PERIODICA POLYTECHNICA SER. CIVIL ENG. VOL. 37, NO. 3, PP. 203–229 (1993)

DESIGN, STRUCTURAL AND BUILDING PHYSICAL PROBLEMS FOR BUILT-UP GARRET SPACES

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Received: June 2, 1993

Abstract

In the past decades, the volume of built-up garret spaces has significantly increased throughout Europe, hence also in this country, primarily, to increase housing stock, but also to utilize garrets for other functions. Garret-space building-up raised significant architectural, structural, building physical problems not always reckoned with by designers and constructors. An attempt is made to recapitulate all design, structural and building physical principles likely to help to develop correct solutions of building-up. Various methods of building-up, correct solutions for layer systems under roofings will be listed, completed with other scopes of importance for roof and wall structures, illumination, thermal engineering and the like, here only superficially treated, illustrated in diagrams (*Fig. 1–11*).

Keywords: garret-space building-up, structural design, building physics.

Introduction

Origins of the tendency to build up garret spaces — increasing in Europe just as in this country — need no special analysis, only to mention essential motives. First of all, utilization of garret spaces is a new possibility to increase the housing stock, of both personal and national interest. Beyond that, there is also the structural instability of flat roofs, interior space forming arising from the nostalgia for old-timer forms — actually overbidden —, as well as an aesthetic approach manifest in the appearance.

This simple formulation may involve a simplification omitting a wide range of consequences arising from these factors, omitting seemingly insignificant construction requirements. Now, a short survey will be given of all structural, building physical, technological, etc., factors ignored in simplifications, pointing out the loss of advantages of the original garret space /the possibility of internal checking of the roof shell, easy detection and repair of leakage points, climatic balance by the attic/. Loss of these advantages may raise real problems if, in design and construction, offsetting of constructional and building physical conditions is omitted.

There are three fundamental cases of garret building-up:

- built-up garret designed with the building;
- transformation of a flat roof into a pitch roof with built-up garret space;
- ulterior building-up of a garret space of an existing building.

At the same time this list is one of eventual design possibilities. Hence, a built-up garret space simultaneously designed with the building, reckoning with actual restrictions, offers the relative maximum of freedom for a correct structure and function. Both other cases raise more of restrictions and limiting factors.

Eventually, problems may arise from adaptation to quality, structural, formal conditions of the existing roof, while for flat roofs, significant alterations have to be reckoned with, of impact also on the environment. In both cases, the designer has to cope with functional difficulties and with requirements of vertical traffic.

Factors Affecting Design of Garret-Space Building-Up

Building-Up Alternatives

Ponderation over alternatives is an initial, primary problem for garret-space building-up, involving rather wide ranges of circumstances and possibilities. Without claim to completeness, the most typical varieties are:

- Detached, low-rise /2–4 storey/ family houses;
- detached multi-storey buildings;
- semi-detached family houses with a common wall;
- rows of low-rise /2 to 4 storey/ family houses;
- atrium-system family houses;
- multistorey strip buildings;
- block /frame/ system of development.

Obviously, among them, the detached houses offer the most convenient garret building-up possibilities, permitting a wide variety of designs — from simple quadratic forms to more complex layouts and mass arrangements, by means of multidirectional façade and roof designs. This multidirectionality also provides for optimum orientation possibilities. For cases of building-up at, or at 3 m from the sidewall, certain limitations in the neighbouring direction have to be reckoned with (see Building Codes).

In designing multi-storey buildings of different heights, vertical traffic means have to be reckoned with, in particular, position of staircases and elevators, and their relation to the garret level, functional relation between the garret and the underlying storey.

For semi-detached family houses with a common gable, three façade or roof surfaces are available for design, while for row houses of a few storeys /strip row, gap-row, linked strip, scattered, sawtooth and loose/, double façade of the building has to be reckoned with, so that rooms in need of sunshine face the optimum orientation.

For atrium-system family houses, the mode of development (closed, L, U), in groups or in carpets, is determinant for the aspect, ways and possibilities of fenestration of the built-up garret-space.

