ROOFING AND SEASONAL CONSIDERATIONS

Common understanding is that the function of roofing, or, more commonly, of the roof, is to define the upper part of a building and to protect the internal environment from the elements. The roof covering, which is the external roof surface, provides a seal against water, while the bearing structure's role is to support the roof covering. The basic purpose of the roof is to prevent humidity increases and to resist the stresses caused by wind and snow.

With specific regard to roofing, an analysis of developing trends in terms of materials and more traditional technologies may be meaningful. Indeed, in Europe we are seeing higher thermal-insulation standards that are moving in the direction of hyper-insulation. This tendency has a noteworthy impact on specific technical solutions. As is well known, roofing is the technical element whose interaction with the thermal-environmental context is most critical. This is true during the summer season, when the air-sun temperature of external surfaces reaches high levels as a function of day-long radiation by the sun. Even in the winter, however, when outside temperatures swing 10 °C above or below 0°C, the roof undergoes mechanical and functional stresses that need to be taken into consideration.

The developing trend toward hyper-insulation requires that greater attention be paid both to the choice of the products that make up the sealing element (which must be motivated by the use of high-quality, exceptionally stable products) and to the installation of roofing systems.

The increase that is to be expected in the thickness of the insulation layer requires that particular attention be paid to mechanical aspects, as a result of increased load-based deformations and wind-resistance. Concretely, the seasonal difficulties that emerge from the confrontation between new housing needs and traditional construction technologies can be summed up as follows:

During hot months:

- overheating of internal environments due to the transmittance of heat produced by the sun via conduction-radiation

During cold months:

- heat dispersion
- discomfort within the environment as the result of excessive humidity
- structural deterioration/alternation and reduction of the durability of roofing materials
- irregular snow melt and sliding of the snow layer

TETTO CALDO

Insulation is essential for creating a roof that reduces heat dispersion, produces noteworthy operational savings and tangible advantages in terms of living comfort, and which protects the structure. This becomes possible if thermal insulation is properly incorporated into a building technology that allows it to perform its role (as a separating layer with an insulating function), but which, at the same time, remains cognizant that roofing as an entire system, in addition to providing heat insulation, must be waterproof, resistant to wind pressure, snow load, accidental loads, etc., and must prevent critical thermohygrometric situations (Fig. 1).

These initial considerations result from the observation of conventional practices, which frequently require the insulation and the waterproofing of the roof (warm roof). This is normally carried out by the direct application of insulating materials onto the bearing structure and, in turn, the application onto the insulating material of a waterproof membrane as an underlayer beneath the roof covering (Fig. 2). A technology of this type may lead to critical thermohygrometric situations because the waterproof membrane placed on the extrados (upper surface) of the roof offers significant resistance to the passage of water vapor, preventing its discharge from the building.

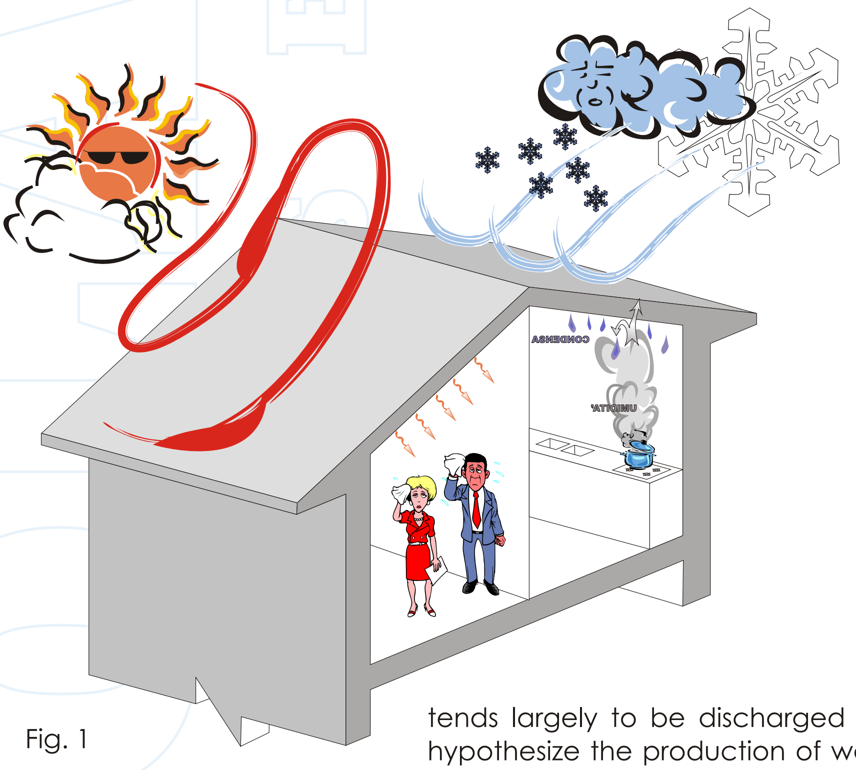


Fig. 1

If we consider that all the water vapor produced inside a building, if it is not removed through air exchange, tends largely to be discharged through the roof and if, in addition, we hypothesize the production of water vapor inside a closed room (placing people inside the room, for example, who are cooking meals or even taking a shower), we see that, at an internal temperature of +25°C, the vapor will disperse into the air without creating any particularly noteworthy effects. As the experiment continues, we will arrive at a point in which we observe that water vapor has begun to condense, forming drops of water. This means that, at that point, the air in the room is saturated and that relative humidity stands at 100%. In such conditions, the amount of water present in the environment is 23g for every m^3 of air. If we were to repeat the same operation with an inside temperature of 0°C, the results would show that, when the relative humidity reaches 100% and condensation begins, the amount of water per m^3 will be only 4.839g. We can deduce from this that the amount of water that the air can support in suspension is a function of and is proportional to the temperature of the air itself. It thus seems clear that, in an insulated roof, with a heat difference between the indoor and outdoor temperatures (during the winter months the inside temperature is generally 20°C while we can conjecture that the outdoor temperature would be 0°C), condensation will be observable in specific areas within the roof. Indeed, if we analyze the roof section point-by-point, repositioning a temperature of +20°C, with 60% relative humidity, from the inside to the outside, the temperature in the roof will progressively decrease until it reaches +12°C, but relative humidity will be 100% (the grams of water in suspension are identical to those present at a temperature of +20°C) (see Table 2) and, as a result, condensation will begin to form inside the roofing package. That, in turn,

