of the first elements to be assessed when installing a green roof are the loads. In fact, roofing with functional layers suitable for greening entails an additional load that must be properly considered. The cultivation layer constitutes the greatest, but there are also the weights associated with maintenance operations, depending on the frequency with which they must be performed.

1. Double-layer ventilated roof (cold roof): the figure shows the construction elements of a double-layer ventilated roof 8 the so-called cold roof). This roof is made up from the surface layer: vegetation -
   vegetation layer - protection/division/storage area - root-resistant waterproofing - protection and division area - planking - counter battens for

ventilation - vapour barrier - vapour pressure compensation layer - protection and division area - planking - joists

2. Low-slope roofs on a wooden structure: the implementation areas of a green roof with low slope installed on a wooden structure are:
   - Pult' roofs, i.e. low-energy and passive houses
   - pitched roofs with very long rafters or simple roof shapes
3. Single-layer roof - without thermal insulation: as far as single-layer roofs without thermal insulation are concerned, we can note that they consist of: (starting from the most superficial layer): vegetation - vegetation layer - protection/division/storage area - root-resistant waterproofing - compensation layer - rough concrete roofing
4. One-layer roof with thermal insulation (warm roof): a one-layer roof with thermal insulation, therefore referred to as a warm roof, consists of the following elements from the surface: vegetation - vegetation layer - protection/division/storage area - root-resistant waterproofing - division area - thermal insulation - vapour barrier - compensation layer - load-bearing substructure
5. One-layer roofs - with thermal insulation (inverted roof): Very special are the so-called inverted roofs. In fact, when analysing their structure, it can be seen that they consist, starting from the surface layer, of: vegetation - vegetation layer - filter/drainage and ventilation - thermal insulation - root-resistant waterproofing - dividing and compensating layer - rough concrete roofing
6. Thermal insulation for one-layer roofs - inverted roofs: In intensive greening, attention must be paid to the tightness of the thermal insulation. And above all, a vapour expansion layer (ventilation layer) must be placed over the thermal insulation.
7. Scale roofs: scale roofs are very special. The building techniques and materials for scale roofs used today are not suitable for greening. Therefore, brick roofs are not suitable. Sheet metal roofs are only suitable in certain cases with additional precautions
8. Checklist for green roofs: prior to maintenance or installation of a green roof, the following must be checked: statics - slope - protection against root penetration - roof edges/wall connections - roof drainage - location
9. With regard to statics, the load analysis and wind suction capacity must be verified. For the load analysis, the maximum water storage capacity of the

structure with all its layers must be calculated. Whereas for the wind suction capacity, calculations must be carried out on the structure and all its layers in a dry condition.

10. Weight of a green roof: the weight of a green roof must be considered: Own weight of the entire green roof (saturated with water) - Snow load - Wind suction capacity - Use load. Roughly speaking, a green roof weighs approximately 15 kg/m2 and must be constructed with a minimum slope of 1.8%.

- **Unit 4: Ventilation and water drainage systems**

Water drainage systems are used to regulate rainwater and groundwater with the aim of ensuring soil stability and supporting the water cycle by avoiding stagnation and possible water bombs.

In particular, surface water drainage systems are mainly used in areas with low soil percolation, i.e. areas where the soil is not able to drain surface water on its own.
In the following module, we will find out why it is important to have a drainage system and what the rules are for best implementation.

1. Important construction details: = quantity of water to be disposed of in litres is calculated as: Q = q x j x F where Q = quantity of water to be disposed of in litres - q = calculation of the rainwater supply (maximum rainwater supply of 300 l/ha.s) - j = runoff coefficient - F = greened roof area. The coefficient j varies according to the type of greening, so we have j for intensive greening = 0.2 - j for extensive greening from 8 cm = 0.3 - j for extensive greening below 8 cm = 0.5
2. Functional layers: The functional layers of a green roof are: Greening - Vegetation substrate - Filter layer - Water storage element - Protection layer - Separation and anti-friction coating
3. Example 1 of extensive layer construction: In the illustration we have a construction example of a green roof with extensive layer. The elements that characterise it are: Draining mat -Protective, drainage and filtering layer, Suitable for inverted roofs
4. Example 2 of extensive layer construction: Another example of extensive layer construction is characterised by: Storage and drainage components
5. e.g. in HD-PE plastic, suitable for inverted roofs - Continuous laying under slabs and green surfaces possible - Additional water storage element

