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# SOLUTION FOR FLAT ROOFS

BY

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**Abstract**. Roofs are constructive subassemblies that are located at the top of buildings, which toghether with perimetral walls and some elements of the infrastructure belongs to the subsystem elements that close the building. An important share in the roofing is represented by the flat roofs. Flat roofs must meet the requirements of resistance to mechanical action, thermal insulation, acoustic and waterproof, fire resistance, durability and aesthetics. To meet these requirements is necessary an analysis of the component layers and materials properties that determine the durability of structural assembly.

**Key Words**: Flat Roof; Inverted Flat Roof; Membrane; Insulation.

## 1. Introduction

Roofs are construction elements that close the building at the upper part, in order to protect against the bad weather – rain and snow, wind, sun, temperature variations, etc. The roof can be designed to provide useful areas located over the roof covering (terrace arranged for household jobs, solarium, garden, restaurant) or below it (mansard, attic).

Roofs of civil and industrial buildings with slopes under $7^\circ$ are called *flat roofs* and with slopes more than $7^\circ$ are called *slope roofs*.

Flat roofs can be circulated or uncirculated.

Depending on the flow of heat, flat roofs are called hot roofs because roof covering is subjected to direct flow of heat, and slope roofs are considered cold, being isolated by the air contained in the attic.

Roofs, in general, over heated rooms can be group in:

a) roofing which include layers of ventilated air (compact flat roof and aerate by the diffusion vapour layers);

b) roof comprising a layer of ventilated air (flat roofs with air channels or roofs with technical or used attic).

Existing flat roofs (Fig. 1) protected with bituminous waterproof generally consist of

a) strength structure;

b) protection structure (thermal-waterproofing).

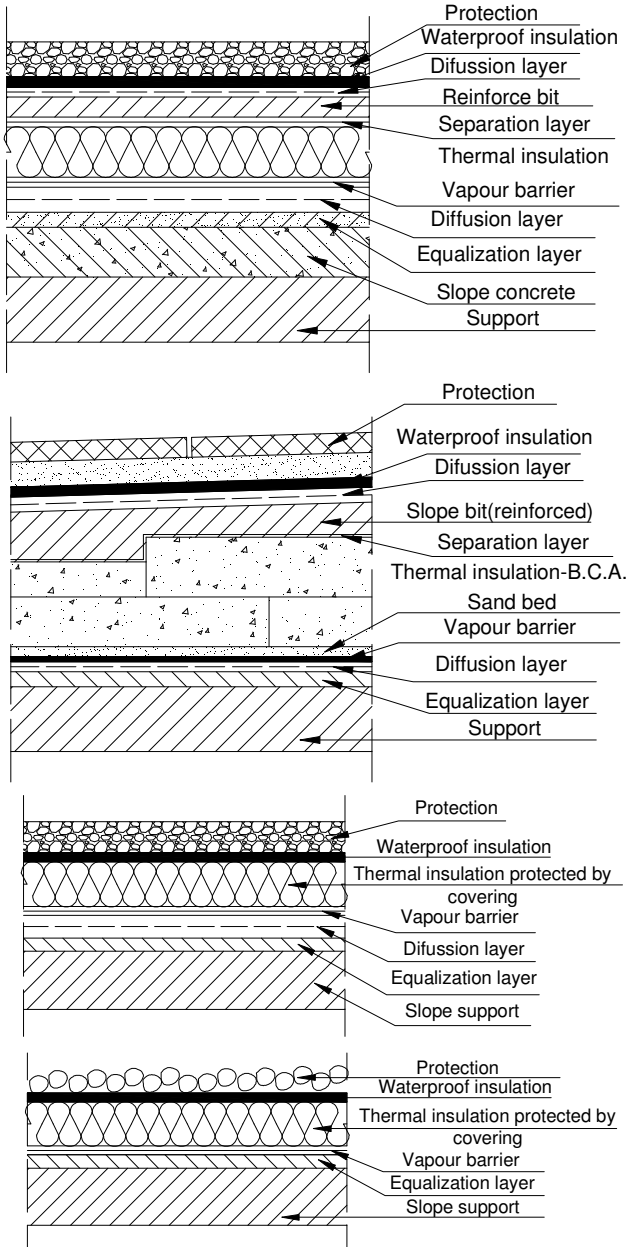


**Fig. 1.** – Flat roof structure.

The strength structure as support layer of thermal waterproofing is achieved in one of the following versions:

a) monolithic reinforced concrete ;
b) prefabricated elements of reinforced concrete or prestressed (flat, curved or wavy);
c) folded metal sheet (anticorrosive protected);
d) wood products (lumber and hardboard panels).