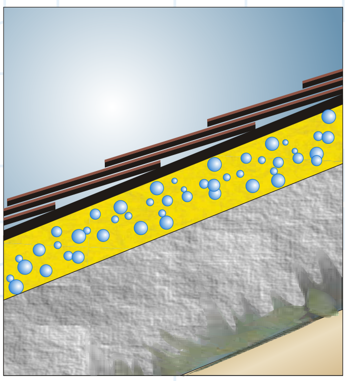


Fig. 2

TABLE OF DEWPOINT TEMPERATURES

internal air temperature °C	Relative humidity of internal air / Dewpoint temperature (or condensation point)										
	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
-10	-17.6	-16.6	-15.7	-14.7	-13.9	-13.2	-12.5	-11.8	-11.2	-11.2	-10.0
-5	-12.9	-11.8	-10.8	-9.9	-9.1	-8.3	-7.60	-6.9	-6.2	-5.6	-5.0
+0	-8.1	-6.6	-5.6	-4.7	-3.8	-3.1	-2.3	-1.6	-0.9	-0.3	+0.0
+2	-6.5	-5.3	-4.3	-3.4	-2.5	-1.6	-0.8	-0.1	-0.6	+1.3	+2.0
+4	-4.8	-3.7	-2.7	-1.8	-0.9	-0.1	+0.8	+1.6	+2.4	+3.2	+4.0
+6	-3.2	-2.1	-1.0	-0.1	+0.9	+1.9	+2.8	+3.6	+4.4	+5.2	+6.0
+8	-1.6	-0.4	+0.7	+1.8	+2.9	+3.9	+4.8	+5.6	+6.4	+7.2	+8.0
+10	+0.1	+1.4	+2.6	+3.7	+4.8	+5.8	+6.7	+7.6	+8.4	+9.2	+10.0
+12	+1.9	+3.2	+4.3	+5.5	+6.6	+7.6	+8.5	+9.5	+10.3	+11.2	+12
+14	+3.8	+5.1	+6.4	+7.5	+8.6	+9.6	+10.6	+11.5	+12.4	+13.2	+14.0
+16	+5.6	+7.0	+8.2	+9.4	+10.5	+11.5	+12.5	+13.4	+14.3	+15.2	+16.0
+18	+7.4	+8.8	+10.1	+11.3	+12.4	+13.5	+14.5	+15.4	+16.3	+17.2	+18
+20	+9.3	+10.7	+12.0	+13.2	+14.3	+15.4	+16.5	+17.4	+18.3	+19.2	+20.0
+22	+11.1	+12.5	+13.9	+15.2	+16.3	+17.4	+18.4	+19.4	+20.3	+21.2	+22.0
+25	+13.8	+15.3	+16.7	+17.9	+19.1	+20.2	+21.3	+22.3	+23.2	+24.1	+25.0
+30	+18.5	+19.9	+21.2	+22.8	+24.2	+25.3	+26.4	+27.5	+28.5	+29.2	+30.0
+35	+23.0	+24.5	+26.0	+27.4	+28.7	+29.9	+31.0	+32.6	+33.1	+34.1	+35.0
+40	+27.6	+29.2	+30.7	+32.1	+33.5	+34.7	+35.9	+37.0	+38.0	+39.0	+40.0

Table 2

leads to the formation of mould, mildew, and humidity stains and to the rapid deterioration of roofing structures and materials.
The insulating material, in addition, as it is permeated with humidity, undergoes a significant loss of its insulating capacity, inasmuch as water is a good heat conductor. The insulating material itself undergoes, as a result of internal humidity, rapid deterioration.
The positioning of the dewpoint in a normal wooden roof, once actual water vapor pressure and saturation pressure trends are calculated, can be seen in the diagram (Glaser Method) (Fig. 3).If the waterproof membrane were not placed on the extrados (upper surface), where it is often used only as a safety precaution for masonry or concrete roofs, the phenomenon would clearly be inferior because water vapor would have the opportunity to move toward the outside air, which, among the materials in question, shows the highest degree of permeability to water vapor.
Evaluating the problem in greater depth, we recognize that roofing materials are not subjected constantly to the most severe weather conditions and that they can even tolerate internal condensation for brief periods, as long as, once the weather improves, condensation can evaporate and insulating materials can return to their optimal operating conditions. In any case, these events need to be considered in the context of the individual building and risks should be evaluated on a case-by-case basis.
In order to resolve the condensation problem and prevent possible deterioration of roofing layers as a result of condensation, the layering of roofing materials itself must be modified, inserting a water vapor barrier (metal) on the intrados (underside) of the insulating material (Fig. 4). Although this does not change the position of the dewpoint, it does alter the "actual water vapor pressure" curve, preventing water vapor from reaching the layers above (those that are colder or more external) and, thus, from condensing, as long as the dewpoint has been correctly positioned within the roofing package.
The excursion into insulated roofs that we've taken up to now has focused primarily on the protection of the materials that make up those roofs, evaluating technological solutions and providing calculations aimed at dealing with the cold season. We have, however, left problems such as snow melt unresolved.