6. Extensive - one-layer construction: Let us now analyse an extensive one-layer roof. This type is a compromise between cost-effectiveness and the result of greening. It is used for the greening of large industrial and small (private) surfaces and for limited requirements
7. Example of layered construction, roof inclination 5 - 15 degrees: For these types of inclinations between 5 and 15 degrees, the following applies: The water storage element balances the surface drainage - The filter layer is missing - The anti-shear substrate is filled directly - Continuous waterproofing, no sliding waves in the surface
8. Extensive greening sloping roof Slope of roof 15 - 25° : for these roofs, an additional anti-slope system with slatted frame must be installed and is only necessary until roots have formed in the substrate
9. Example 1 of intensive layered construction: for these types of greening, there is a large element thickness of the water storage elements for the optimisation of 'local water storage'. In addition, there is optimal vegetation growth.
10. Example 2 Intensive layered construction has a drainage and storage element. Pressure resistance requires more solid materials Employed as "lost" cladding. And also optimal 'buildability' as a requirement

- **Unit 5: Roof installation and maintenance practices**

The roof fulfils at least two fundamental functions for the home we live in: it protects it from the weather and prevents heat loss, thus saving energy consumption. Since, due to its location, the roof is the most exposed part of a building, it is easy for it to deteriorate and need periodic maintenance. A good roof intervention improves the aesthetics of the building and reduces waste through increased energy efficiency. Here we will find out how to understand when a roof renovation is needed, what paperwork needs to be done and what bonuses can be referred to for this type of maintenance.

1. Why roofs with substrates? Multilayer roofs have several advantages including: better water storage and disposal - better storage and exchange of substances - volume of the substrate for better insulation - better stability of the structure - less weight
2. Extensive greening methods: the extensive greening method can be done by hand sowing - planting with low bushes can be done - in general, mats with pre-cultivated vegetation are used - the seed must always be wet.

3. One type of seeding is spray seeding. This type of seeding has several advantages including: Protects the seed and shoots from drying out - Makes the seed and shoots bind well with the growing medium - Activates soil vitality - Ensures a slow and regular release of nutrients - Increases water storage capacity - Protects against erosion.
4. Pre-cultivated mats: One type of pre-cultivated mats are sedum (grass) mats pre-cultivated on a biodegradable substrate e.g. coconut fibre. This type of mats are used for extensive greening of flat roofs with a slope of up to approx. 15°.
5. Start-up maintenance (growth): In extensive greening: It is first of all necessary to achieve the desired cultivation form (adequate vegetation development) - 60% of the slab cover - 75% of the described sedum cuttings have grown - 90% of the described plants have grown - 75% of the cover by means of the cultivation mats - Uniform structure, rooted etc.
6. Maintenance for growth and maintenance: Maintenance for growth takes place after adequate vegetation development up to handover to the client - Maintenance for maintenance begins after handover to the client - Isolated interventions may be required: Checks of drainage systems - Supply of nutrients - Pruning or uprooting of woody formations - Re-sowing for large areas where greening has not taken place - Cleaning of cast iron strips of foliage and wild vegetation

- **Unit 6: Dismantling/Demolition**

Demolishing the roof of a building is a very important category of work that must be carried out very carefully. Many factors influence this phase of work, including the weather forecast, ease of accessibility and/or manoeuvring, and whether the building is inhabited on the floors below. Therefore, the assembly and/or demolition phase of a roof is a very important phase that must be performed in accordance with the assembly and demolition plan.

1. Demolition techniques: It is very important to plan the sequence of works in advance based on a thorough knowledge of the structures and working techniques of the time of construction. There are no demolition techniques that are certainly always and in all cases valid. The demolition technique must be

studied on a case-by-case basis and adapted (even as the work progresses) to the needs and state of the work being carried out.