For multi-storey buildings in strips, overall or partial garret space building-up may follow rules for residential estates (air volume, spacing, etc.). In living houses, the staircase may rise to the garret level, permitting to develop independent home units. In living and office buildings with corridors, two-level units with inner stairs may be constructed. For strip buildings, the two main façades prevail in roof formation, but abutments of the building may also be opened in a third direction.

Development in unbroken rows or in gap frames offers a rather wide variety of garret-space building-up methods, taking differences of orientations within a block (medium and final sections) into account.

Roof Structure, Slope, Form, Roofing, Façade Height and Other Problems

For a garret-space building-up designed with the building, up-to-date, economical trusses, of an optimum space utilization, have to be applied. Systems generalized in this country are: Rotip, Gang Nail, Alba Zenit, Borsod, Pannon-Wolf, and among the composite ones (metal + wood), Filigran. While among conventional trusses, those best meeting the endeavours above: box-section, collar beam may be reckoned with. Purlin trusses supported on strong intermediate floors — in transversally walled buildings — suit to apply (bolted-down) middle purlins, and to form rafting. This solution also helps space utilization at will. A massive slab structure may be extended to oblique lateral surfaces to form sub-windows, as well as to parapet walls, to produce a type of structurally favourable box or staggered slab. Also material selection has to strive not to restrict free space forming (e.g. steel or r.c. frameworks, units).

Roofing and slopes, forms of different roof parts are integer factors. Most of scale-tile roofings suit for deeper sloping roofs convenient for garret-space building-up. For the popular arched and other formations it is, however, advisable to ponder application of certain suitable kinds of scale roofings (flat tiles, rectangular asbestos slates, bituminous shingles). For mildly sloping arched roof surfaces, also up-to-date interlocking tiles may be applied. For special roof configurations, metallic sheet roofs of different materials (tin, copper, aluminium, steel) are possible. In design, however, it must be kept in mind that metal sheet surfaces may be criticized from architectural aspects.

Respect of regional specifications for façade heights is determinant in building design. These have several consequences, depending on local conditions, e.g. determination of storey number, inner or outer parapet walls, parapet height for roof lights, and ridge height.

Design involves to determine the number of useful storeys inside the garret-space. Mostly the system of one storey + loft is applied. For the sake of economical space utilization, even two-storey solutions are frequent, with a minor — or no — loft. All these determine the type of floor(s) above the built-up garret-spaces. These may be continuous with the truss or e.g. may be massive floors supported on structural transversal walls.

Outer parapets of different heights contribute to the utility of the garret space to be built up. In design it has to be reckoned with that truss-dependent lateral forces affecting the outer parapet elicit bending stresses, limiting parapet height. Because of its height, the outer parapet wall and eaves have a combined effect on the building façade appearance. An outer parapet adds to the façade height, to be pondered with respect to specifications.

Inner parapet walls restrict the exploitation of the space to be built up, hence it has less effect on the formation of eaves and façade: if correctly designed, no lateral pressure has to be reckoned with. For an inner parapet wall, also the relative façade height is less.

The utilizable floor area depends on the given roof form. Space exploitation is maximum for steeply sloping pitch roofs with outer parapet walls, also arched or gambrel (Mansard) roofs spanning all the space, as well as partly hipped designs are favourable. Forms with no outer parapet walls, other than hipped or single-pitch roofs are less favourable for inner space utilization.

The so-called useful floor area is the area with a headroom of 1.90 m or more. The area between the parapet wall and the headroom of 1.90 m suits certain utilizations (sight, couch, desk, built-in cupboard, radiator, kitchen furniture, bath tub, lavatory, WC) depending on the parapet wall height and on the roof slope. In the case of an inner parapet, the part between the eaves and the parapet wall may be considered as a loss, of a rate again depending on the parapet wall height and the roof slope.