Protection structure of the roof consists of

a) thermal insulation;
b) waterproof insulation;
c) auxiliary;
d) connections to adjacent elements.

Actions on the roofs of the terrace can be physical or mechanical namely

a) water from rainfall;
b) the sun;
c) temperature variations;
d) the fire;
e) from inside act high humidity of the air;
f) the wind and snow action;
g) occasional movement (during repairs), or permanent of the people.

In agreement with the exterior and interior stresses, as well as technical requirements, flat roofs have different solutions, different combinations of elements.

## 2. Flat Roof as Associated Structure

The flat roof is composed of materials with different physical and mechanical characteristics and well determined role.

Floor slab, the element of resistance for the flat roof, which take permanent, special and live loads, it is generally composed of monolithic concrete or prefabricated.

Layer of equalization, which flatten the floor surface, is made of cement mortar or grained sand.

Vapour barrier is made from: film paints based on flex oil, cut bitumen applied in two layers, email-based ”Romalchid”, bitumen cardboard sheet and bitumen knitting glass stuck between two layers of bitumen or cement sheets polyethylene welded or attached with adhesive.

Layer of balancing the vapour pressure is made of perforated bitumen cardboard (CBP S 400) and armored with coarse sand or knitting glass fiber bitumen perforated, pressed on one side with sand, and on the other side with granular material.

Vapour diffusion layer can also be composed of: bitumen sheets of cardboard or knitting stuck with bitumen mastic in stripes or points, construction corrugated cardboard or corrugated cardboard with aeration through ondule.

Thermo-layer complete thermal resistance of the flat roof in order to meet the needs required by the inside climate.

Thermal insulator materials are considered those materials which have a coefficient of thermal conductivity less than 0.25 W/mK.

Thermal insulator materials are porous bodies and they have a structure made of a solid skeleton and air from pore or material gaps.

After their nature, these materials could be inorganic, obtained on mineral substances base and organic, coming from substances of organic nature.

Thermal insulator materials can be classified by their structure too in: consistent cellular material (BCA), granular incoherent (granulite), fiber (mineral wool), consistent with a mixed structure (granulate concrete), materials from synthetic polymers (cellular polystyrene).

Cellular autoclaved concrete is delivered in the form of blocks and plates, having a porous, homogeneous structure.

Depending on the composition, cellular autoclaved concrete is divided into: GBN gas concrete type based on sand, binder cement, lime and gypsum, and GBC gas concrete type based on thermal ash, with binder lime and gypsum.

Granulite (or granulite concrete) is expanded granulated clay, made by wet or dry mode in a revolving furnace. Granulite can be used in bulk or like granulite concrete plates form. Mineral wool and glass wool are obtained from melted acidic furnace slag or siliceous rocks, respectively, glass, by centrifuge or by blowing steam or compressed air. Mineral wool can be delivered in the form of the following assortments: mattresses, blocks, plates, shell, chenille patches.

Cellular polystyrene is obtained from styrene granules which contained integrated a volatile hydrocarbon. On heating, styrene polymerase and volatile hydrocarbons determines an increase in volume of 20. . . 50 times becoming a cell structure with small pores. By partial melting of styrene is performed a binding of expanded granules. This thermo insulating material is made in form of blocks and plates, in two types: normal (PEX) and fireproofed (PEXI).

Cellular polystyrene is deposited in landfills by stacking dry away from direct contact with water and sources of heat or fire. It is resistant to the action of water, organic oils, acids and alkali, also to attack of macroorganisms, but being sensitive to the action of mineral oil, gasoline, cetones and melting point is lowered. It is recommended only for thermal proofing in the domain of atmospheric temperatures and refrigeration.

Protection of thermal proofing layer against moisture from the concrete slope is made of bitumen cardboard with glued edges or bitumen applied by painting. Slope concrete, additional dead load, it's advisable to be executed from light concrete, granulate or slag in order to contribute too to the roof thermal insulation.

Waterproofing support is made from a layer of cement mortar, which will be reinforced, when the slope concrete is missing or is located under thermal insulation. Reinforcing performs a rigid protection of thermal insulation against

mechanical actions. Waterproof seeks to avoid direct contact between the isolated element and water or solutions which can cause corrosion of material, or worsening some of the characteristics. Waterproof materials must, in a thin layer, to be impermeable and insensitive to water, vapour or aqueous solutions.