Roof bedding:
- waterproof membrane 4 mm
- glass wool 50 mm
- matchboarding 20 mm

Ambient conditions
- Ti +20° - HR 70%
- Te -10 - HR 70%

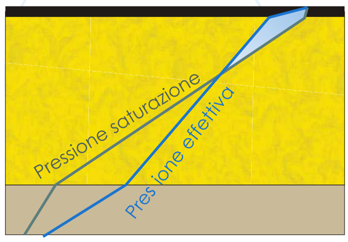


Fig. 3

Roof bedding:
- waterproof membrane 4 mm
- glass wool 50 mm
- **aluminum barrier**
- matchboarding 20 mm

Ambient conditions
- Ti +20° - HR 70%
- Te -10 - HR 70%

Fig. 4

Indeed, whatever the structure's "U" value may be, a heat dispersion always exists that is directly proportional to that value. Consequently, the discharge of heat onto the roof will heat the roof covering first and, next, the snow that has accumulated on it. The underlayer of the snow will thus begin to melt and, as a result, the film of water that has formed beneath the snow will cause the snow to slide toward the eaves where it falls to the ground. The risk at this point is that the movement/accumulation of snow will damage the roof covering and/or gutters. It may even create infiltrations, because dispersion in the eaves is markedly inferior and leads to the formation of ice dams and water traps at the perimeter walls, with consequent water return onto the slope and infiltration into underlying layers (Fig. 5).

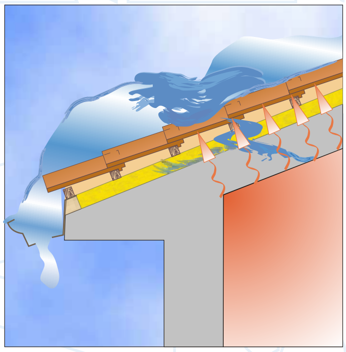


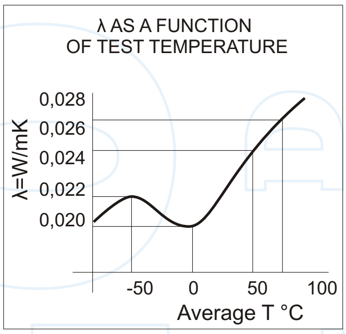
Fig. 5

With the insulation of the roof as described above, the requirements of Legislative Decree 192/05, which are briefly summed up below, are satisfied for the winter months:

- Energy savings.
- Formation of condensation, appearance of mold and mildew.
- Snow melt
- Deterioration of insulating materials and of roof structures.

Let us now turn to an analysis of technical approaches for the summer season.

For all insulating materials, the theoretical value of "λ" has been tested at an operating temperature of 10 °C. If the same tests were to be conducted at higher temperatures, the "λ " values (e.g., 60°C) would produce a progressive and exponential loss of their insulating capacity as temperature increases, as shown in Graph. 2.



Graph.2

This information helps us to evaluate the behavior of the insulating layer in a warm roof, when the temperature, following a period of daily solar radiation, may even reach 75/80 °C while night time cooling may result in values even below 20 °C. If we compare heat conditions with variations in insulating ability defined by "λ ," we come to realize that the heat transfer (and, thus, the accumulation of heat within inhabited attics) during daylight hours is markedly greater than is the possibility of discharging that heat during evening or night time hours. This is true because the resistance offered by insulating material, when it is no longer receiving the sun's rays, returns to its basic state, slowing or stopping the discharge of heat accumulated during the day. The effects of this heat flow in inhabited atticswhich, at first, is directed from the outside to the inside and, later, from the inside toward the outside (because heat moves toward the cold)render the environment barely tolerable during the evening-night time hours. Indeed, that phase of the day seems hotter, more humid, and more uncomfortable than the external environment as the result of heat radiation from the surface of the roof. The amount of absorbed Kcal is enormous (as much as 500 Kcal/m^2 [582 W/h m^2]), and this heat radiates into the environment for hours at night, creating significant discomfort until the temperature of the roof surface once again matches the ambient temperature. Comments such as "it was hotter inside than outside" or "I was only able to rest after three in the morning when it started to cool off" will hardly sound unfamiliar. (Fig. 6).

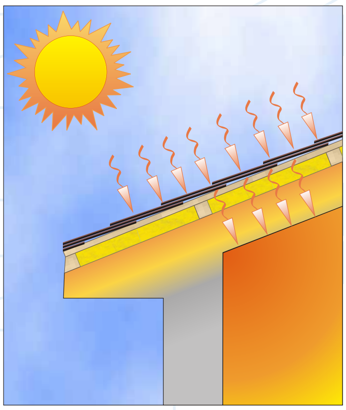


Fig.6

In the sections that follow, we will evaluate a technology that, when applied to pitched roofs, can resolve problems of thermohygrometric comfort in a passive mode during the hot season, in keeping with Legislative Decree 192/05.

VENTILATED ROOFS AND THERMOHYGROMETRIC COMFORT

The attention and the sense of emergency that has gripped Europe regarding environmental protection is shifting attention toward energy savings that result from ecocompatible development. This has led to the development of technologies aimed at maintaining a constant internal building temperature and to containment of energy waste.
Experience leads us to believe that this new attention, no matter how worthy and important the goal, may not produce the level of well-being that human beings want. Indeed, the perception of temperature depends upon a combination of factors that may be summed up as follows:

- Internal air temperature
- Surface temperature of walls and ceiling
- Level of insulation of glazed areas
- Relative humidity of the environment

A consideration of thermohygrometric comfort, then, becomes essential. Unfortunately, as one may have guessed from these preliminary remarks, new housing needs, even if they do receive the attention they require, can produce problems such as the appearance of mold and mildew or the premature deterioration of the elements that make up the roof.
Experience confirms that, in the majority of cases, such phenomena are not directly attributable to the roofing materials themselves but to a design that is often completed in haste or which lacks the essential elements that would allow the building to be considered in a global sense.
Perhaps the most important passive-type solution for thermohygrometric comfort is the ventilated roof. If we think about the buildings that are part of the Italian tradition, whether in urban or mountain settings, it is clear that builders were fully aware of the concept of thermohygrometric comfort. The design of those wooden roofs included "breathability," water-vapor permeability, and the use of air to avoid the overheating of under-roof spaces during the summer season, techniques born from the builders' careful observation of their errors and aimed at protecting wood from deterioration. It was only later that the human element was considered: the designer's main interest was in making sure that his work was durable and would last through time. There is no denying that changing needs and recent technologies (such as insulation, new tools for efficient weatherproofing, and the use of concrete and hollow clay infill blocks for roofing) have created new potential in the building industry, but it is equally true that they have notably reduced building permeability, suffocating the materials that are used in the construction of the building envelope, and, with them, us. It's only in the last decade that those basic principles for proper design and living have been rediscovered. Thus, let's look at the benefits of roof systems that take such considerations into account, organizing the various layers in a way that ensures both excellent performance and durability. The ventilated roof is the best passive-roofing technique available and offers numerous advantages for living comfort, structural durability, and energy savings (see Fig. 7).

