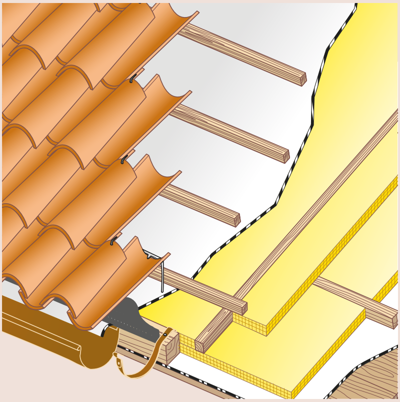
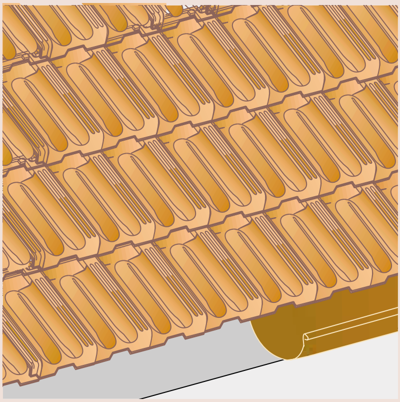
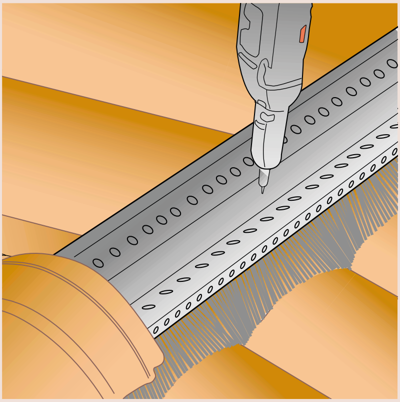
Clay roofing tiles correct installation and solutions for the thermohygrometric comfort

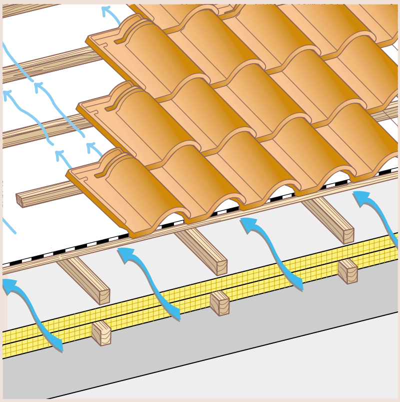
Made in Italy
100% NATURAL COTTO

COPIA ANDIL









‘*Roof*’: a short and simple word which, evoking an articulated group of functions, such as shield, protection, safety, comfort, has always precisely identified an essential part of each building.
The ‘roof’ is often taken for granted, as if it could simply and magically materialize with two inclined pencil lines on a white sheet.
This banalization can imply serious consequences on the durability, the costs of maintenance, the performance and, not least, on the aesthetics of the building.
The increased sensibility which can be found in recent years towards energetic efficiency, acoustic insulation, home comfort, respect for the environment, in a nutshell towards the functionality of the ‘roof system’, has determined an inevitable reinterpretation of it, giving rise to its careful and punctual revaluation.
The result is an enrichment of the range of products available on the market, both basic and complementary, the proposition of new solutions for assembly, the correct definition and sequence of the component layers, and then the update of the relevant regulations.
In this regard a lot of work has been done, in the European context, developing regulations on roofing materials which can provide clear references on the performance of the products and on their correct installation.

This booklet is a vademecum to address properly the main problems connected to the installation of the most important and widespread roofing mantles in Italy: clay roof tiles.
The first and the second part are extracted from the book by Antonio Lauria ‘I manti di copertura in laterizio’ (Edizioni Laterservice, Rome, 2002).
The third part is extracted from the book “Manti di copertura in laterizio: soluzioni per il comfort termoigrometrico” by Marco D’Orazio, Costanzo di Perna, Emanuele Recanatini (Dipartimento di Architettura, Costruzioni e Strutture - DACS, Facoltà di Ingegneria Università Politecnica delle Marche - AN).

Translation by Matteo Ferrario

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Knowing roofs and clay roofing mantles

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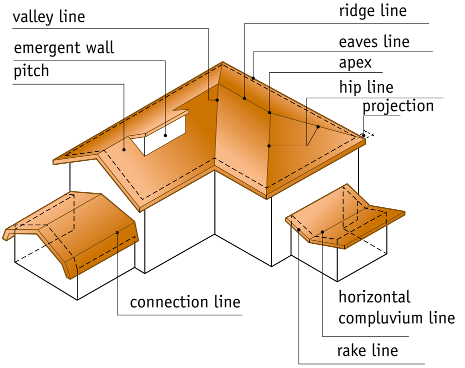
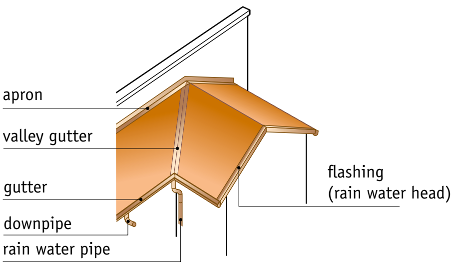
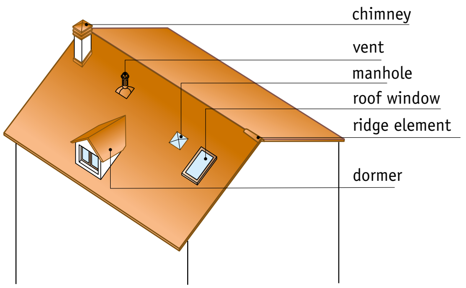
Terminology



Geometric terminology of the roofs.



Terminology of the complementary elements.



Terminology of the continuity solutions.

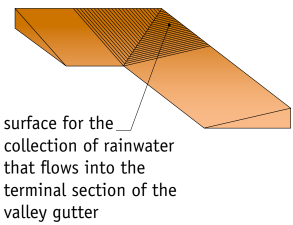
Pitch: sloped and geometrically flat surface of the roof covering
Roof slope: inclination of the roof pitch as regards the horizontal plane measured in degrees or percentage
Actual roof slope: actual slope of the roof which, because of the overlap of the elements, always turns out to be some percentage degrees lower than that of the pitch
Hip line: horizontal or sloped line resulting from the intersection of two pitches with divergent slopes
Valley line: horizontal or sloped line resulting from the intersection of two pitches with convergent slopes
Eaves line: lower boundary line of the roof pitch on which is fixed/placed the element for the collection of rainwater
Ridge line: line resulting from the intersection of the pitches at the top of the roof
Connecting line: line resulting from the intersection of two pitches with different but not opposite slope
Rake line: sloping line that forms the lateral limit of the roof
Apex: meeting point of the horizontal and/or inclined ridge lines
Projection or cornice: part of the roof that protrudes from the wall of the building
Emergent wall: element of connection between the soffit of a pitch and the extrados of another
Apron: element that ensures the water tightness in the junction between the roof covering and emerging volumes
Valley gutter: element that ensures the water tightness at the level of the valley
Flashing (Rain water head): element that ensures the water tightness at the level of the border lines
Gutter: element for the collection of rainwater which corresponds to the eave line
Rain water pipe: element for the channelled discharge of rainwater
Downpipe: element for the dispersed discharge of rainwater
Chimney, vent, antenna roof mount: accessory elements which are normally connected to the mantle by apron flashings
Manhole or trap-door and roof window: elements that allow the accessibility, the natural lighting of the attic and the accessibility to the roof
Dormer: element that allows the natural illumination and ventilation of the attic, allowing the view

Characteristic factors of the roofs

Particular prescriptions
Slopes of around 30-35% are commonly adopted for climates with average rainfall and moderate snowfall; slightly lower slopes may be suitable for dry climates without storm rainfall; slopes of around 150% are reached and exceeded for climates where snow is abundant. The slope is also influenced by the type of roofing.

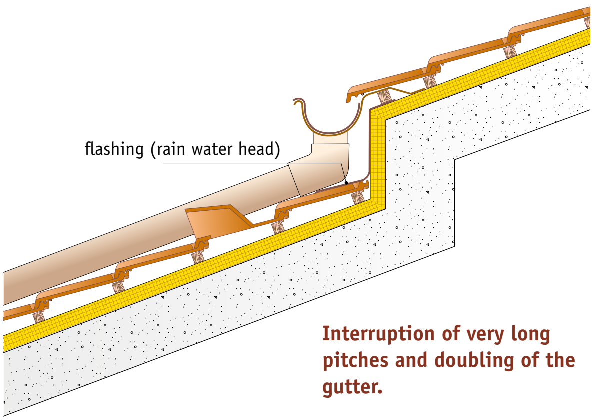
Slope	Roof tiles		Bent tiles	
In percentage	Overlapping	Installation tips	Overlapping	Installation tips
> 60%	By interlocking	Integral fixing	7 cm (2,8 in)	Necessary fixing
45 - 60%	By interlocking	Fixing of the eaves row and of 1 tile every 5 in the rest of the roof covering		
35 - 45%	By interlocking	No fixing	7-9 cm (2,8- 3,5 in)	Recommended fixing
35%	By interlocking			
30%	By interlocking		9 cm (3,5 in)	

The geometric regularity and the length of the pitch
When the eaves line and the ridge one have the same length, they're parallel and horizontal, the gutter collects the same amount of water in each section.
If the geometric regularity of the pitch is eluded, as in the case of sloping valley, more or less serious problems of runoff can arise. In these cases a gutter is placed coinciding with the valley. When the length of the pitch is considerable (10 to 12 m – 32 to 40 ft), the flowing rain water can penetrate the sealing edges of the tiles, infiltrating below the mantle.



The valleys determine a geometric discontinuity in the pitch.

Roof slopes in relation to the type of mantle
The interruption of the pitch represents a valid solution because it allows to intercept, by means of a second collection channel, the water falling on the first section of the pitch, and to slow its speed.

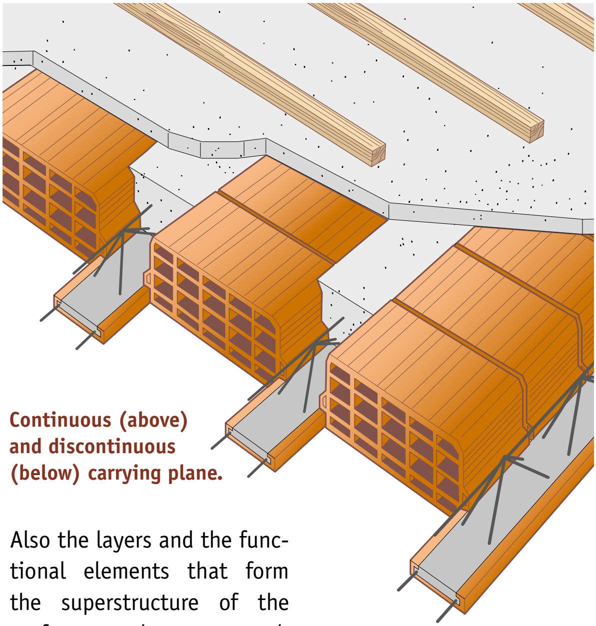


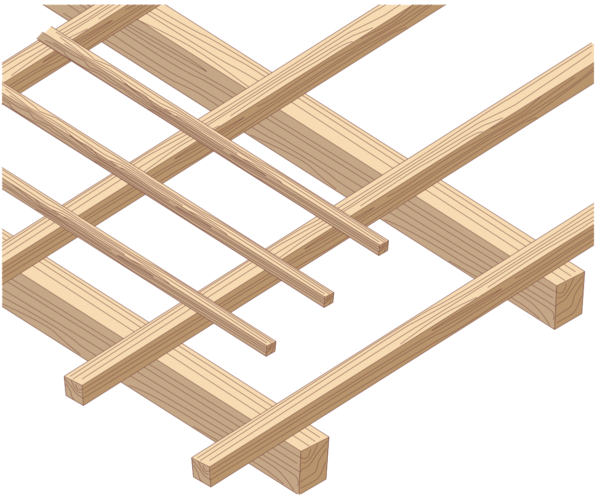
Interruption of very long pitches and doubling of the gutter.

Load strength

The carrying structure of the roof, which normally has the function of bearing the permanent loads (its weight plus the weight of the superstructure) and the accidental overloads of any nature (due to atmospheric agents, to the presence of equipment, to hygrothermal variations, to the passage of workers...), can be attributed to two main typologies:

1. 1. *continuous carrying plane*. If the load-bearing function is carried out along the entire surface of the pitch;
2. 2. *discontinuous carrying plane*. If the load-bearing function is carried out only along some lines.





Continuous (above) and discontinuous (below) carrying plane.

Also the layers and the functional elements that form the superstructure of the roof must have strength properties which are commensurate to the functions they have to realize. In particular, the roofing mantles must withstand the loads due to the passage of installers and maintainers, as regards to which the resistance to bending stress assumes a specific relevance.

One of the properties of the roof is, of course, the resistance to atmospheric precipitation and, in particular, to the loads due to hail, snow, ice and wind thrust.