The main materials which meet these conditions and are used frequently are

a) bitumen and tars used in layer applied hot (in melted form) or cold (cut bitumen, bituminous emulsions);

b) bitumen cartons and sails;

c) foils of polymers (polyethylene, PVC, etc.) and synthetic resins.

Waterproof will be protected on the outside, on uncirculated flat roof, against solar radiation, with a layer of granular sand for slope – over 3°, pebbly gravel – for slopes under 3°, asphalt mortar dig or hydrated lime and cellulose fibers. In case of slopes under 3° it could be use a double layer of protection for the waterproofing, which is obtained from a layer of bituminous mastic for fixing the gravel, which is placed over another paste layer of bituminous mastic, which is also fixed by a layer of gravel. In case of slopes under 3° the layer of protection can be achieved from a layer of free gravel.

At flat roofs that are circulated, floor support may be achieved depending on the intensity of movement, from a layer of river sand, or in case of a very intense movement, from a reinforced mortar bit.

Thin layer shall be made from concrete plates or mosaic binder plates or mosaic poured on site.

Flat roofs are classified as

a) roofs with a membrane;

b) roofs with two membrane.

Flat roofs with a membrane are, in general, without opening of ventilated air. These roofs, whose floor is the top floor, are known as hot roofs. In this type of roof, waterproof is placed over the layer of thermal insulation, constitutes a strong barrier against vapour, which will condense inside thermal insulation.

To prevent entry of vapour into thermal layer, it will be set a vapour barrier against vapour from the bottom of this layer, aiming that the resistance to permeability of vapour of the layers under thermal insulation to be equivalent to that of the layers above.

In case of rooms with high relative humidity (over 10%), diffusion layers will be provided in the composition of the roofs. These diffusion layers are designed to enable the distribution of water vapour and evacuation in exterior air.

Sometimes thermal insulation layer may be provided with aeration channels, which are associated with exterior atmosphere.

Flat roof with two membranes and with ventilated air opening has the quality to be durable and reliable in operation, in any climate and high relative humidity (80...90%). The water vapour that diffuses from the room through the floor and

thermal insulation layer in air opening will be discharged to the outside so that they could not condense.

In order to ensure a permanent drying of thermal insulation layer, where rooms have relative humidity (above 75%), will be provided, inside the roof, an opening.

Ventilation is achieved by providing the roof with holes for air circulation. These holes for entry and exit of air are in contact with the outside atmosphere. Provide air circulation is achieved by: positioning holes for air entry below than those of output; the area of the entrance must be greater than that of the exit holes, holes for entry will be provided in the wall that is perpendicular to the direction of prevailing winds.

Opening height of ventilated air, holes dimensions and structure will be adopted depending on the roof surface and the climatic conditions inside and outside the building.

Flat roof with two membranes are, thus, positioned thermal insulation layer without vapour barrier against vapour on the first membrane – slab to last floor, and the second membrane – roof slab, represents a support for waterproofing.

Below are presented the main layers of the flat roof and some considerations on these ones.

Waterproof have the role to prevent rain water from entering into the flat roof. Being situated at the top of the roof, in contact with solar radiation, will degrade trough aging and bitumen stiffening, and bitumen cartons and sail, consisting of organic material, are exposed to rotting.

To avoid damage to waterproofing, through ageing, it is protected with a layer of monogranular gravel or light aggregate (granulite or expanded slag), devoid of waterproof. In order to protect this layer against solar radiation, can be used paints with light colour on polymers based.

Waterproof being generally located above the thermal layer, acts as a strong barrier against vapour and water, producing, during the winter, condensation of vapour in the thermal insulation layer. Reducing impermeability of waterproofing to vapour can be achieved in case of roofs with large slopes, using bitumen cloth and bitumen suspension (SUBIF), this layer (waterproof ”cold”) is impermeable to water and permeable to vapour.

Large temperature variations between night and day or summer and winter seasons act on the layer of waterproofing and her support, causing their cracking.

To reduce efforts in waterproof, caused by the thermal extension of bit - support, and to prevent formation of blisters in waterproof, will be inserted below this layer a perforated cardboard.