2. Strengthening of structures: Before work begins, the structure to be demolished is analysed and checked, verifying: location of the work (urban, industrial, suburban context, etc.) - intended use (civil dwelling, industrial shed, school building, etc.) - the type of construction and the period to which it dates - construction materials - verification of the preservation and stability conditions of the various structures to be demolished. In relation to the result of this verification, the reinforcement and shoring works necessary to prevent untimely collapse during demolition must be carried out.
3. Analysis of the structure: In the analysis of the structure conducted in advance, it is necessary to: distinguish load-bearing parts from accessory parts, bear in mind any damage or alterations that structures or materials have suffered, as a result of

   loads or stresses that differ from the original (subsidence of the ground, new constructions built in adhesion); due to water infiltration (rainwater, leaks from drains and pipes); due to ageing of materials (mortar weakened by humidity and salts, oxidised keys and reinforcing irons, rotten wood); due to subsequent changes that may have affected the bonding of the masonry (new openings, renovations); due to possible cases of original construction inexperience due to inadequate material.
4. Order of demolition: Demolition work must proceed carefully and in an orderly manner, must be carried out under the supervision of a supervisor and conducted in such a way as not to jeopardise the stability of load-bearing or connecting structures and any adjacent structures. The sequence of the work must be set out in a contained schedule that must be kept available to all.

CONCLUSIONS

In recent years, a growing interest in the use of 'green' infrastructure in architectural design has led researchers and engineering companies to study the effect of such practices on rainwater volume mitigation and energy consumption. However, green roofs not only meet sustainable development criteria, but also have a direct and significant impact on the real estate market. Energy efficiency is the parameter that can best describe the construction quality of a building. This parameter has an economic impact on buildings and this impact can be quantified in terms of added value to the property. Therefore, constructing buildings in accordance with environmental sustainability criteria does not only lead to savings in energy costs but also to an increase in property value.

This article provides guidance on the procedure for estimating the added value provided by the presence of green roofs in buildings. This guidance concerns valuation methods based on international valuation standards. The valuation methodologies used in this study can be traced back to the MCA and ASA used synergistically. This study also applied the identified methodology to a concrete case study. The study also considered the cost of installing and maintaining a green roof with specific characteristics, in order to compare the increase in value of the property due to the presence of the green roof with the cost of maintaining and operating it.

The analysis shows that the increase in value of the property where a green roof is present is greater than the total cost of planting and maintaining it. In conclusion, it can be stated that the presence of green roofs is not only economically viable due to the fact that the planting and maintenance costs are offset by the energy savings resulting from their installation, but also due to the fact that their presence leads to an increase in unit value that is greater than the costs.

2. Questions and Answers

Q1: What are the 3 methods of valuing a property?

A1: The 3 classical methods for the valuation of a property are the Market Oriented Approach, the Income Approach and the Cost Approach (or depreciated reconstruction cost method).

Q2: What is meant by Market Oriented Approach?

A2: The Market Oriented Approach provides an indication of the value of a property by comparing the subject with other similar properties recently bought or sold, when transaction price information and property data are available . The approach comprises a number of procedures. The main procedures included in the Market Oriented approach are: the Single Parametric Estimate, the Apportionment System, the Market Comparison Approach (MCA), the General Appraisal System (ASA), mixed procedures

Q3: What is meant by Income Approach?
A3: The Income Approach is based on the capitalisation of property income. The income capitalisation procedure includes methods that analyse the ability to generate monetary benefits of a property and the ability to convert these benefits into values. The procedures within the financial method are Direct Capitalisation (which converts the expected annual income into the market value of a property), Yield Capitalisation (which applies the financial calculation to convert the income series into a value by means of a capitalisation assay), Discounted Cash Flow Analysis (taking into account the different costs and revenues, in a time interval between the date of purchase and the date of resale of the asset to be estimated, returning a final market value).

Q4: What is meant by Cost Approach?
A4: The Cost Approach is an approach based on estimating the cost of reconstructing a similar property, possibly depreciated to take account of its state of use and obsolescence. The cost approach applies the economic principle of substitution whereby a buyer is unwilling to pay more for a property than it would cost to rebuild another similar property with the same degree of utility.