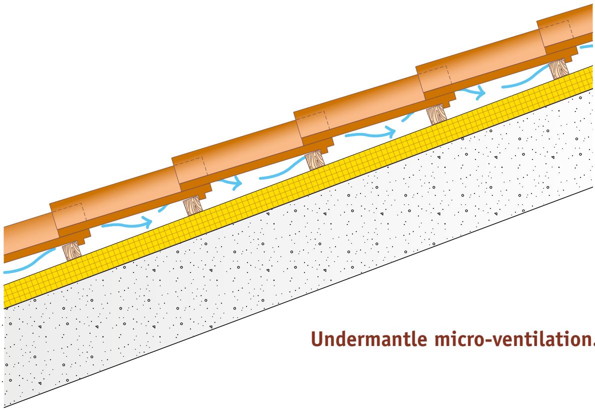
For the purposes of structural dimensioning, the values of these overloads are set by the regulation in force.

Undermantle micro-ventilation

The *undermantle micro-ventilation* is essential for the efficiency and the reliability of the roof and allows to keep the intrados of the mantle dry, preventing the decay and the deterioration of the support elements.

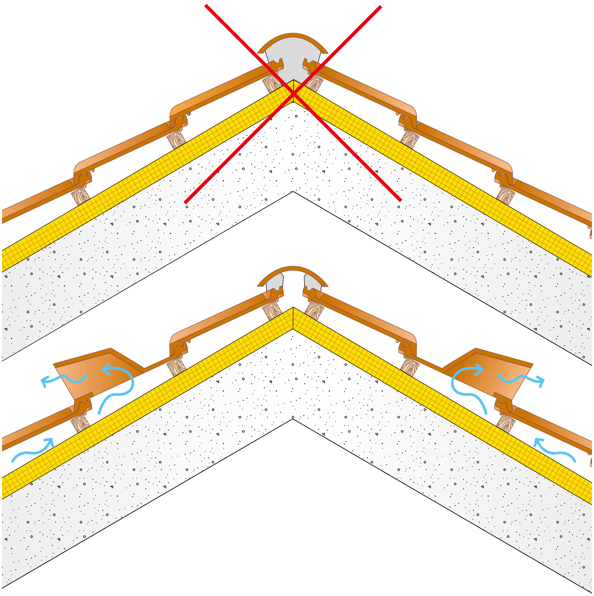
It is made possible by the *dry* installation of the elements of the roof covering on supports, which in most cases are placed parallel to the eaves line.

It's essential that the eaves line and the ridge one are as free as possible from obstructions, so that the circulation of the air can take place.



Undermantle micro-ventilation.

Bird protective grids are placed coinciding with the eaves line, to prevent the access of birds in the cavity.



Wet fixing of the ridge: wrong example (above) and correct example (below).

Special *ventilation tiles* can be used to increase the micro-ventilation.

Having to resort to the 'wet' fixing of the elements that form the *ridge line*, it is essential that:

- the mortar is placed only on the marginal parts of the bent tile;
- ventilation tiles are placed in the second line from the ridge.

The installation of the mantle by creating a mortar bed must be absolutely avoided, because, besides preventing the circulation of the air and creating areas where water is more easily retained, it prevents the natural dimensional variations with a thermal origin in the brick artefacts of the mantle.

Ventilation

In the summer period the roof must have the capacity to store heat and delay its transmission towards the interior, so that the maximum surface temperature of the intrados can occur when the spaces underneath it aren't used or at night, when the air can be more effectively cooled by means of the natural ventilation.

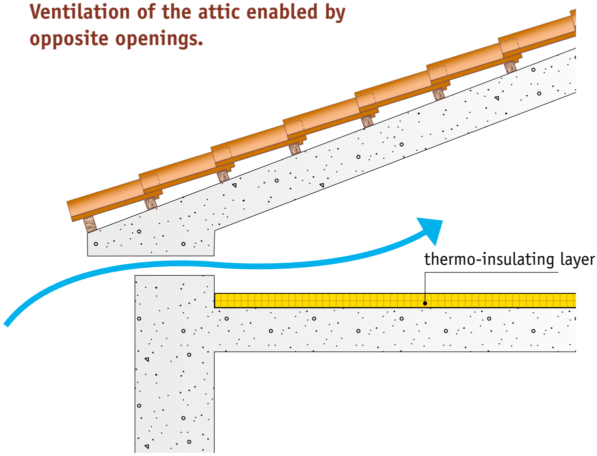
If the attic isn't inhabited the ventilation can be activated by a discontinuous supporting structure or opposed openings in the vertical closures.

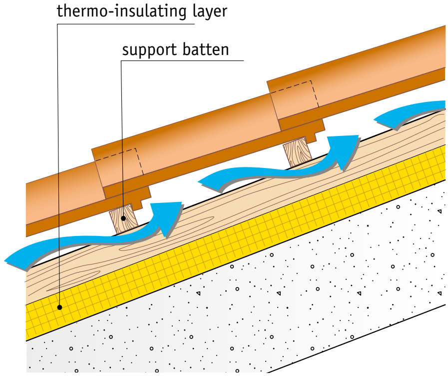
When the attic is inhabited the limitation of the incoming heat flow can be ensured by means of the *undermantle ventilation*.

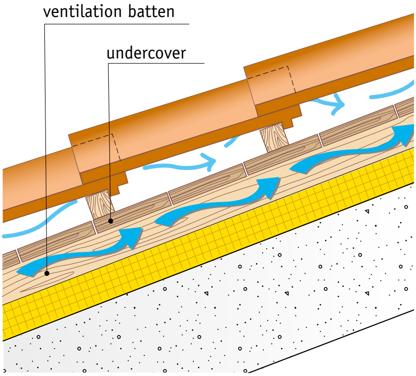
This can be achieved by using a double batten framework: the first – for the ventilation – perpendicular to the eaves line; the second – for the support of the tiles - parallel to the eave line. The construction can also be separated by a layer of continuous support (*undercover*): in this case, the *microventilation* layer is separated from the *ventilation* one.

The ventilation chamber for mantles of roof tiles must be ≥ 550 cm² (0.59 ft²) per meter of pitch width (for mantles of bent tiles ≥ 275 cm² - 0.29 ft²) and be clear of obstructions in coincidence with the eaves line and the ridge one.

Ventilation of the attic enabled by opposite openings.



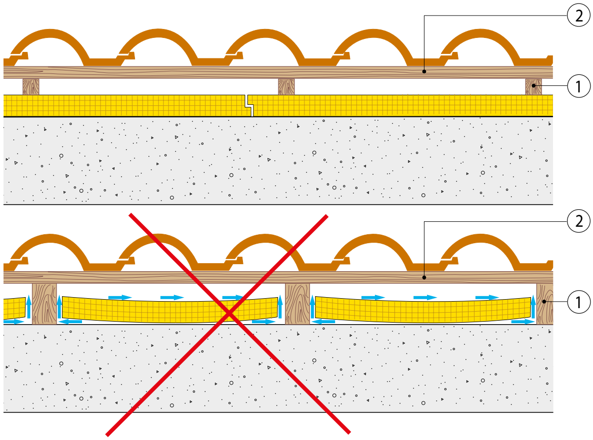




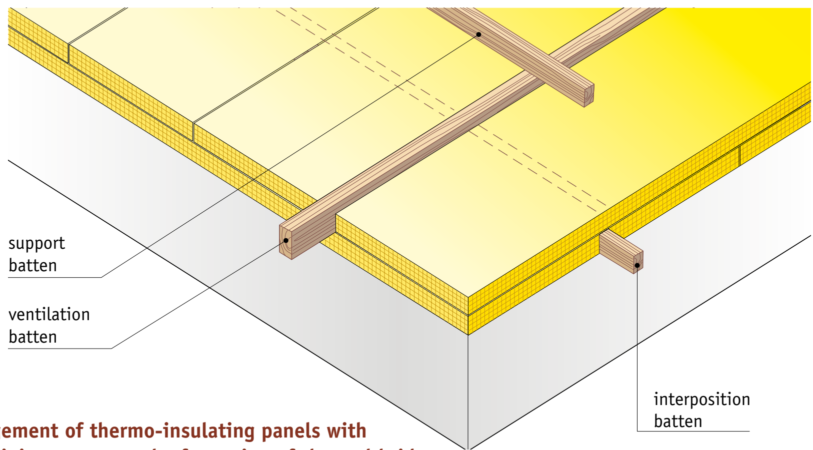
Undermantle ventilation through unique (left) and double (right) cavity.

Thermal insulation

For a good thermal efficiency of the roof (low dispersion, high heat storage capacity) it's good to place the thermo-insulating layer always above the roof slab; if there is a ventilation layer, the thermo-insulating layer must be placed *always below* it.
The thermo-insulating layer can be placed below or *interposed* to the ventilation battens.
In the first case, to ensure a proper compression strength, it is recommended to use high density thermo-insulating panels (≥25 kg/m^3 - 1.56 lb/ft^3), possibly with interlocking or hinged joint. In the second case, if the interposition is accomplished by simply drawing the insulating panels close to the battens, localized areas of heat loss (*thermal bridges*) may be formed.
The loss of thermal efficiency is drastically reduced by resorting to a double layer of staggered panels: a second layer with staggered joints and interposed ventilation battens is superimposed on a first one (with possible interposition of battens of the same thickness, if high density thermo-insulating panels aren't used).



Correct (above) and incorrect (below) placement of the thermo-insulating layer.



The arrangement of thermo-insulating panels with staggered joints prevents the formation of thermal bridges.

Vapour Permeability

In the roofs there are often integrative layers of water (and vapour) resistance of the *continuous* kind, placed in the 'cold' layers of the covering (above the layer with a thermo-insulating function).

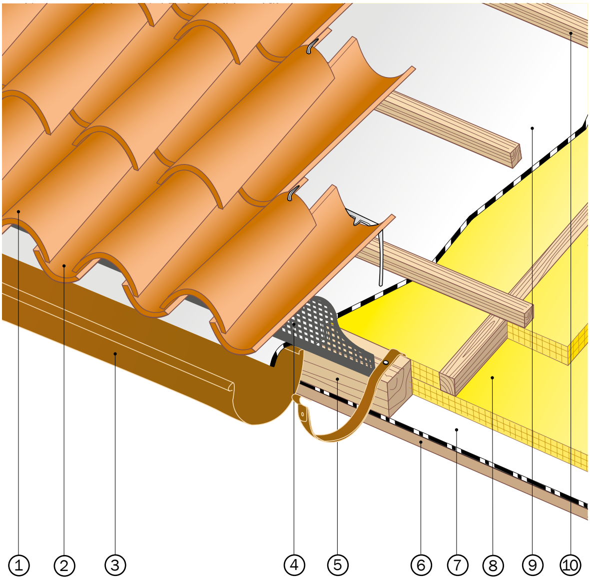
In winter, a high impermeability of the adopted solution may give rise to the formation of condensation of the vapour coming from the inner layers, resulting in the rapid degradation and loss of thermal performance of the roof covering itself.

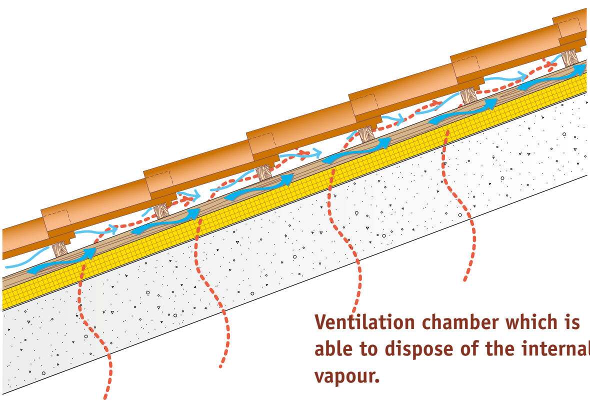
Since the *vapour barriers* affect the transpirability of the roof and therefore the purity of indoor air, it's always preferable to *remove* the water vapour rather than *block* it.

For this purpose, it's possible to resort to a *ventilation chamber* ≥ 200 cm^2 (31 in^2) per meter of width of the roof pitch or the use of *transpiring* membranes.

Insulated and microventilated roof with use of a vapour barrier.

1. upper bent tiles
2. bottom bent tiles with nib
3. eaves
4. bird protective grid with eration function and elevation of the first line of bent tiles
5. rabbet batten
6. support
7. vapour barrier
8. double layer of thermo-insulating panels placed with staggered joints and interposed by battens
9. water resistant layer
10. support batten

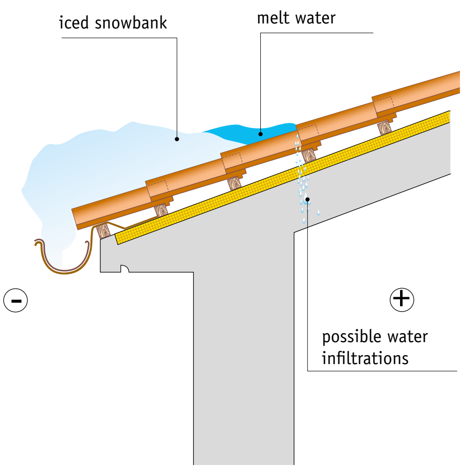




Ventilation chamber which is able to dispose of the internal vapour.