In case of a garret-space building-up designed simultaneously with the building, a priori the whole installation needs inside the garret space may be reckoned with — at a difference from ulterior garret-space building-up. For building up in two times, bases for certain installations (water, sewage, electricity, heating, etc. ducts) have to be provided for already in the first time.

Problems of Layout (Functional) Design of the Garret Space

In case of garret-space building-up designed simultaneously with the building, there is a possibility to design a functionally complete apartment, though, with several restrictions, such as:

- layout area;
- roof form, slope;
- providing for vertical traffic (staircase);
- structural and installational unity between garret space and lower storeys.

Design is different according to whether if refers to a single-storey or a two-storey building-up. A single-storey solution requires a greater floor area and a higher proportion of inner rooms, or an apartment of less floor area has to be made up with. Two storeys increase the floor area, at a reduced or zeroed number of inner rooms. The layout has to include an inner stair flight.

One- or Two-Storey Building-Up of the Garret-Space Joining the Underlying Storey

Well organizable, two- or three-storey apartments of large floor areas, maybe for several generations, with a space with gallery formation, are possible by connecting the garret space and the underlying storey. Layouts are similar to those of two-storey apartments, excepted that certain functions (work-room, studio, etc.) may be on a separate storey.

Other than Residential Garret-Space Utilizations

Garret spaces of different residential (urban, recreational, sports, tourism, etc.) and office-type buildings may be well utilized for functions proper to the given building. These building types are assumed to have a layout with corridors accommodating sanitary units for each room unit, or a separate water block, joining the underlying storeys. Room units and lavatories in wider buildings may join a middle corridor, possibly with natural illumination from the abutment wall.

Roof Shape Dependent Design

In case of gable pitch roofs, designers mostly make use of architectonic hence illuminational advantages of gables. These may include solitary windows, balconies, or terrace-vitrous wall systems extended to all the façade width. Purlins overlapping along the gable edge permit the terrace or loggia at the gable wall to be partially or entirely covered.

Natural Illumination of Garret-Space Rooms

A window in the roof plane – one of the most frequent means of garret space illumination – has several constructional, positional requirements. Normally, window dimensions are such as to fill rafter gaps. In need of narrower roof windows than that, an auxiliary skeleton has to be applied; if bigger ones are needed, then the rafter has to be trimmed. The window position in the roof plane is determined by the parapet height, the lintel height, and the roof slope. Advisably, the window lintel is at max. 2.00 m from the floor plane. For a greater height than that, it is beyond reach and needs a bar, a string or a mechanism to be handled.

As to functioning, there may be horizontally pivotted or top hung windows.

Special care is needed in forming connections around the window perimeter – roof shell, metal sheet borders, caulkings, heat insulation, plastic sheet, drain.

For windows protruding from the roof plane, vertical window plane, hence easier handling is a doubtless advantage, at the same time it requires an intensive intervention into the roof structure. Some among the numerous formal and structural solutions for so-called subsidiary roof windows frequently applied are the following. As to shape, there may be pitch roof, arcuated, broken plane (trapezoidal, etc.) flat or raised roof plane designs. Structural aspects are also related to the window position, namely, whether they are built on an inner or outer parapet, or independent of it.

Cut-back window and door systems are also effective in motivating the built-up garret space. roof configuration, and may much affect all the roof structure, in particular, if the cutback suits at the same time development of a roof terrace-loggia.

A free-standing gable roof offers a means of illumination, on one hand, as solitary windows, on the other hand, as French balconies, loggias and balconies. Thus, essentially, all the possibilities offered by external walls occur, including various sun shields.

Floors

An important problem in design and construction is to select the rafter space (dividing) floor structure, the more so since the floor structure as basic roof floor – if properly designed – is an integer part of the designed building. Most of these floors are compact, but there are up-to-date roof structures (e.g. Pannon-Wolf) where the timber basic floor is an integer part of the system. Structurally, rafter space dividing floors have the following possibilities.

Floor structures – mostly non-passable – united with the floor structure where collar beam, pair of grips and upper tie beam row are joists of the dividing floor. These solutions fit both conventional and up-to-date roof structures, depending on the expected function of the garret space.