Q5: What are the costs of building a roof?
A5: The construction cost is the sum of the amount of material needed to construct one square metre of green roof;
The cost of labour, calculated in man-hours per square metre;
the transport cost of materials corresponding to the elementary prices deducted from official price lists or current market prices. To the amount thus determined was added a percentage for safety-related expenses, a variable percentage (13-17%) for general expenses, and finally a percentage (10%) for contractor's profit

Q6: What is specified in UNI 11235?
A6: In the UNI 11235 standard, in relation to the type of roof, whether intensive or extensive, an indication is given of the annual maintenance required. The degrees of maintenance are also specified: start-up for control (testing); start-up at steady state (only for extensive roofs); ordinary and extraordinary (UNI 11235 and FLL).

Q7: What is an extensive green roof?

A7: Extensive green roofs are an environmentally friendly alternative to conventional surface protection such as gravel. They are lightweight and their thickness is reduced. For this type of system, we use proven plant communities adapted to the environmental conditions (sun, wind, humidity, etc.) prevailing on the roof in question. Once implemented, the extensive green roof requires very little care. As a rule, maintenance is limited to one or two operations per year.

Q8: What is an intensive green roof?
A8: Intensive green roofs can easily be compared to the construction of a rooftop. They are usually multifunctional and usable. They weigh more and their structure is deeper. Maintenance must be regular and depends on the layout, as well as the plants chosen. Depending on the thickness of the substrate, any solution is possible: lawn, Dachgarten perennials, shrubs, trees and other options such as ponds, basins, pergolas and terraces.

Q9: What is meant by Dachgarten?
A9: The 'Dachgarten' greening system is a multifunctional system with high water storage. It is suitable for turfgrasses, perennials and, with increased substrate thickness, also for shrubs and trees. Combinations with other forms of use are also possible, e.g. walkable roofs, terraces, carports or playgrounds.

Q10: What types of roofs have the potential to become 'green roofs'?
A10: Roofs that can be converted from traditional to green roofs are:

- Double-layer roof - ventilated (cold roof)
- Single-ply roof - without thermal insulation
- Single-ply roof - with thermal insulation (warm roof)
- Single-ply roof - with thermal insulation (inverted roof)

Q11: What checks must be carried out before starting work on roofs?
A11: The following points absolutely must be checked before the roof is built:

- statics
- slope
- protection against root penetration
- roof edges/walls
- roof drainage
- location

Q12: What are the parameters to be considered for the weight of a roof?

A12: The parameters to be considered for the weight of a roof are
- Weight of the entire green roof (saturated with water)
- Snow load
- Wind suction capacity
- Load from use

Q13: What is the approximate weight of a green roof?
A13: A rule of thumb indicates a weight of approx. 15 kg/m² per cm construction layer

Q14: What is the minimum construction slope of a flat roof?
A14: Flat roofs must be constructed with a minimum slope of 1.8 %.

Q15: What are the methods of extensive greening?
A15: Extensive greening methods are:
- Sowing by hand
- Planting with low bushes
- Mats with pre-cultivated vegetation
- Wet willy

3. Case studies

Case Study 1

It is a residence in Via di Monte d'Oro that completes the lot of the Borghese Palace and is part of the type of historical building widespread in the post-unification period and the first decades of the 20th century. The characteristics of the building are shown in Table 4 below. It was built in 1911 by architect Salvatore Farinetti as an appurtenance of the Palazzo itself and has similar architectural features to many other buildings in the capital's historic centre.

CHARACTERISTICS OF THE CASE STUDY BUILDING	
Website	**ROME**
Year of construction	**1911**

Cubage - gross volume	**10.400 m3**
Average gross floor area per floor	**~ 630 m2**
Solar pavement surface	**533 m2**
No. of floors above ground	**4**
Building height	**16,10 m**
No. of rooms (including stairwells and corridors)	**80**
No. of stairwells	**2**
SUPPORTING STRUCTURE	
Elevated structure	**solid brick masonry slabs in**
Closure and horizontal partition	**iron and brick**
Inclined internal partition	**Roman-style staircase with reinforced shaft**
DISPERSING SURFACE OF THE ENVELOPE	
Opaque	**2.765,18 m2**
Transparent	**370 m2**