Water resistance

In some specific environmental conditions or in the presence of equipment that needs regular maintenance, it is prudent to create a *complementary water tightness layer* of the continuous type (for example, bituminous or synthetic membranes). The layer of continuous water tightness must be considered indispensable: in the lower part of the pitch for a height of at least 150 cm (59 in) from the eaves to the ridge, because this is the part of the roof that receives the water of the whole pitch; in correspondence with the continuity solutions of the pitch, when it meets emerging elements; more generally, in all those situations in which stagnations of water or snow are predictable.
The installation of the impermeable layers must be made by horizontal overlaps, with the upper layer surmounting the lower one by about 10 cm (3.9 in). In any case, it's good to use *breathable waterproof membranes*, which allow the passage of water vapour, but block the infiltration of rainwater.



Effects of the differential thaw in the overhang area in case of inhabited and heated attic.

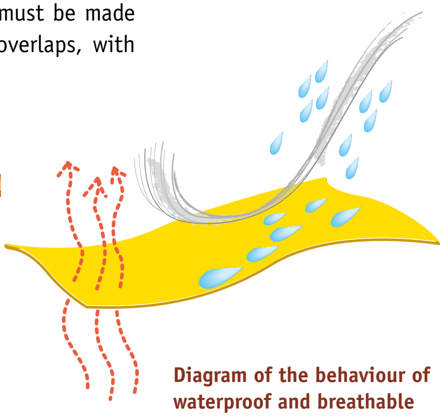
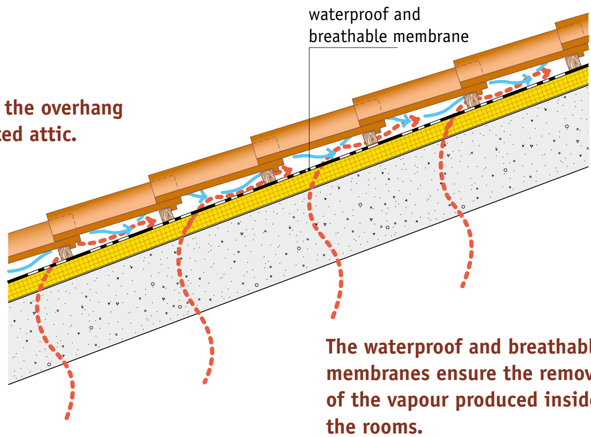


Diagram of the behaviour of waterproof and breathable membranes.



The waterproof and breathable membranes ensure the removal of the vapour produced inside the rooms.

Collection and removal of water

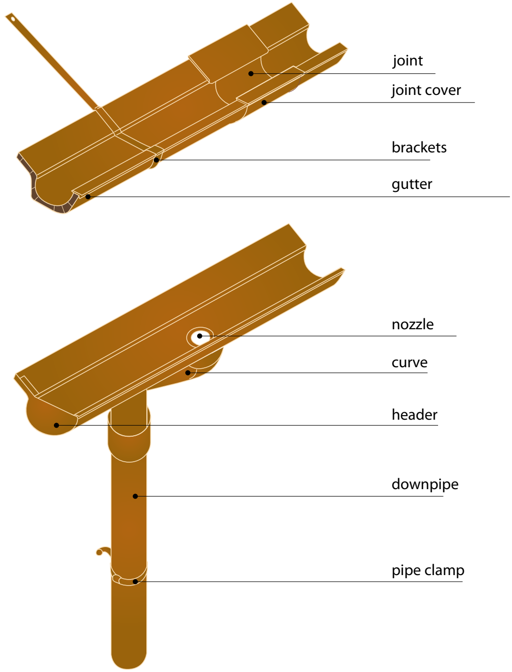
The most widely used system of collection and disposal of rain-water is based on the combination gutter-downpipe.

After reaching the eaves by gravity, the water, thanks to an inclination of the channel which is between 0.3 and 0.5%, is directed to the downpipes.

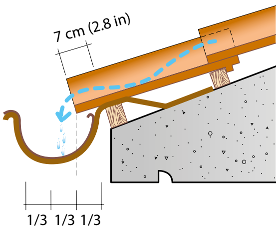
Usually, sections of gutters and downpipes of 0.8-1.0 cm^2 (0.12-0.15 in^2) per m^2 of the pitch projection on the horizontal plane should be planned.

The eaves line is a delicate point since here the water can creep under the mantle also because of the wind action, and for this reason it is recommended that the first line of tiles has a projection on the gutter which approximately corresponds to 1/3 of its width.

In order to prevent that the water spills over towards the wall, the external edge of the gutter must be 1-2 cm (0.4-0.8 in) lower than the internal one.



Elements of collection and removal of water.



Projection of the first row of tiles on the gutter.

Section of the gutters and downpipes in relation to the surface of the pitch		
Roof area in horizontal projection (m^2 - ft^2)	Diameter of the gutter (cm - in)	Diameter of the downpipe (cm - in)
Up to 10 (107.64)	8 (3.1)	4 (1.6)
11 (118.40) to 25 (269.10)	10 (3.9)	5 (2)
26 (279.86) to 50 (538.20)	12 (4.7)	7 (2.8)
51 (548.96) to 100 (1076.4)	15 (5.9)	10 (3.9)
101 (1087.2) to 200 (2152.8)	18 (7.1)	10 (3.9)

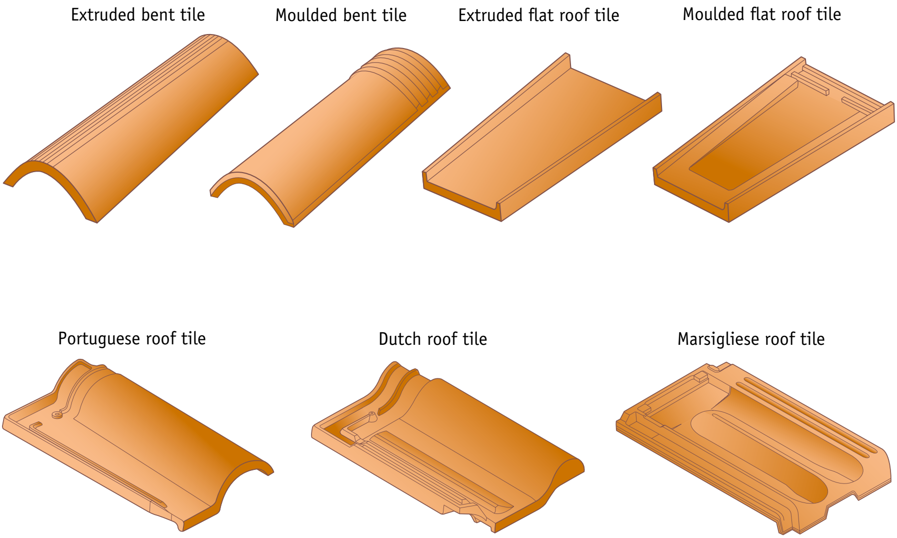
Criteria for the dimensioning of gutters and downpipes.

Bent tiles and roof tiles

The lateritious elements for roofs can be qualified into to two specific typologies: the *bent tiles* and the *roof tiles*.

Special elements, *accessory elements* and *innovative elements* are also available for each typology, to improve the aesthetics and the reliability of the roof and to facilitate the installation.

The *bent tiles*, produced with the technique of extrusion or moulding, can be equipped with nibs.



Examples of standard elements.

The *flat tile* (or *plain tile* or *flap pantile*) is usually adopted together with the bent tile, more rarely with other superimposed flat tiles; the ones produced by moulding are equipped with special reliefs for the rabbet of the upper bent tile.

The *Portuguese roof tile* and the *Dutch* one incorporate morphological characteristics of the bent tile and plain tile: the flat part allows the rapid water runoff, the curved part gives an adequate mechanical strength to the element.

The Dutch roof tile differs from the Portuguese one mainly for the profile of the curved part.

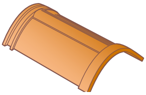
Elements with the curved part to the right or to the left are available.

Thanks to its peculiar shape, the *Marsigliese roof tile* is very versatile and can be used also for slightly curved roofing mantles. The special overlap joints, which all the *roof tiles* (with the exception of the *flat one*) are equipped with, effectively ensure the water tightness of the mantle.

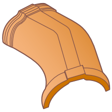
Special elements

The special elements are necessary to solve specific problems in coincidence with critical points of the mantle. Some examples are indicated below.

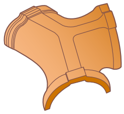
One way ridge



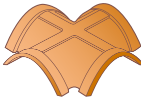
Two way ridge



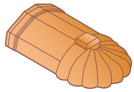
Three way ridge



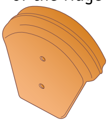
Four way ridge



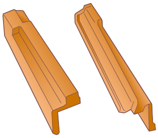
End ridge



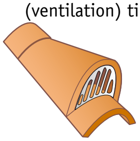
Front piece of the ridge



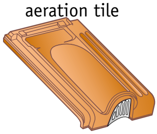
Verge tiles



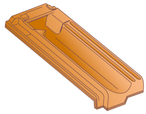
Aeration (ventilation) tile



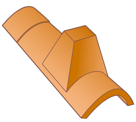
Marsigliese aeration tile



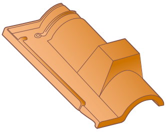
Marsigliese half-tile



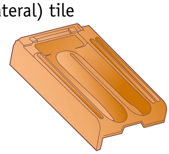
Snow stop tile



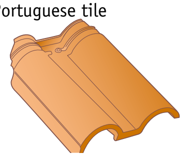
Portuguese snow stop tile



Marsigliese side (lateral) tile



Double-wave Portuguese tile



The ridge elements
They ensure the continuity of the water tightness of the mantle along the hip lines. Depending on the number of joined pitches, they can be two, three and four ways.

The front pieces
They are used to refine the ridge lines at the edges of the pitch.

Verge tiles
When necessary they're adopted to clad the side edges of the pitch.

The aeration (ventilation) elements
They're used to improve the air circulation at the soffit of the mantle. They must never be used as vents for bathrooms or boilers, because not designed for this purpose.

The snow stop elements
They hinder the slipping down of the piles of frozen snow accumulated on the roof.

The lateral edge elements
They allow the closing and protection of the lateral line connecting the pitch plane with the vertical closing, avoiding the recourse to elements of integrative sealing and protection elements (for example, metallic flashings).

The double-wave tile
It allows the installation of the side roof tile of the edge ensuring a correct connection with the standard roof tile.

The Marsigliese half-tile
It is used in coincidence with the edge lines for the installation of the mantle with staggered joints.

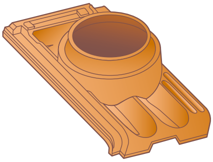
Accessory elements

The *accessory elements* are used in correspondence with continuity solutions of the mantle.

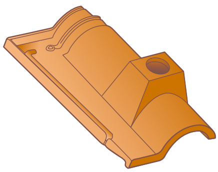
To prevent problems of integrability (colour, size, morphology, anchorage system...), it's recommended to use accessory elements manufactured by the same company that supplied the standard elements.

Some purely indicative examples are shown below.

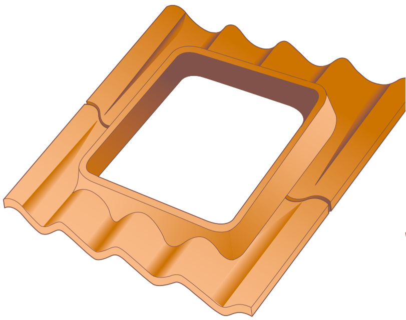
Marsigliese roof tile for vent



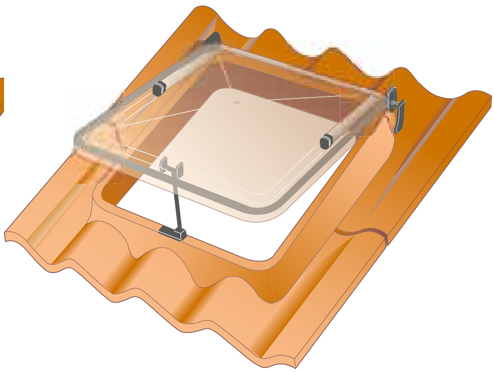
Portuguese roof tile for antenna



Basic element for chimney



Basic element for skylight



Element for vent

It allows the exit of the terminal elements of vents on the roof.

The use of clay vents or chimneys is not recommended.

Element for antenna

It allows the installation of antennas for radio and television reception or the like.

Element for chimney

It allows the installation of the chimney flue.

It's an element of multiple dimensions compared to those of the elements of the mantle. It's produced in concrete, coloured with paste, and it's shaped so as to adapt to the elements of the mantle.

Element for skylight

It allows the illumination and the ventilation of the attic and the accessibility to the mantle. It consists of an element, equipped with a skylight, of multiple dimensions compared to those of the elements of the mantle. It's produced in concrete, coloured with paste.