In this way, two kinds of floor systems may arise: either a high-grade space division of a complex set of layers, with flooring, etc., or an attic where the floor forms a ceiling system with lining, heart insulation, vapour barried sheet and board walk for occasional traffic. In designing the floor structure distinction has to be made between conventional and up-to-date roof structures also from the aspect of the truss type.

Massive garret space floors may be of different kinds. Extending of the transversal or longitudinal structure of the building to the garret space permits a monolithic or precast r.c. structure to be applied for the garret space floor (slab, beam, joist, etc.). The load bearing structure may be a wall, a wall and a superposed lintel, or a semi-skeleton or skeleton system.

A monolithic r.c. broken-plane slab, truly following the shape of the garret-space built-up, a priori includes the garret space floor.

Also roof structures composed of hot or cold-rolled, solid or hollow web steel frames or bar units suit forming of lightweight floor structures, maybe for composite structures of reinforced concrete and steel.

Roof as Outer Confinement of Built-Up Garret Spaces

Outer confining roof structures for built-up garret spaces – one of the most important structural problems – belong among double-shell cold roofs. Essentially, a double shell includes an aerated core between shells or layers. Structural design aspects to be respected are:

- the outer shell hence roofing has to be such as to drain rainwater and to prevent it from entering internal layers and rooms, taking shell material, fastening, slope, accessories into consideration;
- necessity of a safety rainwater sealing under the shell (sheet or plate);

- aeration of air layer above and below the safety dampproofing, to avoid – on one hand – primary (sub-sheet), on the other hand – secondary (over-sheet) condensation, and to reduce summer heat load;
- thermal insulation of the required material and thickness providing for the standard thermal transmission factor;
- application of inner vapour barrier, joint sealed sheet;
- selection of inner linings of the due material and texture;
- sound-damping requirements for structures confining the built-up garret space.

In order to function perfectly, the listed system of layers requires several detailed analyses.

Among roof shell systems, up-to-date scale-type roofing methods with a number of accessory units (vents, edges, snow-fence, piercing shields, running board tiles, safety grids, combs, perforated bands closing air funnels, various cone washers, valley units, etc,) meet the wide range of demands for garret-space building-up. For certain conventional roofings, most of the listed accessories are missing, so that the designer attempts to supplement them by individual solutions, with more or less success.

The shell support may be of different structures, depending on the roofing, the safety rainwater sealing, and the way of aeration. Possibilities are:

- safety rainwater sealing (sheet) placed on the rafter, with the intermediary of a counter-lath, providing for two aerated air layers;
- safety rainwater sealing (e.g. tar paper) supported on spaced board, over that a counter-lath provides for two aerated air layers;
- the shell (artificial slate, bituminous shingles) is supported on boards overlying the rafters, with the intermediary of a safety rainwater sealing, without an upper aerated air layer;
- counter-lath overlying a hard thermal insulation on rafters, with an inner lining fixed to the lower plane of rafters; or, a thermal insulation on boards supported on rafters, where boards constitute at the same time the inner lining, with exposed rafters;
- certain (e.g. alfol)-laminated or impermeable thermal insulations (extruded-expanded foams) missing safety rainwater sealing;
- hard thermal insulation layer overlying rafters, with a top texture suiting fixing, supporting of the shell.

This enumeration points out the several kinds of safety dampproofing layers in use, such as waterproof plastic sheets directly for such uses (e.g. Hungisol A, Grabiol-TA, Polifoam, etc.) refractory sheets of special composition, or, in lack of them, other layers of a different composition (e.g. tar papers).

Sheet on the top level of rafters is fixed by counter-laths and laid parallel with the eaves, with an upward overlapping of at least 10 cm. Mid-rafter, the sheet needs a sag of 1.5 to 2 cm, to cope with thermal shrinkage and drainage. The sheet has to overlap the metal edge at the eaves, while below the ridge, an about 20 cm strip has to be left out for aeration, or better, to be covered in the upper plane of counter-laths, with at least 10 cm overlapping. For a gable edge, the sheet has to be runned out to the gable board (fixed to its side), while in the top plane of the gable wall section protruding over the shell plate, it has to be driven under the metal sheet roofing.