ISSUES RELATED TO STRUCTURAL LOADS

The realisation of a green roof on an existing structure, and moreover, one that has not been built recently, must first of all start by defining the level of knowledge of the structures

The characterisation of the entire building must therefore include several steps: knowledge of the existing structures and the modifications they have undergone over time, identification of stresses, assessment of past damage in quantitative and qualitative terms, identification of the technical and construction deficiencies of the structures, adoption of adaptation or, better still, improvement criteria compatible with the conservation of any elements of considerable historical value (wooden beams, paintings and surface coverings, decorative façade decorations, etc.).), definition of the degree of feasible safety and damage limit states imposed by the regulations in the light of the preservation of these elements, design of technical solutions that affect both the mechanical resistance characteristics and the state of tension (geometry, materials, loads) in the search for the lowest material and aesthetic-figural impact, final static and dynamic verifications.

In the present case study, the first step was to acquire data from a direct survey in

order to characterise the geometry and morphology of the construction details (type of masonry and floors, etc.) and material properties from which to deduce the characteristic strengths.
The type of construction of the terrace roof is of the mixed iron and brick type and is one of the most widely used in Italy, with some variations, from the mid-19th century onwards.

This solution is referred to in the literature as an 'attic with iron girders (normal-profile NP 180) and solid brick sheet vaults'. Of this particular solution, there is a variant with the warp of the bricks arranged on the floor ("cat's back" i.e. with the bricks laid vertically), with a self-weight of between 250-280 kg/m2 and an estimated breaking load of approximately 6600 kg/m2.
The technical reference standards of the early 1900s provided the data for dimensioning

FULL SHEET BRICKS WITH 1 m INTERAXIS	
OWN WEIGHT	
	kg/m^2
Floor and subfloor	**80**
Refurbishment	**110**
Bricks and plaster	**130**
Beams (on average)	**20**
Total floor weight	**340**
DIMENSIONING	
NET LIGHT	
Beam NP (mm)	
3,00	**120**
3,50	**140**
4,00	**160**
4,50	**160**
5,00	**180**
5,50	**200**
6,50	**200**

The state of preservation of the load-bearing structures, both vertical and horizontal, is good and shows no signs of subsidence, lesions or significant deterioration.

Depending on the type of green roof to be built, it is necessary to assess the new loads and carry out an accurate evaluation of the static and dynamic behaviour of the entire package: supporting structure + green system.
The problems of overloading for this type of floor construction can be solved by structural reinforcement using a collaborating slab with trapezoidal sheet metal and subsequent overlapping of the green system.
The superimposition of a structural lightened concrete slab at least 7 cm thick, reinforced with a network of bars and connected to the load-bearing steel beams could adapt the floor to the current construction requirements, considering the advantages of reinforcement with lightened concretes, which, for the same strength (250-350 kg/cm2) provide a 40% reduction in weight compared to a traditional floor and better thermal insulation due to the low transmittance of lightened aggregates (0.42-0.54 W/mK).

Energy analysis

The ultimate goal of this study is to highlight the benefits that a green terrace can bring to improving the overall energy performance of an existing historic building.
In the overall assessment of an energy refurbishment intervention, it is necessary to evaluate first of all the improvement in the performance of the individual building component, followed by the improvement that such an intervention brings about on the overall performance of the building organism, in this case particularly interesting due to its wall structure, in terms of overall energy savings and therefore the possible payback time of the investment.
On the building that is the subject of this study, the first verification required was the evaluation of the thermo-hygrometric characteristics *ante operam* and *post operam in* relation to an intervention to transform the roof into a green roof.
The existing terrace roof was characterised by the construction materials described above, a typical section of which is shown in Figure 9.