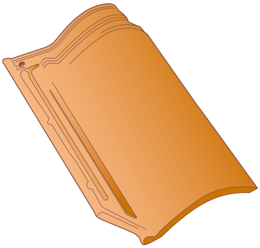
Innovative elements

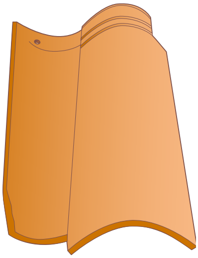
Currently, the market also offers some innovative elements in terms of dimensions, morphology of the profiles, connection techniques and surface finishing.

Among the *innovative elements* we can mention:

1. the special roof tiles which reproduce the appearance of a traditional roofing mantle made of bent tiles and which, thanks to the particular wings that act as an element of collection and removal of water, surpass the traditional double installation (bottom bent tile and upper bent tile);
2. the antiqued elements which, with their colour gradations (brown, black, ochre yellow, red...) properly mixed and alternate, favour a more moderate insertion in the ancient rural or urban contexts.

Usually, the elements of different nuances are already mixed in the single packages provided by the manufacturers.

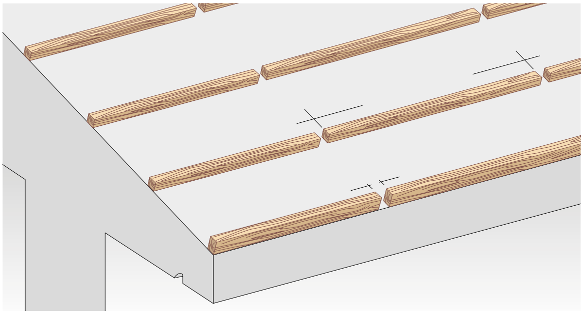




Examples of innovative elements: to the left, artefacts with interlocking wings, which combine the appearance of a roof covering made of overlapping bent tiles with the executive simplicity of a mantle made of roof tiles; below, artefacts with an antiqued finishing layer.

Linear and flat elements

The support elements of the mantle must ensure the undermantle micro-ventilation and the stability of the elements.
The interax of the support elements must take into account the overlapping of the elements of the mantle which for the roof tiles is fixed, but for the bent tiles varies from 7 to 9 cm (2.8 to 3.5 in), depending on the inclination of the pitch.



Interruption of the supports.

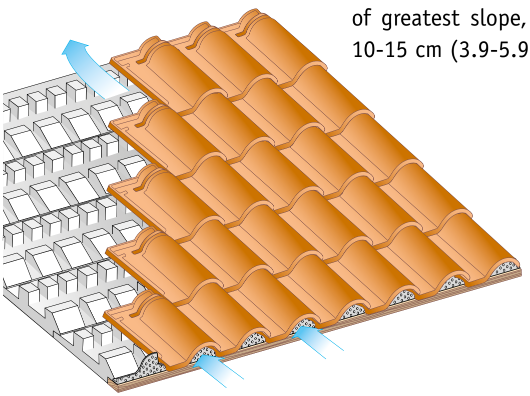
Wooden battens
These are normally made up of strips with a 4x4 cm (1.6x1.6 in) section.
Each about 150-200 cm (4-6 ft), they must be interrupted for 2-3 cm (0.8-1.2 in).
It is appropriate that the interruptions are aligned.
In case of discontinuous carrying layer, the section of the battens are related to the free span between the supports, the operating load of the roof covering and the accidental overloads.

Metal and plastic battens
Also in this case, the rules of installation coincide with those of the traditional wooden battens.
The elements can be perforated to facilitate the micro-ventilation.

Pre-made mortar mini curbs
Usable in presence of a continuous, coplanar and homogeneous carrying layer, it isn't actually a recommended solution, because it may result in some dangerous *hydraulic bridges* between the roofing mantle and the underlying layers.

Preformed thermo-insulated panels
Modular artifacts, available in different materials, shapes and thicknesses, distinguished also in function of the type of mantle to be adopted.

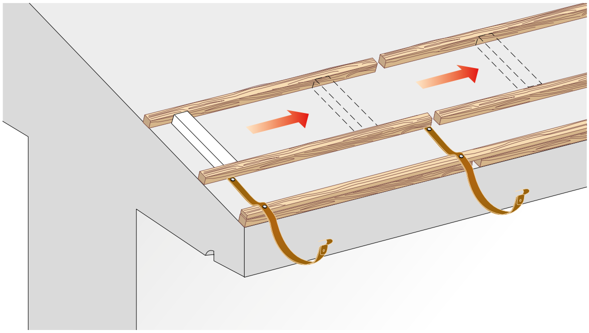
Ribbed plates
Generally the plates are anchored to the carrying layer by mechanical fixing, surmounted laterally by at least one rib and, along the line of greatest slope, by about 10-15 cm (3.9-5.9 in).



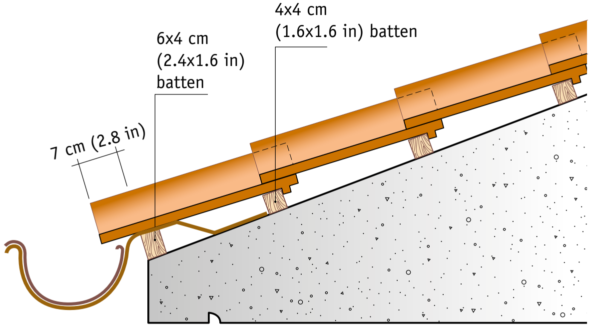
Example of thermo-insulated preformed panel.

Supports for roof tiles

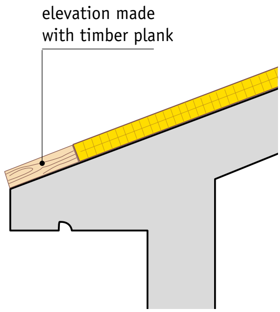
The roof tiles of any type are shaped so as to need to be based on a framework of battens which is *parallel* to the eaves line (‘*Lombard*’ way).
To ensure the correct inclination of the first row of roof tiles, the eaves batten must be 2 cm (0.8 in) higher than the next ones, so as to compensate the absence of the tile below.
For example, using battens with a 4x4 cm (1.6x1.6 in) section, the first operation to perform is the fastening of a 6x4 cm (2.4x1.6 in) eaves batten, with the longer side in vertical, or a 4x4 cm (1.6x1.6 in) one with the second batten of a 2x4 cm (0.8x1.6 in) size, to be fixed after the installation of the brackets that will carry the gutter.
The eaves batten must always incorporate the bird protective grid.
If there is a layer with a thermo-insulating function, it’s necessary to create an elevation of the rabbet, to be as long as the eaves and with an height which is equal to the thickness of the panels, in correspondence with the eaves line itself.
The battens following the eaves ones must be placed at a distance which is equal to that between the extruding anchoring teeth; to facilitate the installation of the subsequent battens, the operator can use a template.
The distance between the first and the second batten is different from the others, because the first row of tiles must protrude from the edge of the pitch by a measure which is equal to about 1/3 of the diameter of the gutter and in any case not more than 7 cm (2.8 in).



Example of construction of the (*double*) eaves batten and methods of use of the template.



Eaves batten and standard batten.

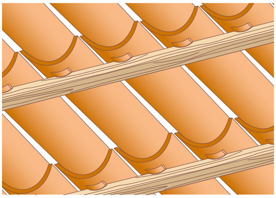


Example of elevation of a rabbet.

Supports for bent tiles

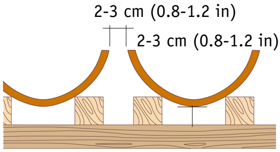
If the bottom bent tiles are equipped with *nibs* that protrude from the intrados, the framework of the supports is entirely similar to the one described for the roof tiles. The distance between the battens must ensure the necessary overlapping of the bent tiles and, at the same time, the reaching of the ridge line of the roof with a row of complete bottom bent tiles. If the bottom bent tiles are devoid of nibs, two methods of installation can be implemented:

1. the construction of a stable housing for the bottom bent tiles by a double warping of battens;
2. the dry fixing of all the upper bent tiles with the bottom bent tiles resting on the special shaped battens.



Intrados of bottom bent tiles with nibs.

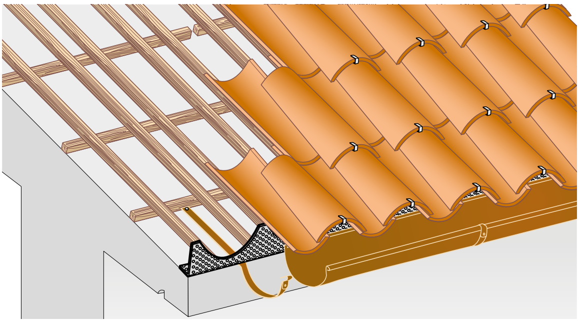
The distance between the battens must be such as to avoid the contact of bent tiles between themselves and with the battens of the lower framework (warping).

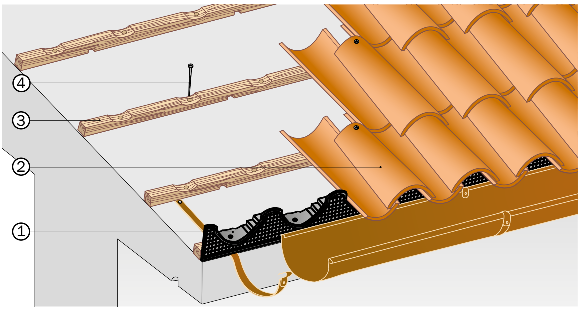


In the first case, the lower warping will be composed of battens which are *parallel* to the eaves line and placed with a proper gauge; the upper one will have *pairs of battens* with a 5x5 cm (2x2 in) section, *perpendicular* to the eaves line, spaced in such a way to prevent contact points of the bent tiles between themselves and with the battens of the lower warping. During the installation it is recommended to exploit the tolerance of the pace in order to obtain a whole number of tiles which are uniformly distributed over the width of the pitch.

In the second case, the fastening of the upper bent tiles can be made by screws or hooks.

As for the roof tile, also for the bent tiles it is necessary to raise the first course in correspondence with the eaves line.



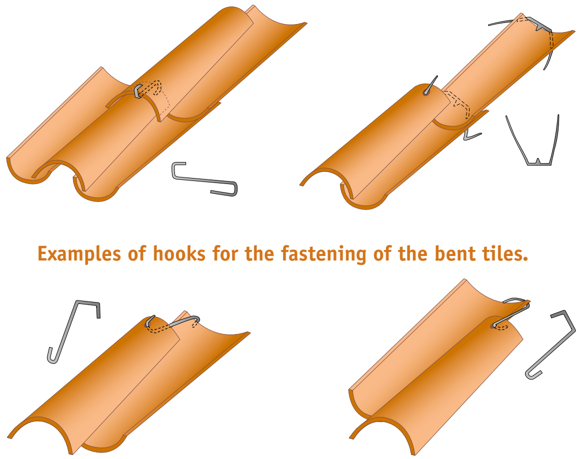


1. perforated bird protective grid
2. starter bent tile
3. wooden shaped batten
4. screw for the fastening of the battens

Two systems for the installation of bent tiles with no nibs.

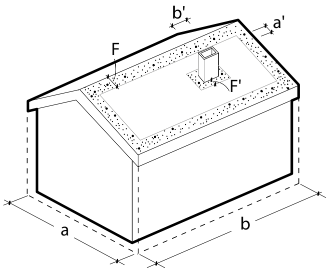
Typologies and dimensioning

The fastening of the mantle must always be made with a dry method, using techniques that encourage the simple removability and substitutability of the damaged elements.
If the roof covering is heavily exposed to the wind, it is recommendable to fix also all the elements at the edges of the pitch, of the eaves and ridge line and of the perimeter of the emerging elements.



Examples of hooks for the fastening of the bent tiles.

Dimensioning of the fastening areas.



If a < 30 m (98.42 ft)	F = a/8 in any case: 1 m (3.28 ft)≤ F ≤ 2 m (6.56 ft) If a/8 ≤1 m (3.28 ft) F = 1 m (3.28 ft) If a/8 > 2 m (6.56 ft) F = 2 m (6.56 ft)
If a ≥ 30 m (98.42 ft)	F = a/8
If 0,50 m (1.64 ft) < b′ ≤ 2 m (6.56 ft)	F′ = 1 m (3.28 ft)
If b′ > 2 m (6.56 ft)	F′ = b′/2 in any case: 1 m (3.28 ft) ≤ F′ ≤ 2 m (6.56 ft) If b′/2 ≤1 m (3.28 ft) F′= 1 m (3.28 ft) If b′/2 >2 m (6.56 ft) F′= 2 m (6.56 ft)

The elements for the fastening of the roofing mantle can be divided into two typologies:

1. *hooks, brackets and metal wires*, for which the presence of the fixing hole on the clay element is not always necessary. In the case of mantles made of bent tiles, some systems provide for the anchorage of the upper elements to the bottom ones, in order to prevent their slip.
2. *nails and screws*, that provide for the positioning of the element of the mantle and then its locking trough the hole which has been purposely made on the upper edge of the element itself.