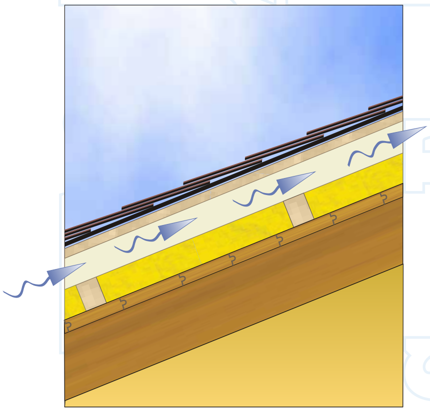


Fig.7

A ventilated roof can be considered "ventilated" when roof sheathing is detached from the insulating layer (Fig. 8), or from the structural/laying surface if insulation is not present, thus creating an air gap in which air moves upward. The air, that is, heated by conduction-convection through the roof covering under the influence of solar radiation, increases in volume, decreases in weight, and rises toward the roof ridge, where it is discharged. In so doing, "fresh" air is taken in from the eaves (the chimney effect, see Fig. 7). In this way, the heat accumulated in the roof covering is eliminated naturally and progressively, avoiding transmittance into the building. The temperature of the intrados (underside) of the roofing materials will thus be only slightly higher than that of the outside air. In the winter, air circulation will ensure that

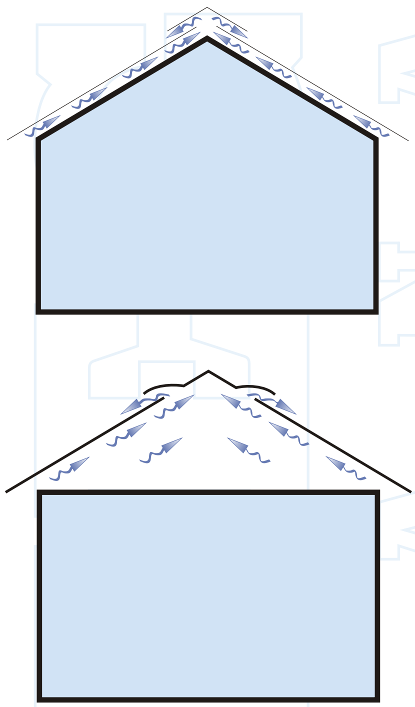


Fig.8

the insulating material is always well-ventilated (and therefore dry), avoiding the formation of internal condensation. This allows the insulating material to maintain its insulating properties, which might otherwise be compromised by up to 80%, depending upon the product used.
In order for ventilated roofs to produce natural air circulation, certain conditions are essential:

- There must be a slope present in the roof.
- There must be an air mass available internally, that can be discharged from openings in the ridge in order to be replaced by ambient-temperature air through openings in the eaves.
- There must be a difference in temperature between the outside air and the air in the ventilation chamber.

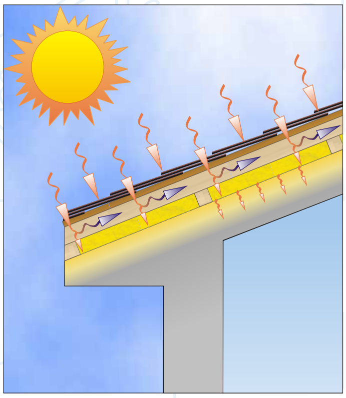


Fig.9

It follows that the thermal properties of the roof are decidedly improved with the introduction of a ventilation chamber in the roof bedding, which allows noteworthy energy savings both in summer and in winter. In addition, it makes it possible for the roof to "breathe" (excuse the term) and, consequently, provides for greater efficiency and durability of roofing materials. Above all, however, it permits the use of the under-roof space as a living unit, creating a noteworthy improvement in living comfort both in the summer and the winter through a moderate initial investment and an ongoing cost of zero.
During the summer season, or in mountain areas where solar radiation is particularly strong, the ventilation chamber allows the heat accumulated in roofing structures to be quickly dispersed and keeps it from being transmitted into the building (Fig. 9). When it is cold, the ventilated roof eliminates common, annoying condensation that is in turn the source of mold and mildew, humidity, and drip. As a result, the durability of all the roofing elements is increased (insulating materials, structures) because they remain dry. In mountain areas, where the presence of snow on the roof frequently causes ice dams to form in the projection of the eaves (Fig. 10), ventilated roofs offer the unique advantage of blocking their formation, causing water vapor or heat dispersion to flow out through the air outlets placed along the ridge line for that purpose and permitting snow to melt as a result of solar radiation. The overall performance that the ventilated roof provides is unequaled by any other roofing system and constitutes a roofing package whose efficiency does not decrease as time passes. Moreover, the construction technology of the Tegola Canadese ventilated roof in no way limits the technical and aesthetic requirements of the designer, providing excellent results even in the most unusual situations (Fig. 11).