Special care is needed for flashings of different roof openings – chimneys, windows, masts, etc. – in applying the proper accessories, continuously placing and folding up dampproofing sheets.

Synthetic sheets are sensitive to thermal effects to a degree depending on their composition, therefore they must not be applied below 0°C, or contact certain materials (e.g. solvents, etc.); they must not be exposed permanently (max. two weeks) to sunshine, they have to be protected even in storage.

Also in applying tar paper, the application methods and aspects above have to be respected. At a difference, it will be spread on boards, so it fits roofings (e.g. artificial slate flat sheets) requiring anyhow board support. Remind that tar papers little fit complex formations (bends, etc.).

For sizes of the aeration layer between the safety dampproofing layer and the thermal insulation, there are different data in special literature, depending on those above. It is advisable to take specifications in DIN 4108 into consideration. Vent sizes, air layer cross-section, flue sizes, required for aerating the air layer, and to maintain air circulation are determined as a function of the roof slope, rafter length, and vapour diffusion resistance.

At aeration layer inlets, catch nets against birds and insects, a combed cover strip fitting the shell form, has to be applied. To provide for air exhaust, aeration tiles have to be inserted in the second (or third) row from the ridge, in a number and position as indicated by the manufacturer (e.g. 1 tile/10 sq.m of roof). Beyond that, for up-to-date roof shells, aeration has also to be provided under ridge tiles, by applying different sheets. Free-standing pitch-roof ridge edges have to be fitted with perforated cone tile caps.

Units perpendicular to the rafter (lintels, flashings, etc.) in intermediate sections of air layers stop aeration, imposing to connect neighbouring air layers by slotting rafters here and there.

The shell of a garret-space building-up thermally counts as an external wall requiring high thermal insulation. Since usually it is of slight mass, it has to be a multi-layer structure with a core of some up-to-date thermal insulation, such as:

- rock or glass wool;
- cement-bound wood wool;
- hard plastic foams.

For high-thickness layers it is advisable to have a thermal insulation of two layers, permitting them to be placed with shifted joints. This is also a means of having one layer between, the other below the rafters, so rafters don't act as thermal bridges any more.

There is a wide variety of both materials and functions of room linings joining the roof and the dividing floor. As to function, the lining material depends on air and vapour conditions in the room, on given mechanical effects.

These include:

Building slabs: for instance, fibre-reinforced plaster slab, chipboard, laminated chipboard or fibreboard, chaff board, plywood, cement-based fibreboard various wainscotes, panels, plastic sheets, surface-treated metal sheets
(laths, plates).

If of adequate thickness, or ribbed, they may be self-supported, else they may be braced or fixed by a carcass.

Plasterings may be either:

- batten-reinforced plastering on boards on the lower plane of rafters or of the timber dividing floor; or
- plastering on cement-bound wood wool (Heraklith) slabs; or
- internal plastering on the lower plane of a massive reinforced concrete roof or dividing floor.

Timber Preservation, Protection Against Corrosion, Fire Safety Protection of Timber against Fungi, Insects.

Units of both conventional and up-to-date roof structures need adequate protection against various fungi and insects. The more so since structural units of built-up garret spaces provided with outer or inner linings are isolated and so ulteriorly about inaccessible. Preference is to be given to chemicals providing timbers complex, lasting protection against a wide range of damages (fungi, insects, dry or damp rot, stuffiness) and even fire protection. Protective agents keep efficient if wooden units are kept sealed against dampness after being built in, and if no infective matter (objects or furniture) get into the garret space. Certain preservatives as water repellents serve for dampproofing (NO MORE DAMP).