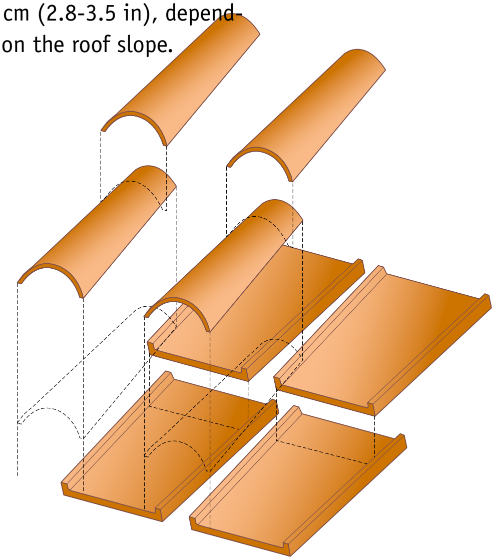
In areas with abundant rainfall, before nailing or screwing the element of the mantle, it is useful to include a gasket in correspondence with the hole, in order to prevent possible infiltrations.

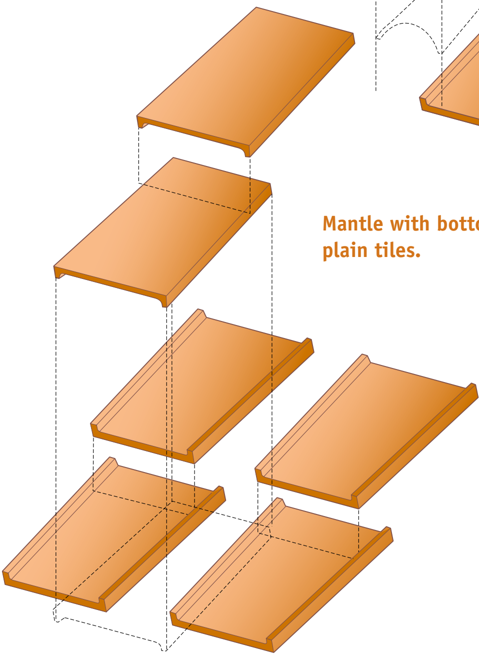
Flap pantile and plain tiled mantles

'Roman style' roofing mantle

It's composed of a lower layer of plain tiles, with a canal function, and a layer of upper bent tiles, placed in between the parallel rows.
The first must be installed with the shorter side downwards; the second with the shorter side upwards. The installation proceeds from the eaves towards the ridge, by courses in the direction of the line of maximum slope: the bent tiles must be placed at least every two courses of plain tiles.
The alignment of the elements must be checked with a straight edge.
The overlap between the upper bent tiles and the plain roof tiles must be at least 7-9 cm (2.8-3.5 in), depending on the roof slope.

Flap pantile mantle with bottom plain tiles and upper bent tiles.





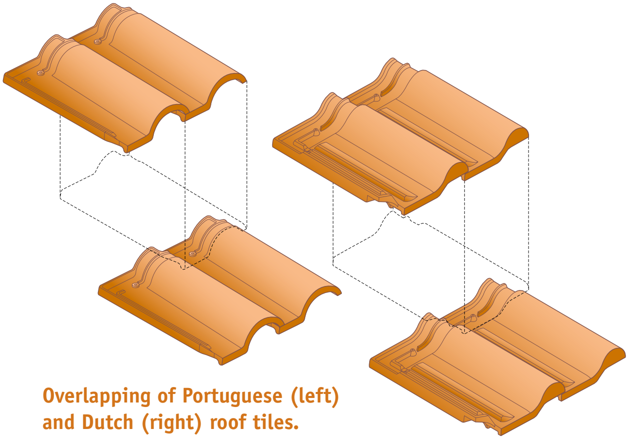
Mantle with bottom and upper plain tiles.

Roofing mantle with plain tiles

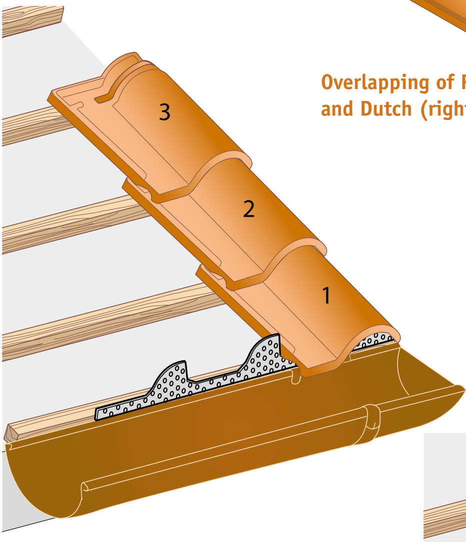
The arrangement is similar to the previous one ('*Roman style*'), with the variation of the use of plain roof tiles also for the upper layer.
Although equally valid, this solution is adopted less frequently.

Mantles of Dutch and Portuguese roof tiles

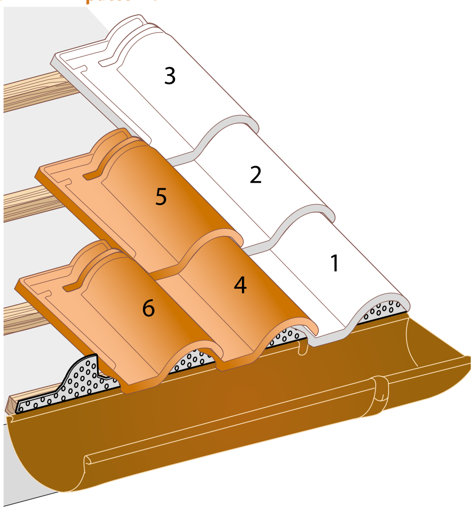
The installation is carried out creating three rows in the direction of the line of maximum slope of the pitch, placing the elements in a diagonal pattern, controlling their alignment, and then move on to the three subsequent courses.



Overlapping of Portuguese (left) and Dutch (right) roof tiles.



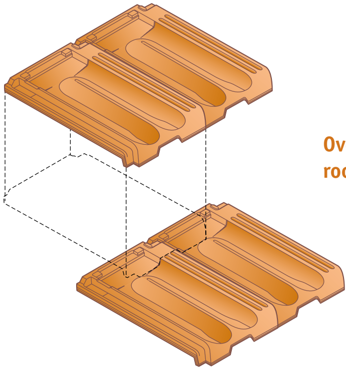
Sequence of installation of the Portugues roof tiles according to the diagonal pattern.



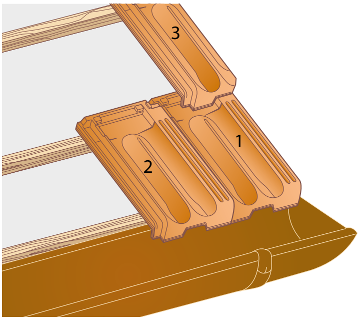
For the roof tiles with curved part on the right side, the arrangement of the elements proceeds from the right towards the left: if the curved part is on the left side, it's necessary to invert the mounting direction of the elements.

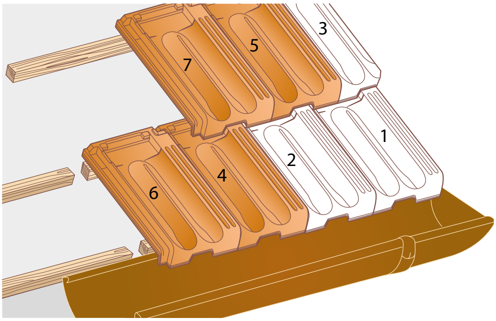
Mantles of Marsigliese roof tiles

The Marsigliese roof tiles are normally installed in rows which are parallel to the eaves line, one by one, or by proceeding with two or three rows at the same time, beginning with the eaves line and proceeding upwards.
In order to obtain the rows with *staggered joints*, every other row must be started with the special *half-tile* element.



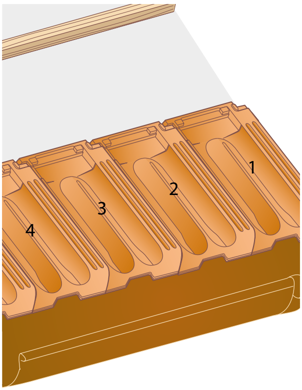
Overlapping of Marsigliese roof tiles.

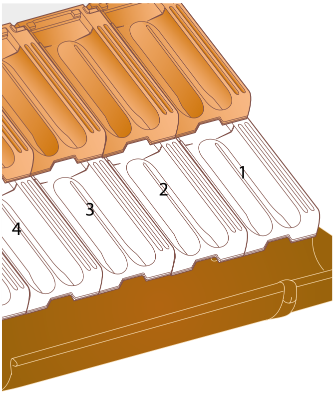




Installation of Marsigliese roof tiles with staggered joints and in courses which are parallel to the eaves line.

In order to obtain a mantle of Marsigliese roof tiles with joints *which aren't staggered*, it is possible to proceed by horizontal or vertical rows: however, in the latter case the installation process is more complex.

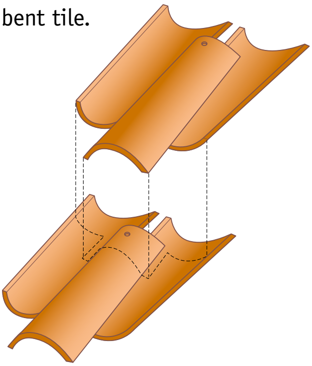




Installation of Marsigliese roof tiles with joints which aren't staggered and in horizontal courses.

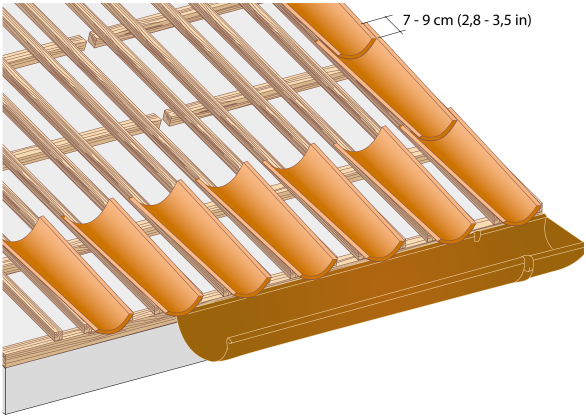
Mantles of bent tiles

The installation of bent tiles on support battens in a "Piedmontese style" is carried out by placing a whole vertical course of bottom bent tiles, from the eaves to the ridge: the bottom elements of a same course must have an overlapping of 7-9 cm (2.8-3.5 in), depending on the pitch slope, but small exceptions are possible in order to attempt to reach the top of the pitch with a full bent tile.



Overlapping between bottom and upper bent tile.

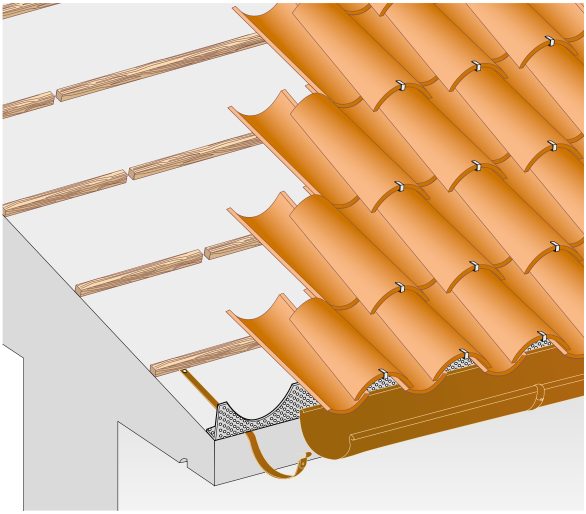
Then begins the installation of the first horizontal row of bottom bent tiles, on which are placed the upper bent tiles, beginning with a first row of starter bent tiles: by means of the staggering, the upper part of the upper bent tile forms the rabbet for the bottom one in the subsequent rows.



"Piedmontese style" installation of bent tiles.

This arrangement offers a greater guarantee against the water infiltrations and, by fixing the upper bent tiles, allows to stop also the bottom ones.

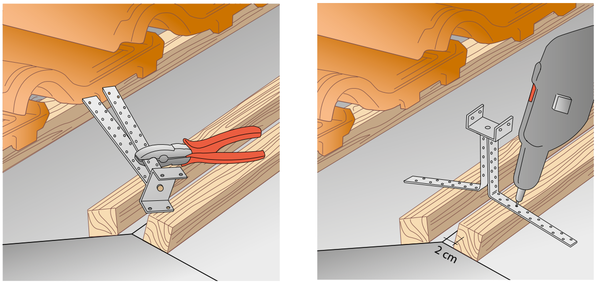
The installation of bent tiles equipped with nib is carried out on a batten framework in a 'Lombard style', according to a diagonal pattern which is similar to the one described for the roof tiles.