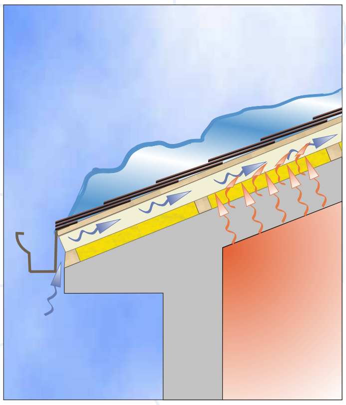


Fig.10

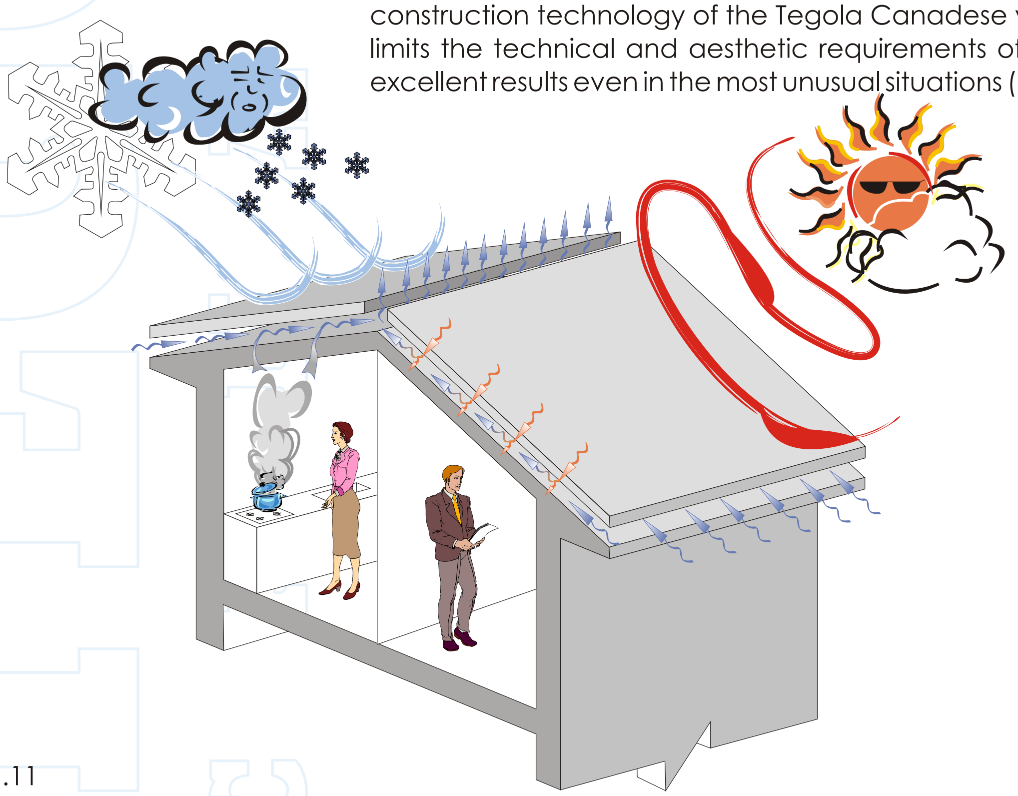


Fig.11

SIZING AND CONSTRUCTION OF VENTILATED ROOFS

Efficient air circulation within the “ventilated roof” requires the correct sizing of the ventilation chamber, whose thickness is a function of the length and pitch of the slope. A long or limited slope requires that the ventilation chamber be thicker, as the values reported in Table 11 (Appendix 2, p. 61) show. Indeed, it becomes obvious that a minor slope in the roof must correspond to greater thickness in the ventilation chamber, in order to compensate for the reduced slope with an increase in available air mass. In addition, the length of the slope also becomes an impediment to natural air circulation, making it necessary to increase the thickness of the ventilation chamber in correspondence with the length of the slope. The size of air inlets and outlets is also calculated on the basis of the pitch of the roof and the length of the slope (Table 12 and Table 13).

Fig.12

The installation of the Tegola Canadese ventilated roof is simple and quick, regardless of the underlying structure (wood, concrete, metal). The principal stages of installation are show in (Fig. 15):

- Attachment of battens, parallel to the eaves and at a distance equal to the dimensions of the insulating material.
- Installation of insulating material between the battens
- The second layer of counter-battens is laid, at a right angle to the first with interspacing of 61 cm or 48 cm. The size of the battens determines the thickness of the ventilation chamber.
- The laying surface, made up of staggered exterior plywood panels (phenolic plywood for outside use), is then applied and attached onto supports. To increase bearing capacity and reduce bending force and, consequently, to add flatness and stability to the laying surface, metal clips are placed between the panels.
- The roof is finished with the application of the Tegola Canadese roof covering which shows the architectural line to best advantage and completes a system whose advantages are numerous.

Fig.13

The stages described must be integrated into the construction of air inlets (Fig. 14) and outlets (Fig. 12 and 13). The most common variety allows an inlet and a continuous discharge in the entire roof section. In some contexts, in response to technical or aesthetic demands, ventilation openings may be required, which can function both as inlets and as outlets (Fig. 13). These small, round openings provide a ventilating surface of 150 cm^2 each.

Fig.14

Fig.15

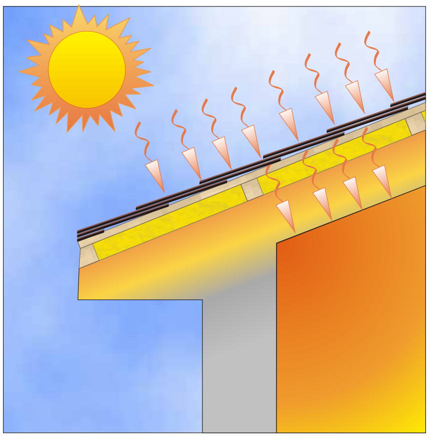
COMPARATIVE ANALYSES

In the preceding pages we have seen the thermohygrometric advantages provided by the ventilated roof, which makes under-roof and attic areas functional, renders them perfectly habitable, and guarantees them a greater level of comfort. In order to make these advantages clearer, the following diagram compares first the warm season and then the cold one.

	Warm roof	Ventilated roof

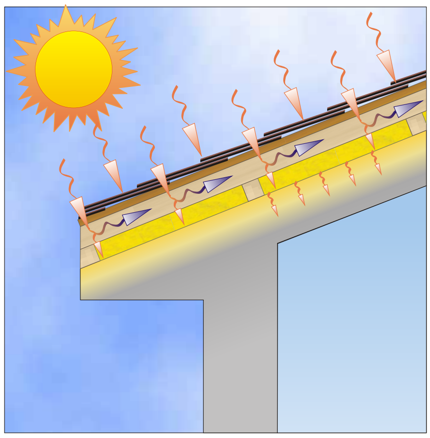
Hot season

Warm roof



The roof, heated by sunlight, transmits heat to the insulating material which can function only as a heat retardant. Heat is next transferred to the roof's bearing structures and to the interior of the building.