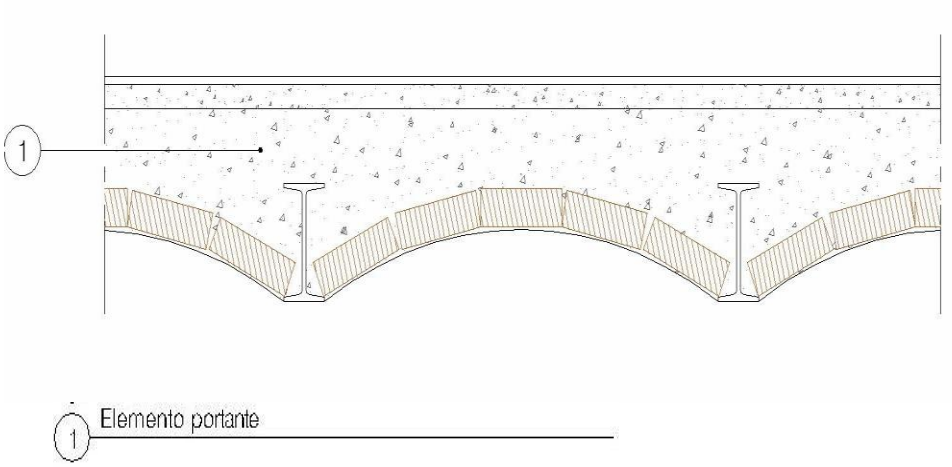

Figure 9: typical floor slab section walkable terrace roof

The thermo-physical parameters adopted within the calculation model were those shown in Table 6.

Resistance	0,537	m K/W^2
Transmittance	1,862	W/m K^2
Periodic thermal transmittance	0,61	W/m K^2
Surface Mass	458	kg/m^2
Phase shift	8.87	h

Table 6: *Ante operam* floor thermal-physical parameters

The choice was made to adopt a green roof system (see figure 10) with a thickness of approximately 17 cm, which does not entail any adjustment of the floor's load-bearing structures, with an overall water-saturated weight of 115 kg/m^2 . The construction of a new lightened foundation also makes it possible to reduce the self-weight of the existing floor compared to a traditional foundation, without increasing the overall final load, even in the presence of a green roof.
The new roof (see Figure 10) was considered without the consolidation of the attic and with an extensive green roof with an added thickness of approx. 17 cm

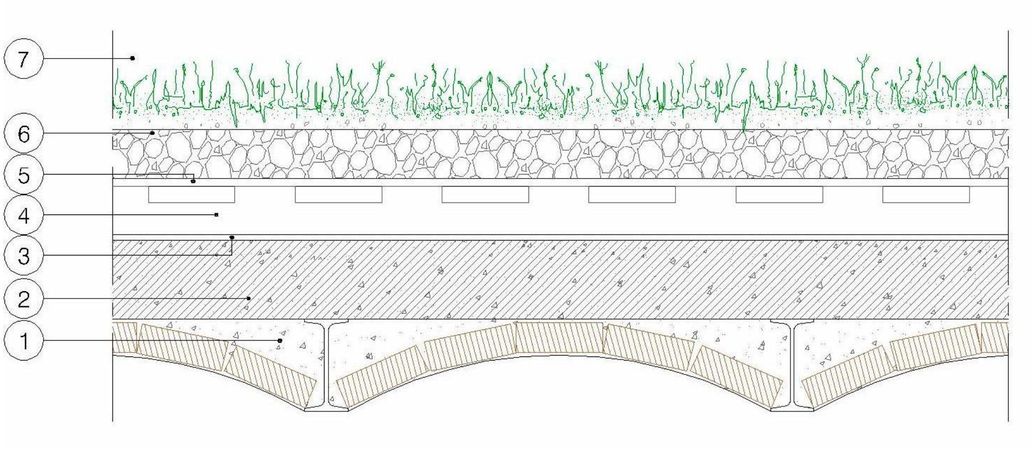

Figure 10: typical floor section with green roof

7. Vegetation
6. Substrate of volcanic material and organic substances
5. Geotextile
4. Prefabricated polystyrene foam
3. Vapour barrier (bituminous sheets)
2. Lightweight concrete screed with gradient
1. Carrier element

Resistance	**2,789**	**m K/W²**
Transmittance	0,359	**W/m K²**
Periodic thermal transmittance	0,02	**W/m K²**
Surface Mass	519	**kg/m²**
Phase shift	**16,78**	**h**

Table 7: Thermo-physical parameters attic with green roof *post operam*

The transmittance undergoes a high drop in value, from the ante operam value of 1.865 W/m² K to the post operam value of 0.359 W/m² K, reducing by approximately 80%.