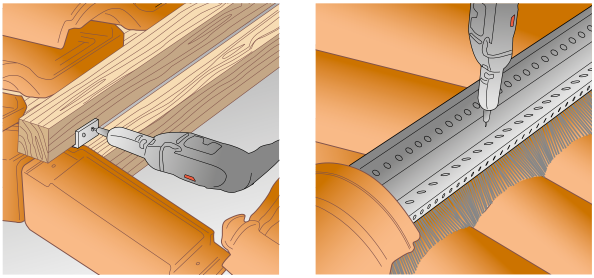
"Lombard style" installation of bent tiles (equipped with nibs).

Hips

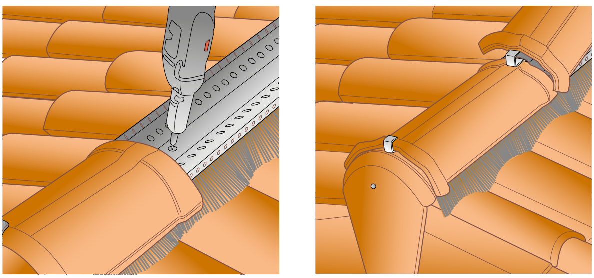
The *hips* - horizontal (ridge) or inclined - are connection lines between pitches with diverging slopes.
When possible, they have to be ‘ventilated’.
The devices for the correct execution of ventilated hips which are available on the market are normally integrated with a water tight layer, that is wide enough to be properly superposed on the elements of the mantle at the intersection of the two pitches.
For the construction of the sloped hips it is necessary to cut the elements of the mantle near the hip; the ridge elements are placed by overlapping them and proceeding from the bottom upwards.



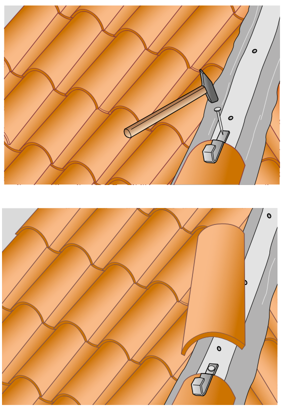
After placing, for each pitch, the last row of battens at a 2 cm (0.8 in) distance from the ridge line and after verifying the height of the support battens of the ridge elements, the wings of the batten-bearing fork are folded and fastened to the warping. The forks must be placed with a gauge of about 39 in.



After completing the mantle (including the rake line) it’s necessary to fasten the ridge battens, with a 5x5 cm (2x2 in) section, to the fork. The terminal element of the ridge is placed and the under-ridge ventilation element is placed and fixed, in such a way that it’s properly superposed to the mantle.



The first ridge element is placed with the help of metal hooks which, on a side, are fixed to the support batten of the ridge. The subsequent ridge element is embedded in the hook of the previous ridge element on one side, and in the subsequent hook on the other.



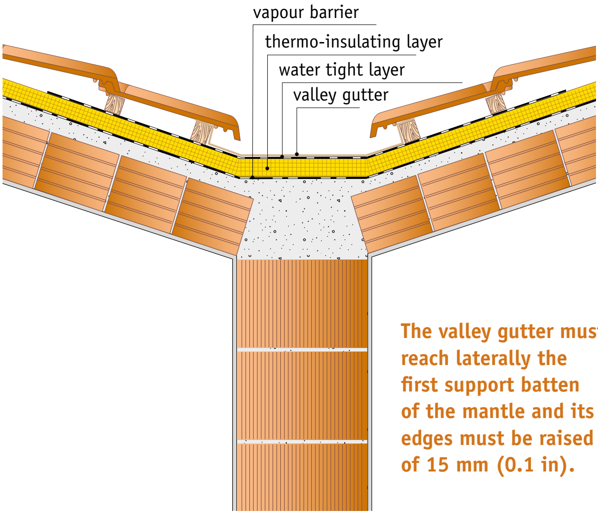
In the sloped hips the ridge elements are placed from the bottom upwards.

Valleys

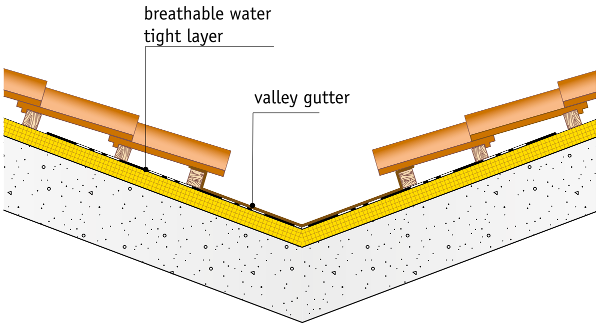
The valleys are junction lines of the pitches with converging slopes: besides collecting and channelling rainwater where two pitch planes converge, they can be affected (especially if horizontal) by accumulations of snow in the winter period.

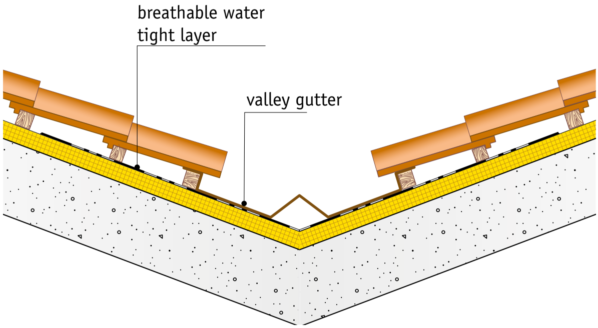
In case of inclined valleys, the water can reach a certain flow speed and, helped by the wind or deviated from the flow line on the maximum slope by some obstacles along the path (leaves, twigs, moss), it can infiltrate into the undermantle.

The valleys need a *valley gutter* which is made in galvanized or stainless steel sheet or in copper, with a thickness of 8/10 of millimetres, that can reach laterally the first support batten of the mantle. It's always recommended to create under the valley gutter a further water tight layer (for example, a bituminous membrane) which can penetrate bilaterally under the mantle for at least 20 in. The valley gutters are installed immediately after finishing the battening, together with the flashings (rain water heads) and the gutters.



The valley gutter must reach laterally the first support batten of the mantle and its edges must be raised of 15 mm (0.1 in).

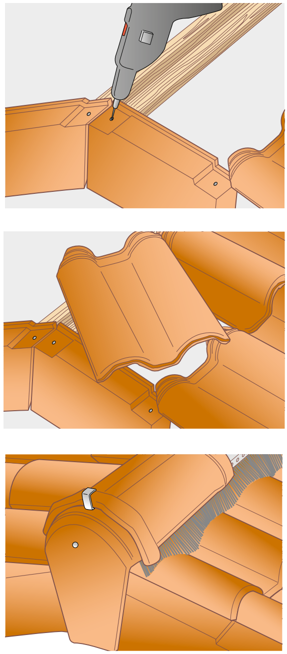




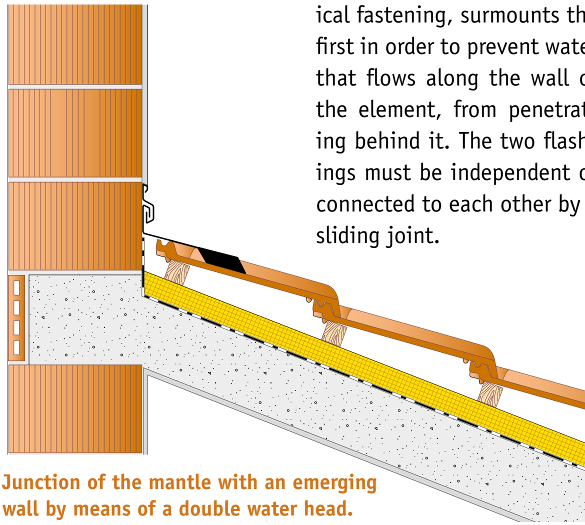
When a strong runoff is expected, it can be useful to create a valley with central flow-breaker.

Connection lines

The free edges, or the connection lines with walls that don't overcome the height of the roofing mantle, can be created by means of clay *lateral profiles* (plus the overlapping element), *lateral edge tiles* or metal or plastic *flashing* (*rain water heads*).
The lateral profiles made of brick must be installed starting from the ridge line after the installation of the mantle; they must be always fastened, by nails or screws, to the support battens and properly surmount the elements of the mantle; the overlap must be aimed at preventing the water infiltrations and the cutting of the standard elements of the mantle. In order to facilitate the junction between the lateral profile and the mantle, it is possible to adopt the *double-wave tile*.
At the intersection line between two pitches, the edge elements can be covered by means of *front pieces* which will always have to be fastened to the support by means of screws or expansion plugs.
The lateral edge tiles are elements that incorporate the edge profile and can be installed like a standard roof tile, except for the fact that they always have to be mechanically fixed to the support battens.
If the wish is to adopt metal or plastic flashings, it's possible to adopt systems with a duct, that collect rainwater and take it to the gutter, or with an overlap wing of the mantle.
The connections with emerging walls, perpendicular or parallel to the eaves line, must prevent water infiltrations both towards the roof covering and towards the wall.
A double flashing is normally adopted: the lower one, which is just leaning, partially covers the first row of roof tiles (or bent tiles) and rises in a vertical direction; the upper one, which is secured to the wall by mechanical fastening, surmounts the first in order to prevent water that flows along the wall of the element, from penetrating behind it. The two flashings must be independent or connected to each other by a sliding joint.



Lateral profile, double-wave tile and front piece.



Junction of the mantle with an emerging wall by means of a double water head.

Continuity solutions

In case an emerging element (for example, a dorm or a chimney flue) obstructs the normal runoff of the water, it's necessary to adopt an apron which, on the upstream side, is prolonged under the first row of roof tiles (or bent tiles) the same way as a valley and, on the downstream side, surmounts the first row of roof tiles (or bent tiles).

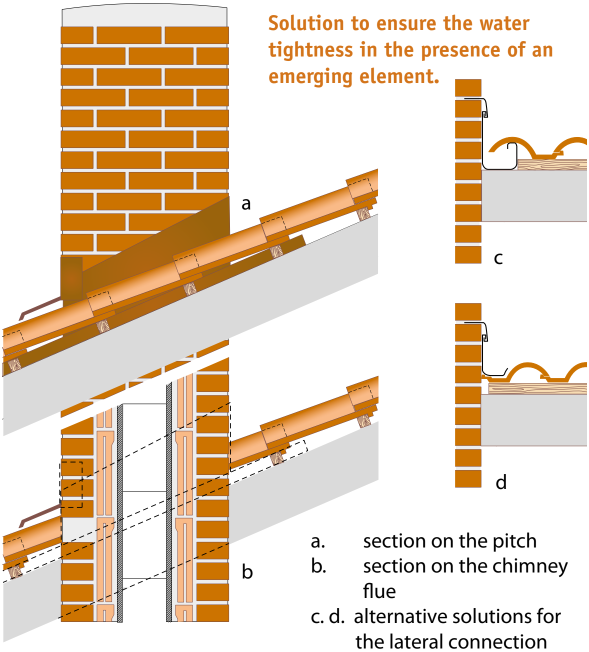
A roof window is normally created by means of a frame equipped with a special connection apron made of metal sheet.

The window is placed in the previously prepared opening and the false frame is fastened to the structure.

The opening must be 1 cm (0.39 in) larger than the window: in presence of the thermo-insulating layer the length will increase consequently.

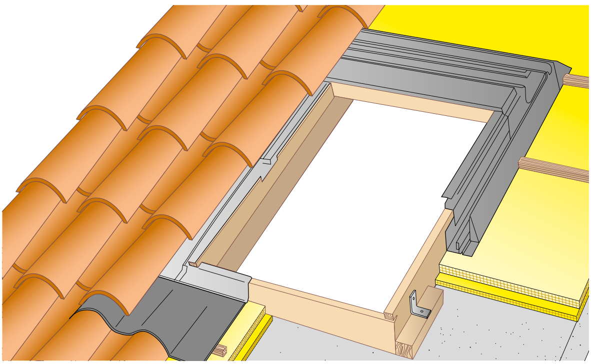
The clay roofing mantle is then installed by surmounting the apron on the upper side and the lateral bands; the protruding sheet on the lower edge, for its part, surmounts the elements of the mantle and is shaped according to their profile.

Regarding the basic elements for chimney it's necessary to add that the dimensions of the hole of the elements must be greater than those of the section for the channelling of the exhaust fumes, in order to allow the adaptability of the element itself to the horizontal and vertical alignments of the elements of the mantle.



Solution to ensure the water tightness in the presence of an emerging element.

a. section on the pitch
b. section on the chimney flue
c. d. alternative solutions for the lateral connection



Junction between roof window and mantle in the case of continuous load-bearing structure.

Installation of the snow stop elements

The need to resort to special snow stop elements arises for roofs whose pitches have slopes between 36% and 176%. In fact, with these slopes the snow accumulates on the roof in blocks which can slide downwards. The purpose of the snow stop elements is precisely to prevent this from happening.

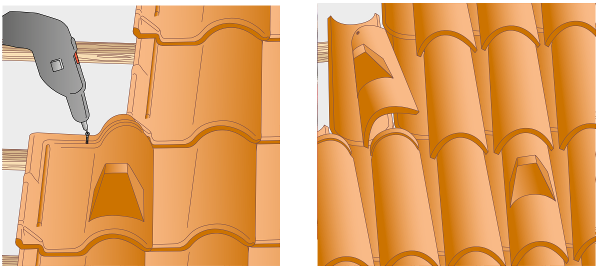
Because of the stresses they are subjected to, the snow stop clay elements must be mechanically fastened to the support battening. The hole must be sealed.