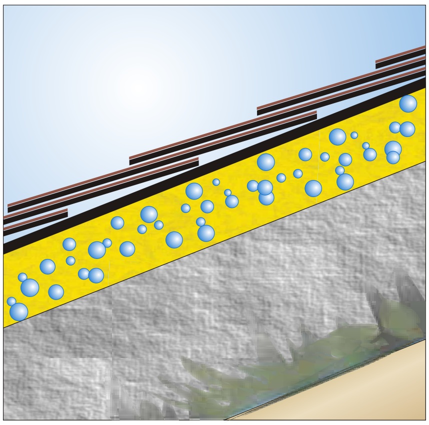
Ventilated roof



The cool air present in the ventilation chamber warms as a result of solar radiation, becomes lighter, and is discharged from the roof ridge, removing heat from insulating material.

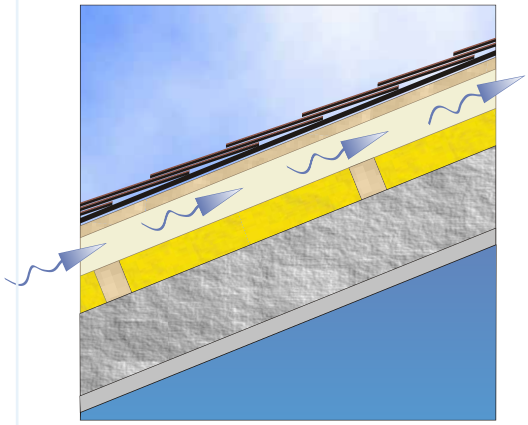
Cold season

Warm roof



As a result of low temperatures, condensation, and resulting mould, mildew, humidity, and drip, may be seen in roofing structures.

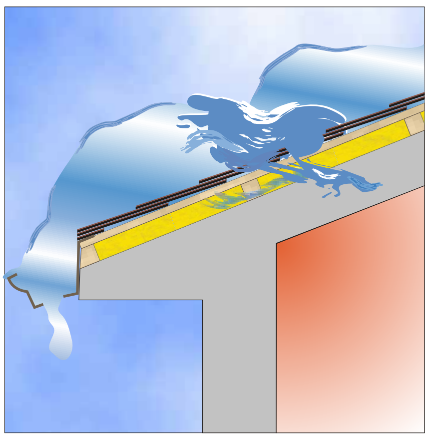
Ventilated roof



In the winter, air circulation will ensure that the insulating material stays dry, thus avoiding the formation of condensation and guaranteeing the durability of roofing materials.

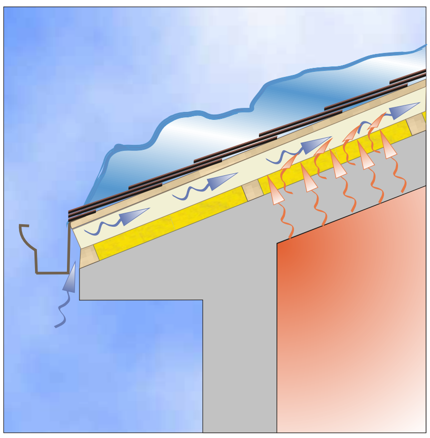
Cold season

Warm roof



In mountain areas, dangerous ice dams are easily created on the overhang of the eaves, resulting in infiltration of roofing structures.

Ventilated roof



Ventilation permits the uniform melting of snow that has accumulated on the roof, thus avoiding the formation of ice dams.

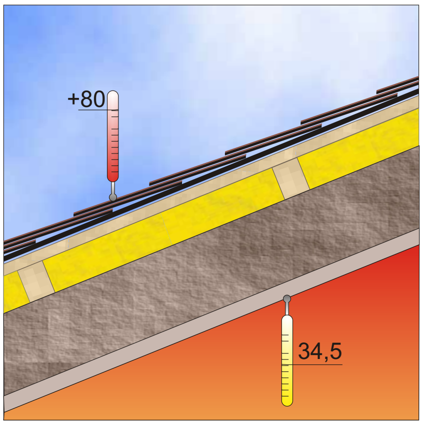
COMPARATIVE ANALYSIS
OF THE THERMAL PERFORMANCE OF ROOFS

Below a series of tests and results are reported. These confirm the benefits produced by various kinds of roofing structures (the influence of which is naturally significant).

HYPOTHETICAL WEATHER CONDITIONS.
- Roof sheathing temperature of +80°C
- Ambient air temperature of + 25°C
- Exposure to 10 hours of sunlight, not considering possible dispersion from the underlying environment
- Absence of wind
- Identical insulating material of equal thickness for all tests

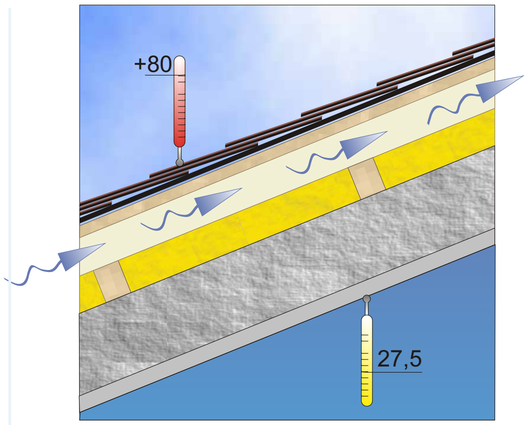
Structure in structural lightweight concrete