The verification of the improvement in energy performance was done using the models implemented on Best Class and Docet simplified analysis software, the

calculation results of which, regarding the building's energy performance, have already been published. The data was systematised in order to define a new model to be entered into a further calculation programme with stationary codes (Termus). The need to use a new model arose because of the need to be able to assess the improvement in the envelope performance index, separately from the overall performance, and to use certified software for the design verification.
The envelope characteristics of the vertical enclosure and the building form data are summarised in Table 7 and 8.

Heated Volume	**618,11**	**m3**
S/V ratio	0,77	
Vertical plugging	1,03	**W/m2K**
Transparent closures	**4,23**	**W/m2K**

Table 8: Architectural data of the building

The results of the Epi_{gl} calculation thus obtained were compared with the results of the study (Table 9), obtained with simplified calculation software such as Docet and Best Class.

	Docet	**Best Class**	**Termus**
Epigl - kWh/m^2 year	**116,8**	**188,1**	**166,27**

Table 9: Comparison of software simulation results.

The green roof intervention, i.e. the replacement of the roof from the model simulated in Termus, resulted in the improved performance change shown in Table 10.

	State of affairs	**Project status**
Epi gl -	166,27	**86,63**

kWh/m^2 year		
Epi_envelope	141,72	**74,29**
Percentage of energy performance improvement = 48%.		

Table 10: Energy performance comparison

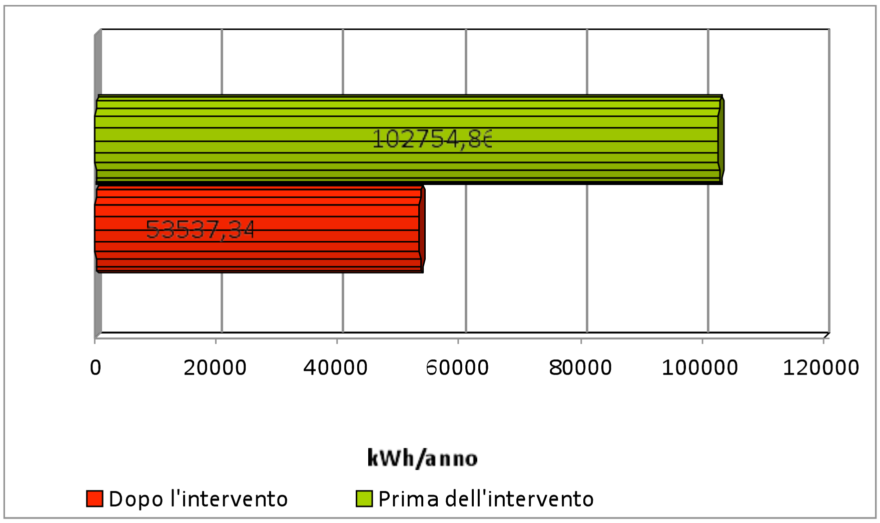

Figure11 : Primaryenergyrequirementsfor for winter air-conditioning before and after the intervention

We estimate an intervention cost of approximately 37,300 Euro and an amortisation time of approx. 10 years considering the rate of increase of fuel costs of approx. 5% and the inflation rate of 2.8%.

The data are in line with studies conducted in climatic areas similar to Rome and with advanced simulation and calculation models [24]. The same literature also showed that the impact of green roofs leads to a reduction in the average indoor temperature in Athens (with climatic conditions similar to Rome) of 2.6°C, in La Rochelle (France) of 2.0°C, and in Stockholm of 1.4°C. The presence of a green roof also resulted in energy demand reductions of 12.8 kWh/m^2 year (32%), 2.3 kWh/m^2 year (6%), and 10.7 kWh/m^2 year (8%) in the three previous cities, respectively.

4. Practical exercises

Exercise 1

Calculate the amount of water to be disposed of in litres on an intensive green roof knowing that the green area is 250 m2 and the maximum rainwater supply is 130 l/ha.s.