Thermal insulation consists of materials with high thermal resistance. Has the role to minimize heat loss and to protect the building against cracks and cracks caused by temperature effects.

In case of roofs with one membrane, when waterproof is applied directly on thermal insulation, the latter must be composed of materials resistant to

temperature and deformation under the influence of repeated dampening.

Accumulation of moisture, from annual moisture balance in the condition of our country and in rooms with relative humidity greater than 60%, can cause early deterioration of thermal insulation layer.

Reducing moisture in this layer can be achieved by increasing the resistance to vapour permeability of the layers above. This is achieved by applying a very powerful vapour barrier, of multiple layers of bitumen cardboard between layers of bitumen mastic bitumen or, more economically, in films of polymers.

In order to decrease the amount of moisture from thermal insulation is used interplay of thin layers or channels aeration. These allow the vapour pressure lowering and removing them to outer atmosphere.

Execution of aeration layers, in case of roofs with a single membrane (warm roof), is made using corrugated or perforated cartons (pressed on the inner face with grained sand), which applies dry on the reinforced concrete floor, above which is affixed the barrier against vapour, only near perforations.

Aeration channels could be executed and in thermal insulation layer at the top or bottom.

Depending on the inside relative humidity can be done one line of aeration layers under thermal insulation (60...70%) or two rows of aeration layers, above and below the thermal insulation layer (70...75%).

Layers and aeration channels are linked with the outside atmosphere on the contours of the roof and additional, when the roof surface is large, with deflection (widths greater than 12 m and slopes greater than 10%).

In case of very high relative humidity (80...90%), thermal insulation layer will be protected against moisture by creating a two membrane roof with ventilated air layer, which, if modern roofs, can be up to 5 cm.

The vapour diffusion layer is composed of continuous air layers and has the role to equalize vapour pressure. Regardless of the composition, this layer must be made in connection with the outside air to allow vapours elimination to the outside atmosphere. This layer has various locations such as between thermal insulation and waterproof or between slab and barrier against vapour.

Vapour barrier is the layer that is usually placed between the slab and thermal insulation. This thin layer has a high resistance to vapour diffusion, which, by condensation, produces a gradually wetting in thermal insulation layer.

Establishing the need for a vapour barrier is based on thermal design.

## 3. Modern Solution for a Flat Roof

Along with the new requirements imposed by the current rules is necessary to adopt the flat roof using modern materials to ensure the requirements of such a roof.

Thus for the existing layers in the flat roof have been used more efficient materials in terms with technical progress occurred over the years. Some of these

materials are listed below:

a) for waterproof: bitumen, knitting glass, fiber composite structures with insertion or side of metal foil;

b) for thermal insulation: polystyrene foam, mineral wool, concrete with lightweight aggregate mineral or organic kind, expanded polystyrene cell polyurethane, plastics;

c) for vapour barrier: bitumen paint, asphalt cloth, polyethylene film and other plastics materials;

d) the gradient layer: gravel and normal concrete, light concrete with different aggregates, granulated slag, expanded slag, granular material from light rocks.

A. *Waterproof system based on plastic materials* (FPO) in a single layer, of high performance, on various thermal insulating holders, with soldering (Fig. 2):

a) superior waterproof membrane;
b) adhesive;
c) thermal insulating material: mineral wool / expanded polystyrene;
d) vapour barrier;
e) priming layer;
f) bearing structures: concrete.

**Fig. 2.** – Waterproof system based on plastic materials.

**Fig. 3.** – Performance system for renovation based on bitumen.

B. *Performance system for renovation based on bitumen in a single layer*, welded, on concrete, for application on old structures that are still functional (Fig. 3):

a) high damp-proof membrane / renovation;
b) priming layer;
c) old structure still valid;
d) bearing structures: concrete.

C. *System based on thermal insulated plates* (Fig. 4):

Concrete slabs can be posed in a layer of crushed aggregate over thermal insulated plates. Between aggregates and insulation, a texture layer of diffusion, resistant to decay (for example polypropylene roll) acts as a layer of separation and protection.

To obtain an adherent pavement, can be used frost resistant ceramic plates fixed on a bit of reinforced concrete over a layer of crashed aggregates with a texture layer of separation for diffusion.