The snow stop elements are placed in rows which are parallel to the eaves line; the centre distances and the distance between the parallel rows depend on the criticality of the situation.

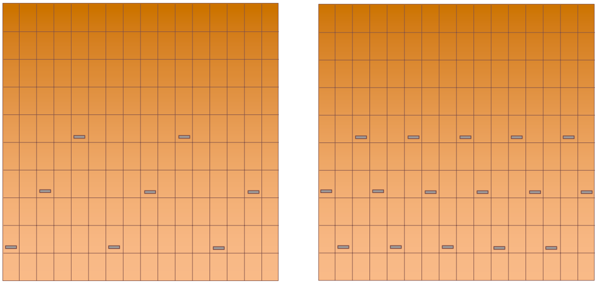
A further evaluation element is given by the eventual presence of continuity solutions or emerging elements on the pitch; in this case the snow stop elements will have to be placed as a protection for them.

In the case of pitches with a slope between 30% and 35% and a length of around 6 m (20 ft), for sites with altitudes which are lower than 750 m (2460 ft) above sea level, it's sufficient to place a snow stop element every 5 standard elements for three staggered rows in proximity of the eaves line; for sites with altitudes up to 1200 m (3937 ft) above sea level it's necessary to place a snow stop elements every 2 standard elements, still in three rows.

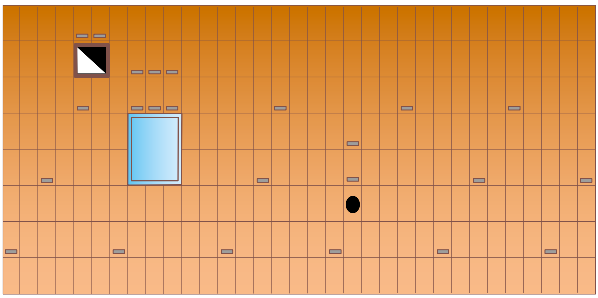
As an alternative to snow stop elements made of brick, it's possible to use special metallic devices, which must be fastened directly to the surface of the support battens.



Mechanical fastening of the clay snow stop elements.



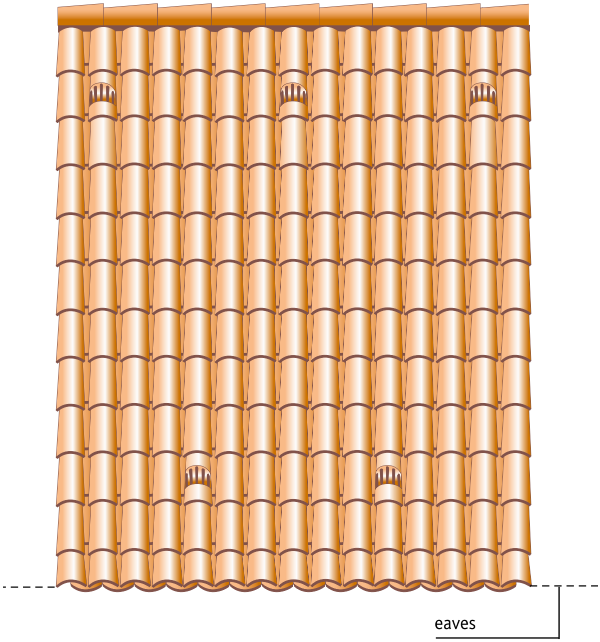
Arrangement patterns of clay snow stop elements for sites with a 750 m (2460 ft) altitude above sea level (*left*) and up to 1200 m (3937 ft) above sea level (*right*).



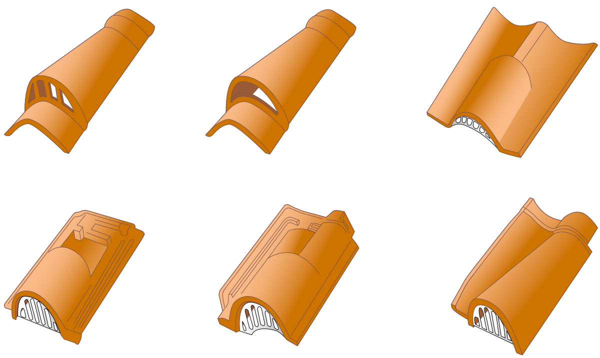
Example of arrangement of snow stop elements to protect continuity solutions and emerging volumes.

Installation of the ventilation elements

The ventilation elements must be installed in such a way that they're staggered from each other in comparison with the line of maximum slope of the roof. The ventilation elements are placed in horizontal rows at the same time of the installation of the standard roof tiles.
Two rows are normally enough on regularly shaped pitches: one on the third row of the eaves line and one on the penultimate row from the ridge line.
Ventilation elements which are placed in the intermediate part of the pitch prove to be of some usefulness only if the pitch itself exceeds 6 m (20 ft) in length.
The number of the ventilation elements of each row varies from 1 every 3 to 1 every 6 standard roof tiles, depending on the characteristics of the roof, the typology of the mantle and the conditions of the context.
Further ventilation elements can be adopted when the geometry of the roof (changes in slope, presence of valleys, hips...) or the presence of emerging elements restricts the undermantle air circulation.



Positioning of the ventilation tiles.



Examples of ventilation elements.

Acceptance requirements

Test	Number of samples	Acceptance requirements of the EN 1304 standard	Test method
APPEARANCE	at least 100	More than 5% of the test pieces which do not comply are not admitted	EN 1304
INDIVIDUAL DIMENSIONS	10	$L_A \leq \pm$ 2% of the value declared by the manufacturer $L_U \leq \pm$ 2% of the value declared by the manufacturer	EN 1024
CAMBER	10	Tiles with sidelock and frontlock, tiles with sidelock only, overlapping tiles, over and under tiles (bent tiles) $R_L \leq \pm$ 1.5% for the tiles whose declared total length is > 300 mm (11.8 in) $R_L \leq \pm$ 2% for the tiles whose declared total length is ≤ 300 mm (11.8 in) Flat tiles R_L, $R_T \leq \pm$ 1.5% for the tiles whose declared total length is > 300 mm (11.8 in) R_L, $R_T \leq \pm$ 2% for the tiles whose declared total length is ≤ 300 mm (11.8 in)	EN 1024
REGULARITY OF SHAPE (just roof tiles)	10	Flat tiles Cp ≤±1.5% for the tiles whose declared total length is > 300 mm (11.8 in) Cp ≤±2% for the tiles whose declared total length is ≤300 mm (11.8 in) Interlocking tiles with sidelock and frontlock, tiles with sidelock only, overlapping tiles Cp ≤±1.5% for the tiles whose declared total length is > 300 mm (11.8 in) Cp ≤±2% for the tiles whose declared total length is ≤300 mm (11.8 in)	EN 1024
UNIFORMITY OF THE TRANSVERSE PROFILE (just bent tiles)	10	$\Delta E_1 \leq$ 15 mm (0.59 in) $\Delta E_2 \leq$ 15 mm (0.59 in)	EN 1024
FLEXURAL STRENGTH	10	Flat roof tiles $F_i \geq$ 0.6 kN Over and under tiles (bent tiles), plain (Roman) roof tiles $F_i \geq$ 1.0 kN Other types of tile (Marsigliese, Portuguese, Dutch) $F_i \geq$ 1.2 kN	EN 538
WATER IMPERMEABILITY (Method 1: passage of water trough the totally immersed roof tile, under a certain water head)	10	Cathegory 1 $IF_s \leq 0.6\ cm^3 cm^{-2}\ day^{-1}$ $IF_m \leq 0.5\ cm^3 cm^{-2}\ day^{-1}$ Cathegory 2 $IF_s \leq 0.9\ cm^3 cm^{-2}\ day^{-1}$ $IF_m \leq 0.8\ cm^3 cm^{-2}\ day^{-1}$	EN 539-1
FROST RESISTANCE	13	Level 1: minimum 150 cycles passed Level 2: minimum 90 cycles passed Level 3: minimum 30 cycles passed	EN 539-2

Number of samples, requirements of acceptance and normative references established by the products of roofs EN 1304 standard for the clay

Key

L_A: width mean value
L_U: length mean value
R_L: longitudinal camber mean value
R_T: transverse camber mean value
C_p: coefficient of twist
ΔE_1: gap between maximum and minimum value, measured on the narrow part of the tile
ΔE_2: gap between maximum and minimum value, measured on the wide part of the tile
F_i: individual flexural strength value
IF_s: individual impermeability factor
IF_m: impermeability factor mean value

Introduction

In recent years, clay roofs have undergone extremely strong transformations: on the one hand, they have changed and the forms that characterize them have grown for the role they have acquired in the composition of the building; on the other, the constructive technologies have been modified and refined, becoming more and more and complex, in order to adapt themselves to the new and more stringent performance, as well as formal, requirements. The roofs have seen their role evolve rapidly: from simple protective element, they have become a strongly connotative component of the building image; at the same time, also because of the increased costs of the residential spaces, nowadays they are more and more frequently chosen as a roofing envelope for houses, and therefore, beside the traditional performance in terms of tightness, they have to offer also very high thermal characteristics (because of the new, more and more demanding standard requirements) in order to ensure the necessary reduction of consumptions and proper levels of interior comfort.

The consequence is that, in order to meet the changing needs, clay roofs have turned into an extremely complex system in which a multiplicity of layers, each with a specific function (heat dissipation, thermal insulation, air tightness, vapour barrier, solar radiation shielding, etc.), hides under the clay mantle and dynamically participates.

In order to provide an outline of technical solutions which are consistent with the new standard requirements, various roofing solutions, characterized by mantles of roof tiles which are fully able to meet the current technical needs, are analyzed in the pages that follow, highlighting how the use of traditional, known and tested materials, can ensure a total respect of the environmental context. In particular, the power of the clay roofs to mediate between insulation and mass allows to obtain, in addition to a now mandatory reduction of energy consumption, a long-lasting moisture protection, acoustic insulation, thermal inertia, architectural value, low maintenance costs, excellent insertion of the “new” into the “existing”.

Each of the different “stratigraphies” is presented together with a concise data sheet which outlines its performance profile, especially from a thermal and hygrometric point of view (stationary and periodic thermal transmittance, phase shift and attenuation, periodical thermal capacity). Moreover, some of the examined constructive solutions have also been experimentally analyzed in order to substantiate the proposals with laboratory data.
The contribution ensured by the manufacturers, in terms of innovation of the products which are offered to the market and guaranteed long term performance levels, has been significant for the achievement of these objectives.

Thus, continuous factory tests certified by a “third party”, CE marking of the materials, improvement of the sealing devices, expansion of the range of colours, perfectioning of the fastening methods, development and exploitation of the “ventilated” typologies, contribute together to configure a modern “clay roof” as a multifunctional technological system, which is complete and reliable.

The reduction of energy consumptions and the environmental sustainibility

The necessity to reduce the effects of pollution, and particularly the amount of CO_2 which is released into the atmosphere, has determined, after the Kyoto Protocol and the SAVE European Directive, the issuing of a specific regulatory framework in the single countries and national guidelines for the energy certification, with the aim of promoting the reduction of energy consumption for the air conditioning of buildings.
The energy needed by the construction sector (about 40% of the national annual requirements) is, in fact, produced mainly by combustion processes and is therefore a cause of the emission of CO_2 into the atmosphere.

In addition to imposing a global containment of energy consumption for the building, derivative regional Decrees and Laws have set limit values of thermal transmittance (under stationary and/or dynamic conditions) both for the external wall solutions and for the roof coverings. The attention of the legislator has been strongly pinned to the latter in particular, since they are responsible of the overall energy loss of a building for an average of between 25% and 35%.

It follows that nowadays a solution for a properly designed and executed roof covering, from the point of view of the thermohygrometric performance, must adopt thicknesses of insulating materials which are much greater than those at which the building context has hitherto been accustomed, besides additional stratifications (for the ventilation, air tightness, vapour barrier) that were not always present in the constructions of the past.

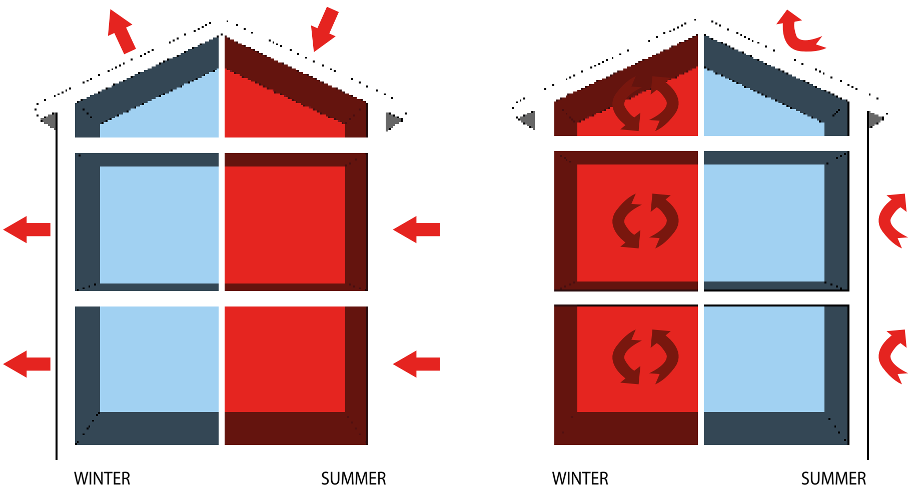


Figure 1 – Insulation differences between the past (left) and the present (right) with the elimination of the thermal flows through the building envelope.