Warm roof



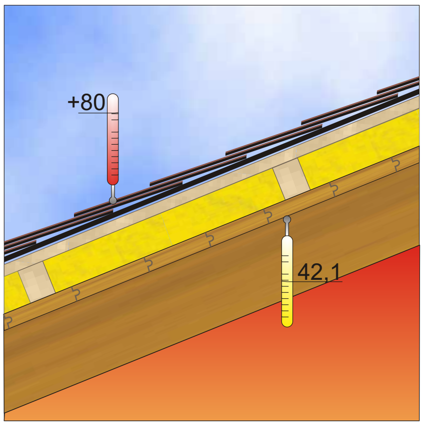
- Roof U-value = 0.5
- Temperature of plasterwork after 10 hours of exposure to sunlight: +34.5°C
- Absorbed W/h: 523 per m² of roof

Ventilated roof

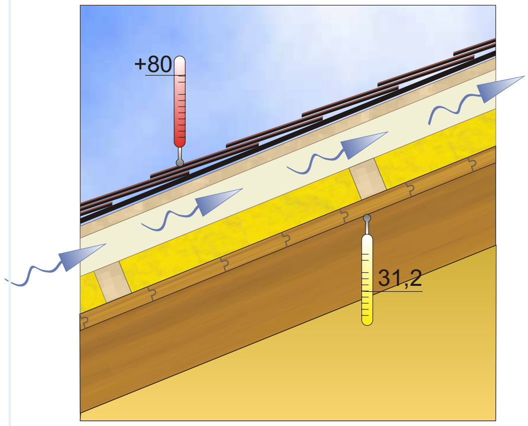


- Roof U-value = 0.5
- Temperature of plasterwork after 10 hours of exposure to sunlight: +27.5°C
- Absorbed W/h: 116 per m² of roof

Wooden structure



- Roof U-value = 0.5
- Temperature of the matchboard after 10 hours of exposure to sunlight: +42.1°C
- Absorbed W/h: 319 per m² of roof



- Roof U-value = 0.5
- Temperature of the matchboard after 10
- hours of exposure to sunlight: +31.2°C
- Absorbed W/h: 116 per m² of roof

The ventilated roof is the most advanced technique available for the construction of roofs with thermal insulation in the slope. The heat advantages it offers are made abundantly clear by the outcome of testing that two different roofing typeswith either concrete or wooden structureshave undergone. The ventilated roof complies with the provisions of Legislative Decree 192/05 aimed at limiting energy demands for summertime air conditioning and at controlling inside temperatures.

CONTROLLING WATER VAPOR

Roofing, as a complex construction system, is intended to perform in a specific way, and is composed of a series of elements (specific structures, seals and insulation, accessories) which contribute to its general functioning and among which appropriate or inappropriate (unintentional) interactions may occur. Roofing should be waterproof, resistant to weather-related stress, and correctly insulated, but in addition it should also be designed in such as way as to ensure that critical hygrothermal conditions are not created at its interior a situation that is particularly common during the winter months when the following are common:

- heated inside environments
- reduced or absent air exchange
- severe outside temperatures

The relatively recent popularity of the use of under-roof areas as living spaces has underscored these needs. Such areas have been transformed from wasted space into valuable mansards and "half-lofts" (creating a new kind of construction in the process). In these attic/mansard areas, but also in the case of swimming pools, restaurants and other structures in which the production of water vapor compromises functioning and durability of the building envelope, it becomes necessary to employ technological layers in order to regulate the passage of water vapor. In so doing, both the user of the space and the materials used in building the roof, which are naturally subjected to this flow of vapor that tends to be discharged through the roof, are benefited. Physical comfort is strictly tied to the thermohygrometric conditions of the living environment and thus the need to control and manage the temperature and humidity of the environment arises: This can be accomplished only through the proper use of materials and systems that allow "breathability," waterproofing, insulation, etc.
As far as weather-related issues are concerned, the primary needs are protection from rain and the maintenance of temperatures at an acceptable level even during the winterthus, excellent waterproofing and good heat insulation are essential qualities.
Constant improvement in materials' waterproofing and insulating qualities (and the inexperience of the user) has nonetheless highlighted the inadequacy of thermohygrometric controls. It is, then, sometimes the condensation of the water vapor created inside the building that produces problems similar to those that result from the infiltration of rain wateror worse, if condensation water has stood for long periods in insulating materials.To translate these concepts into numbers, comfort conditions exist at +20°C with relative humidity between 35% and 70% (assuming 17.3 g/m^3, 100% relative humidity means from 5.19 g/m^3 to 12.11 g/m^3). Note that at 40°C, the saturation pressure is much higher and the same amount of water vapor, on a percentage basis, is much smaller: 9% and 22%. This explains differing sensations or discomfort in very humid areas even if they are relatively cool and of comfort in areas that are very hot but dry.
But let us return to the roof bedding and to the waterproof membranes that may come into contact with meteoric water (construction phase) but which block or foster the flow of water vapor that comes from inside the building. In order to technically evaluate a product, we need parameters that are easily understood and technically reproducible. In our specific case, we need to evaluate how much a membrane will block the passage of water vapor, and the parameter to be evaluated is the "sD" (factor of resistance to the passage of water vapor) which is measured in meters.
Water vapor is a gas and follows the physical laws of gases. Resultantly, diffusion will always be from areas of greater pressure toward areas of lesser pressure (generally, from warm areas to cold areas or from the inside to the outside of buildings). Thus, the ability of water vapor to be diffused should increase from the inside toward the outside.

Vapor barriers must be placed exclusively in warm areas within the insulation. To provide a higher drying capability, use materials with an sD value that increases from outside to inside (which is absolutely necessary in wooden structures to prevent the growth of mould and mildew). (See Fig. 16.)

The factors that influence permeability to water vapor are:

- The diffusion resistance factor (with respect to the air) = "μ"
- The thickness of the material = "s" in m
- Internal and external air temperatures "t" in °C
- Relative humidity and pressure gradient "φ"

By definition sD= μ s

In order to determine the μ value, one experimentally evaluates the amount of water vapor that passes through the product sample and compares that with the relative air value.

In order to render the results uniform, the analysis is conducted at 23°C and 85% HR (relative humidity).