Solution

Q = q . j . F = 130*0.2*250= 6,500 litres

q= 130 l/ha.s.
j= 0,2
F= 250 m2

Exercise 2

Knowing that the quantity of water to be disposed of is 35,000 litres and that the roof is of the extensive type and has a surface area of 320 square metres, and that the maximum water supply is equal to 250 l/ha.s. Determine whether the thickness of the green roof is greater or less than 8 cm.

Solution

Q = q . j . F

Q= 35,000 litres
q= 250 l/ha.s.
F= 320 m2

J= Q/q*F = 35000/250*320 = 0.43

The roof is less than 8 cm thick

5. MCQs

QUESTION 1

During the load analysis of a roof, one must

A Calculate the minimum water storage capacity of the structure with all its layers.

B Calculate the maximum water storage capacity of the structure with all its layers.

C Calculate the maximum water storage capacity of the structure.

QUESTION 2

Flat roofs must be built with a minimum slope of

A 1,8 %

B 2,5 %

C 2,8 %

QUESTION 3

Drainage devices include

A Roof gutters - Internal drainage gutters - Guttering or water drainage gutters

B Roof gutters - External drainage gutters - Guttering or water drainage gutters

C Roof gutters - External and internal drainage gutters - Guttering or water drainage gutters

QUESTION 4

What are extensive greening methods

A Sowing by hand - Pre-grown vegetation mats - Wet sowing

B Hand sowing - Planting with low bushes - Pre-grown vegetation mats - Wet sowing

C Sowing by hand - Planting with low bushes - Mats with pre-cultivated vegetation

QUESTION 5

Hand sowing - Planting with low bushes - Pre-grown vegetation mats - Wet sowing

A Protects the seed and shoots from drying out, ensures that the seed and shoots bind well with the vegetation substrate and decreases water storage capacity by facilitating rainwater runoff

B Protects the seed and shoots from drying out, ensures that the seed and shoots bind well with the vegetation substrate and increases the water storage capacity

C Protects seed and shoots from drying out and decreases water storage capacity by facilitating rainwater runoff

QUESTION 6
During the demolition works of a roof in adhesion with other buildings:
A Provision must be made for the use of possible and appropriate reinforcement measures, i.e., shoring, substructure, piling, etc., to safeguard other buildings.
B No employment is necessary as all structures are self-propelled
C It is the owner of the adjacent building who provides for the use of supporting works

QUESTION 7
When does the green maintenance phase begin?
A After delivery to the client.
B It is implemented from the installation phase up to the delivery phase
C Both sentences are true

QUESTION 8
What are the most common types of green roofs?
A Extensive green roofs
B Extensive green roofs, intensive green roofs and mixed intensive green roofs
C Extensive green roofs, intensive green roofs and simple intensive green roofs

QUESTION 9
Are scale roofs suitable for a green roof?
A Yes, but only for intensive green roofs
B Not recommended
C Yes, but only for extensive green roofs

QUESTION 10
Calculations to check wind suction capacity.....
A must be carried out on the structure and all its layers, in a dry condition
B must be carried out on the structure and all its layers, in all conditions
C must be carried out on the structure and the last layer, in a dry condition

QUESTION 11

When verifying the weight of a roof, one must consider

A Own weight of the entire green roof (saturated with water) - Snow load - Wind suction capacity - Use load

B Own weight of the entire green roof - Snow load - Wind suction capacity - Use load

C Own weight of the entire green roof - Snow load - Wind suction capacity -

QUESTION 12

What is the substrate thickness for extensive green roofs?

A 5 to 10 cm

B 10 to 20 cm

C 5 to 15 cm

QUESTION 13

What is the substrate thickness for intensive green roofs?

A over 30 cm

B Up to 20 cm

C No more than 30 cm

QUESTION 14

Is hand sowing planned for extensive greening?

A No, it is never recommended

B Yes, it is one of the methods

C Yes, but only in certain areas

QUESTION 15

During the construction phase of a roof, what absolutely must be checked before it is built?

A statics - slope - protection against root penetration - roof edges/wall connections - roof drainage

B statics - slope - protection against root penetration - roof edges/wall connections - roof drainage - location

C statics - slope - roof edges/wall connections - roof drainage - location