The operating patterns of the roofs in the current context

A clay roof covering is a particularly complex constructive system in terms of performance, because of the characteristic air permeability of the external mantle. In fact, the presence of an undermantle ventilation layer, associated to roof tiles or bent tiles which are permeable to air (thanks to the joints between the same elements) gives rise to thermal and hygrometric behaviours of the "stratification" whose dynamics is associated to the way the air circulates in the cavity.

In principle, the classic theory of ventilation is used to explain this motion: warming itself, the air reduces its own density, moving upwards and creating the effect which is normally known as "chimney". However, being based on the assumption of an absolute impermeability of the mantle, this theory tends to encourage constructive solutions which are based on remarkable heights of the ventilation cavity: the larger the area of the air inlet, the greater, in fact, the flow rate.

Actually, it's necessary to consider that a clay mantle, compared to a continuous surface, is highly permeable to air and the total area of the contact joints between the assembled elements (roof tiles and bent tiles) equals, and easily exceeds, that which must be implemented to ensure the air inlet into the eaves. Therefore, as shown experimentally, a constructive solution with clay tiles possesses dissipative capacities (both thermal and hygrometric) which are definitely higher than those which the classic theory of ventilation can predict, ensuring beneficial effects even with little air flow rates.

Even from a normative point of view, in terms of thermohygrometric performance, the roof coverings are nowadays divided into *micro-ventilated* and *ventilated* ones.

The first have a ventilation cavity formed by the mantle, simply resting on the battens, which are orthogonal (or parallel) to the pitch slope. Unlike them, the second ones are characterized by a ventilation ensured by the doubling of the batten (one parallel to the pitch slope and one superimposed orthogonally) or by lifting devices of the mantle (in metal, plastic or obtained using shaped insulating materials). It's possible to create also roof covering in which the ventilation channel is physically separated from the undermantle micro-ventilated space by wooden boardings.

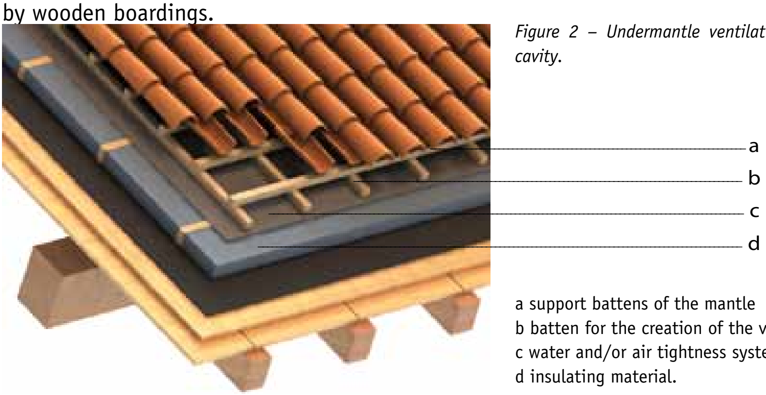


Figure 2 – Undermantle ventilation through single cavity.

a support battens of the mantle
b batten for the creation of the ventilation channel
c water and/or air tightness system
d insulating material.

In the summer period, the air inlet from outside (with temperatures which are hardly higher than 30 to 35°C – 86 to 95°F), both through the eaves and through the joints between the various elements of the mantle, is able to facilitate the abatement of the temperatures of the different layer that compose the roof covering, thus cooling, also on the lower side, the mantle itself, which, by effect of solar radiation, can even reach temperatures of 50 to 55°C (122 to 131°F). The passage of external air (in the winter period, with low content of water vapour) in the ventilated cavity also has the advantage of reducing the moisture content in the insulating materials. This is a particularly important aspect, since the thermal conductivity of the insulating layers tends to decrease with the increase of water content inside them. In fact, each material placed in an environment at a certain relative humidity adsorbs the vapour molecules on the surface of the pores that constitute it and, given the significant conductivity of water compared to the insulating material (100 to 1), its performance rapidly gets worse.

As known, the current regulations on energy saving in building have enormously increased the demand for thermal insulation of the roofs, dissociating the thermohygrometric behaviour of the upper mantle from that of the supporting floor. In fact, in the summer phase, the presence of a very thick insulating layer implies (as will be punctually explained below) a significant reduction of the heat flows which are transmitted into the inhabited environment trough the roofing elements, causing at the same time a rise in the temperatures of the elements of the mantle and the external surface of the insulating layer.
This results in some significant changes to the basic criteria according to which the roof coverings have been designed and built until now: for example, the ventilation will reduce its importance for the thermal comfort; smaller ventilation chambers will be sufficient; the ventilation itself, however, will ensure the durability of the "package", because it will allow to adjust the temperatures of the mantle and the thermal insulation placed in the roof "package"; if the latter is hygroscopic, it must have an upper barrier to air and a vapour barrier on the warm side (bottom); given the reduction of heat flows through it, also from the inside outwards, the floor will have to be dimensioned according to its use, also as a thermal flywheel for the storage of the heat that may be entered through the transparent elements or produced by internal heat loads.

Figure 3 – Micro-ventilated roofing mantle, left, and ventilated roofing mantle (with double batten), right.

The support of the experimental data

In order to verify the previously reported statements, experimental activities, consisting in the construction of a building with some roofing solutions (detailed in the included tabs), were conducted and put into comparison in the same environmental conditions.
The 80 m^2 (about 861 ft^2) building is equipped with a roof covering composed by 6 different types of "stratification" with south orientation (with a slight rotation of 10 degrees westwards) for the analysis of the relative performance in the summer phase, and as many with north orientation (for the winter analysis). The roofs with southern exposure have a slope of about 17 degrees and a length of 6 m (19.78 ft). The roofs with northern exposure are 3 m (9.84 ft) long. The conducted research has allowed to demonstrate how, in spite of the classic theory of ventilation, there are important differences of thermal behaviour between the different roofing systems which were taken into consideration, highlighting how the "cotto" solutions present actual benefits, related to the peculiar characteristics (radiative properties and permeability to air) of the materials used for the mantle.

In effect, the experimentation which was carried out has demonstrated that, with equal ventilation, in the summer period the "discontinuous" clay mantles give rise to the half of incoming heat flows compared to those with a continuous mantle (metallic, for example). This is because the lateritious is characterized by high average coefficients of absorption (lower overheating by radiation) and emissivity (a large amount of heat can be reflected back).
In addition, since in the "cotto" roof coverings the effect of permeability of the mantle (joints between the component elements) prevails on the chimney effect (undermantle ventilation), there was a predominant air flow between the roof tiles (or the bent tiles) rather than between eaves and ridge, demonstrating that these types of roofs have dissipative properties which are not possible in the roofing systems with a continuous (or perfectly sealed) mantle.

The different roofing mantles (from left to right):
– ventilated metal roof (6 cm – 2.4 in) on a reinforced concrete and hollow tiles mixed floor;
– ventilated clay roof (6 cm – 2.4 in) on a reinforced concrete and hollow tiles mixed floor;
– ventilated clay roof on wooden beam floor;
– micro-ventilated clay roof on wooden beam floor;
– ventilated metal roof on wooden beam floor;
– non-ventilated metal roof on wooden beam floor.

Figure 4 – The case study building and the continuous and discontinuous roof coverings which were object of study.

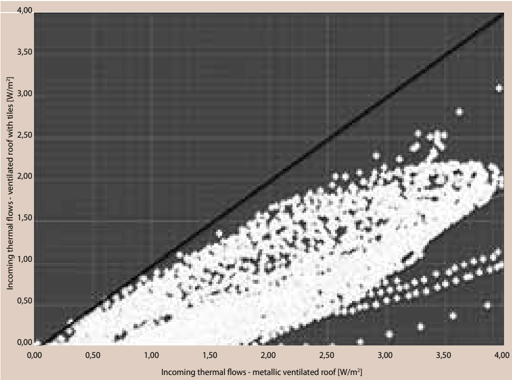


Figure 5 – Heat flows passing through a roof covering with equal transmittance and chamber ventilation: each point on the graph is singled out by two values (x and y) which are, respectively, the flows passing through a metal roof and a clay one. If the point is below the line (locus of a set of points through which the passing flows are identical), this means that the flows passing through the metal roof are greater. In the summer phase, it is possible to observe heat flows which are about twice those passing through a clay roof in the same climate conditions.

It should be noted, however, that the high thickness of the insulation required nowadays in all the roofs, reduces the influence of the mantle and its permeability on the internal comfort compared to the past: the differences in behaviour which were observed with the adoption of ventilation chambers with heights of 6 to 8 cm (2.4 to 3.1 in) compared to only 3 to 4 cm (1.2 to 1.6 in) of the support batten (micro-ventilation) are very restricted and concentrated in the very few hours of maximum irradiation during the day. Finally, the experimentation has shown the important role of the ventilation for the durability of the roof system.
In particular, the solutions with metal mantle and absence of ventilation, because of the high thickness of the insulation (which, by reducing the heat transmission to the indoor environment, causes the increase in the temperatures of what is above), have reached in the mantle and in the insulation, in times of increased radiation, high temperatures which could compromise the durability, particularly that of the materials of a synthetic nature. In addition, for the non-ventilated roof coverings with continuous mantle - not made of clay – it was possible to observe temperatures which were 60 to 65°C (140 to 149°F) higher than the 40 to 45°C (104 to 113°F) of a solution with a lateritious mantle.
Finally, the positive role of the reinforced concrete and hollow tiles mixed floor has been noted, compared to the wooden beam floor, in the inertial behaviour of the roofing system in presence of internal thermal loads (heating): the presence of the mass mitigates the fluctuation of the surface temperatures (increased comfort) and minimizes the thermal loads required for the heating (up to 25%). It should be clarified that this statement refers only to the mass which is placed inside (slab), as the high insulation of the constructive solutions adopted nowadays minimizes the role of the external mass (mantle) for the purpose of thermal lag. Turning to the hygrometric aspects, the experimental data confirm that, even with high thicknesses of insulation, the ventilation can ensure the preservation of the performance of the roof over time, preventing abnormal hygroscopic accumulation in the insulating layers, while in the non-ventilated solutions (continuous mantle) it is possible to note progressive increments of water in the hygroscopic insulation.

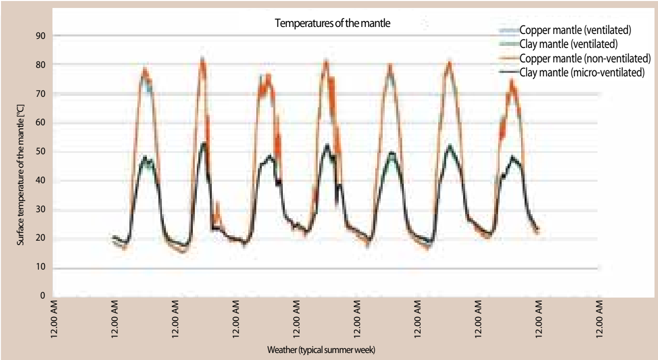


Figure 6 – Temperatures measured on clay and metal roof coverings in the summer phase (the 4 roofs are identical in terms of stationary transmittance).

In conclusion, the main performance characteristics of the "roof system" can be summarized in terms of:

– *indoor wellbeing*: in the summer phase, the discontinuity between the elements of the clay mantle allows an additional heat dissipation capacity compared to other types with ventilated systems, ensuring proper comfort conditions in the inhabited environment and limiting the use of air-conditioning systems;

– *hygrometric control of the constructive system*: the particular ventilation mode allows the reduction of the water content in the materials placed under the mantle, improving the thermal performance of the insulation and reducing the risk of formation of moulds which are toxic to humans;

– *correct operation of the roofing system*: the conformation of the ventilation system, coupled to the clay mantle, prevents the insulation from reaching excessively high temperatures, especially in summer, and it also keeps the materials in optimal operating conditions. The high level of insulation required nowadays encourages the use of "hyper-insulated" systems which, as a consequence, are interested by the achievement of high temperatures on the external surface of the insulation;

– *durability*: the historic centre of the Italian cities are dominated by the red colour of the "cotto" roof coverings, thus incontestably witnessing that lateritious, unlike other types of mantles, possesses the capacity to remain unchanged through the years.

Moreover, further consideration from an environmental point of view can be added: the lateritious of the mantle is inert; it doesn't release any substances (heavy metals, etc.) which can cause pollution of waters, unlike other types of materials for roof coverings; finally, it's totally recyclable at the end of its lifecycle.

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