The diffusion of water vapor through the membranes is evaluated experimentally:

the movement of water vapor from the external environment toward receptors (Fig. 17), which are weighed before and after the experiment. Their weight determines how much water vapor has crossed the membrane being analyzed and which separates the two environments.

The result is WDD=g/m^2 x die

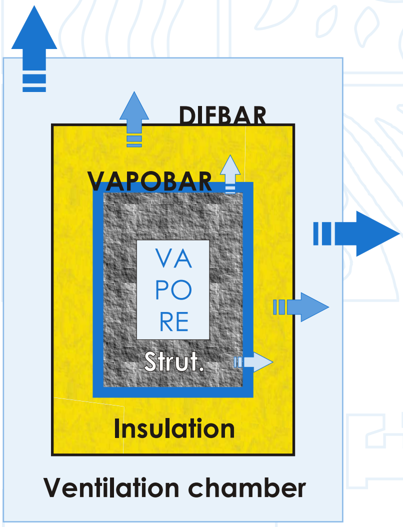


Fig.16

μ = 40000/WDD s

sD= μ s [m]

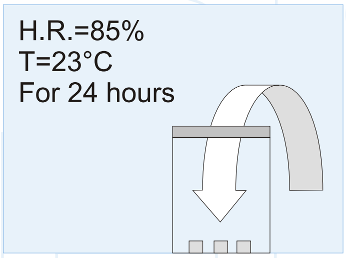


Fig.17

"the value in m (meters) can be considered the air layer equivalent to provide identical resistance to the passage of water vapor." The smaller the sD value, the better is its ability to allow water vapor to pass.

Classification of membranes as a function of the "sD": sD = μ x thickness in meters		
Type	Thickness equivalent to sD diffusion in m	Permeability to water vapor WDD [g/m^2 die]
VAPOR DIFFUSERS	0,02<0,2	1200>120
VAPOR BREAKS	0,2<130	0,24<120
VAPOR BARRIERS	>130	<0,24
METAL VAPOR BARRIERS (copper-aluminum)	Infinite	0

Table 3

Energy savings and the use of insulating materials require the control and the regulation of the passage of water vapor through the roof. Alubar, Vapobar, and Difbar are products that make it possible to create healthy, well insulated, and well protected environments. The perfect regulation of humidity within the living unit increases well-being.

In "warm" roofs it is difficult to force water vapor out of the roof because of the lack of ventilation within the roof bedding. The presence of a waterproof membrane on the extrados (upper surface) of the roof (with an sD=120) keeps water vapor from being discharged. In critical environmental conditions, vapor can condense within insulating materials causing premature deterioration of the roofing package.

Size the insulating material so as to position the dewpoint within it and place the "Alubar" membrane (vapor barrier) beneath the insulating material and thus beneath the dewpoint (as shown in Fig. 18). In so doing, water vapor is prevented from reaching the insulating material (and consequently the dewpoint) and cannot condense.

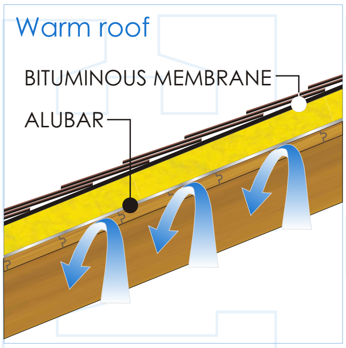


Fig.18

Ventilated roofs allow water vapor produced inside the living area to be discharged through the roof, maintaining appropriate thermohygrometric conditions and, consequently, comfort within the environment. To allow this flow of water vapor without losing efficiency in the insulating layer, it is advisable to position the Vapobar and Difbar membranes as shown in Fig. 19-20. In wooden roofs, Vapobar controls excess water vapor (cooking, etc.) and prevents cracking of the matchboard, keeping it in better hygrometric balance. In addition, it provides a separating layer between the roof and the internal environment, defending it from particulates that may enter through the normal structural movement that is typical of a wooden roof. Difbar in no way blocks the flow of water vapor; rather, because it is waterproof, it protects insulating material from possible infiltrations. The layering is made up of materials with sD values decreasing toward the exterior. Any waterproof membrane laid on the extrados (upper surface) of the roof has no impact on the management of water vapor because the thin layer of air in the ventilation chamber constitutes a first line of defense and allows the vapor to be discharged naturally.

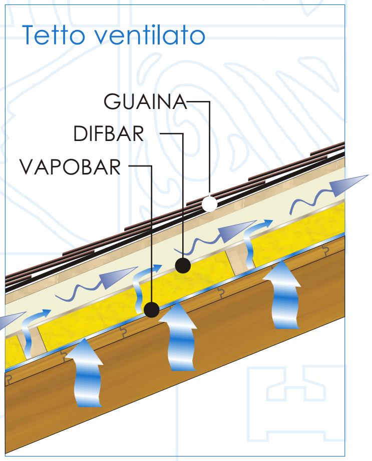


Fig.19

Fig.20

CONCLUSIONS

Judging from what we have observed up to this point, it seems evident that innovationregardless of what the building-products market does or will offercan develop appreciably only if the design strategies of building systems are able to optimize the potential offered by research and by the marketplace. Specifically, the most interesting developments involve the creation of hybrid systems or the improvement of the building envelope by means of passive solutions such as roofs or ventilated wallssystems in which internal environmental performance, during the entire year and according to the season and external climatic conditions, may be controlled via natural systems, reducing the use of heating/air conditioning systems to the most critical periods.

It is, then, design innovation alone that has the ability to effectively bring to built environments the development potentials that are encompassed by the concept of sustainability, too often trivialized as cultural exoticism. It thus becomes essential to expand or to abandon the design approach contained in the "learn by doing" method in favor of a more solid approach based on doing after having acquired a certain level of information ("do by learning"). That, in turn, obviously requires modification of training programs at all levels, as well as basic change in the degree of discretionary power present in current design practices, whose deployment in poorly integrated specialized stages constitutes a significant barrier to innovation and affects building industry systems and processes as a whole.