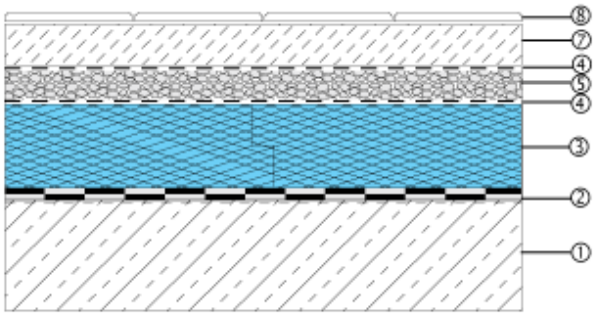


**Fig. 4.** – System based on thermal insulated plates: *1* – concrete slab; *2* – bituminous waterproof membrane; *3* – ROOFMATE SL-A; *4* – texture layer of separation-diffusion; *5* – gravel; *6* – concrete plates; *7* – concrete layer; *8* – ceramic plates.

D. *The inverted roof system* (Fig. 5):

Inverted roof system is applicable to all types of flat roofs. Standard construction is an uncirculated roof with gravel ballast on the top side. Inverted roof system also allows the use of roof areas as terrace, terrace-garden, parking plateau.

Since insulation is applied over the waterproof membrane, a solution of energy saving and efficiency on the cost to renovate flat roofs is possible by installing an additional inverted roof over existing roof.

The inverted roof assures the following advantages:

a) protection of waterproof membrane;
b) protection membrane is installed on roof slab (concrete slab);
c) simple construction without supplementary vapour barrier;
d) installing layers above the membrane is weather independent;
e) quick and easy assembly.

Standard construction for inverted roof system contains the following elements:

a) waterproof membrane installed on concrete slab;

b) insulating panels with sectional edge (a single layer);
c) separation layer allowing;
d) gravel ballast.

Bituminous additive membranes are composite materials arising from the combination of two main elements namely

a) bituminous mixture on the basis of bitumen modified with thermoplastic polymers;
b) support (reinforcement) a fabric of various materials;

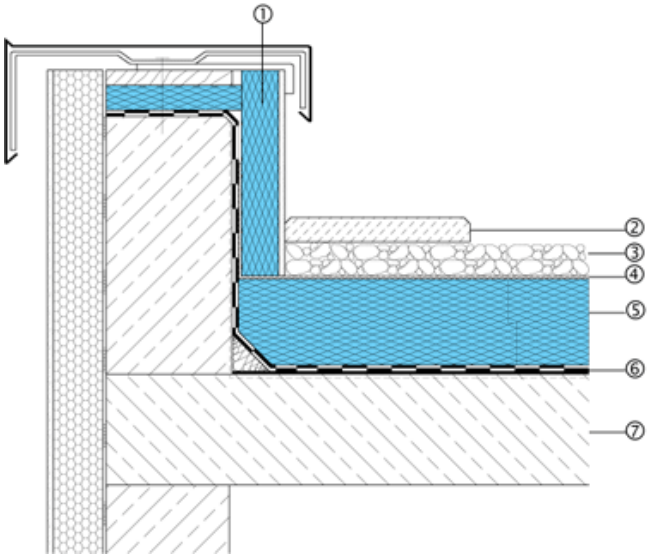


**Fig. 5.** – Inverted roof system: *1* – ROOFMATE SL-A; *2* – plates; *3* – gravel; *4* – layer of diffusion; *5* – ROOFMATE SL-A; *6* – bituminous waterproof membranes; *7* – concrete slab.

The two components work together very well, bitumen providing power to waterproof, while reinforcement provides a uniform distribution of the load and a high mechanical strength.

Bitumen from composition of membranes is modified with polymers to correct undesirable characteristics; (unchanged bitumen is very sensitive to temperature variations, aging much more quickly and loses its features more readily when exposed to heat and UV, is also brittle at low temperatures).

To select the optimal polymer are taken into account a number of features such as: polymer must be compatible with bitumen to prevent separation of compounds and to obtain a homogeneous mixture. Two of polymers that meet these conditions are: polypropylene (APP) and rubber styrene-butadiene-styrene (SBS). Both polymers change bitumen characteristics leading to a higher aging and greater flexibility in the cold.

## 4. Conclusions

From components analysis of a flat roof layers it result that the structure is heterogeneous, made of materials with different properties (concrete, mortar, bitumen, fiber glass knitting, BCA).

The different properties of materials and different life time (10 years for bitumen and 50 years for concrete) lead to compromise performance of the flat roof structure.

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SOLUŢII PENTRU ACOPERIŞURI TERASĂ

(Rezumat)

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