Up-to-date roof structures are given proper timber protection, but in course of checking before, and during building in, these have also to be dampproofed (sheets, aerated air layers, etc.), Timber units of the conventional timber trusses, and of roof structures of other materials, have to be immersed before building in, by the dipping-soaking method, according to rules of application for the given agent. For pre-existing trusses, raw surfaces possibly supporting a woodwork constructed later may be protected by brushing or spraying, so as not to damage adjacent matter (sheets, etc.), at the same time respecting work safety and environmental specifications.

Corrosion Protection of Metal Structural Materials

Corrosion protection of steel roof structures and its supporting and accessory units hints to special caution because of outer and inner moisture effects, as well as of ulterior inaccessibility of these structures. From this aspect, distinction has to be made between hot-rolled, and thin-walled cold-rolled (hence more sensitive) sections. Metal surfaces, including connections, need surface protection. Actually, there is a wide range of proper agents. Coatings applicable for steel structures are, as a function of planned service life: hot-dip galvanizing, painting, thermosetting coat; air-drying coat system.

Fire Safety

Fire codes and standards relevant to the design of garret-space building-up require multiple measures. This means that, on one hand, there are requirements expressly for garret-space building-up, on the other hand, also specifications for all the building, its materials, function, and storey number, have to be respected.

Accordingly, in building up a garret space, the followings have to be taken particularly into consideration:

- Specifications for built-up garret spaces exclude some functions (e.g. rooms for nurseries, children care, education and therapeutics). In layout design, the number of occupants, escape ways and their length (passages, stairs); necessity of fire sections, fire retardant anterooms, walls, doors, alarms and fire extinguishers have to be reckoned with.
- In garret-space building-up, the area of fire section depending on the fire resistance degree, as well as combustion-fire safety of building structures is also related to the storey number or elevation of the building;

- Building materials and building structures made with them are classified for combustibility as non-combustible and combustible, the latter as lowly combustible, medium, or highly combustible. Layer systems in the garret space being concealed, the requirement to systematically test and post-treat structures treated with fire retardants and extinctors is of particular importance. Combustibility and fireproofness limits of built-in structures are specified in the relevant standard.
- Also the category of inflammability of structural and coating materials of the dividing floor is of importance. Massive silicate-based materials are better than wood, metal and plastics.
- As to the behaviour of materials in fire, special consideration is due to thermal insulations in the core of the layer system, among them the best are rock and glass wools classified as non-combustible, while hard plastic foams (polystyrene, polyurethane) classified as medium or lowly combustible are disadvantageous by emitting gases in fire. By the way, there may be a difference between exact findings, and indications by foam manufacturers. For instance, in literature, poisonous emission is indicated in ppm (parts per million), concerning both carbon monoxide and other gases and aromatics typical of the basic material.

Building Physics, Thermal and Vapour Technique

Elevated requirements for roof shells have absolutely to be met for built-up garret spaces.

Climatic Impacts and Structural Development

Roof shell is primarily expected to protect from precipitation, but conventional hard roofings in themselves – being not dust-tight – are not safe against snow-dust, snow storm, stormy rain, etc., even if top quality. While the penetrating – usually slight – precipitation does not cause leakage in attics, for built-up garret spaces it may seriously damage both thermal insulation and lining. To reduce such damage, dust-proof roofs have been developed, where the required tightness is provided either by the shell material (folded metal sheet, reed roof, etc.) or by a properly applied underlay sheet.

Also for traditional building methods, a roof of outstanding dust tightness is possible with proper folding and straw bundles. For the most of hard-roofings, however, a safe snow, dust and storm tightness is conditional by an accessory underlay.

'Old-timer' roofs were normally overlying a free air space of important volume. Air in this storage space was in general as cold or as warm, as moist or as dry as the outer atmosphere, because of the permanent air change across the roof shell and the gable window (cold roof). The about equal upper and lower temperatures protected shell material, so these roof types raised practically no physical problems.

For a utilized garret space, however, summer and winter thermal conditions impose construction of confining structures of adequate heat insulation between outer and inner spaces, eliminating thereby "air storage" in the built-up, heat insulated garret-space. This deficiency has absolutely to be made up be aerating the air core under the lower plane of the roof shell.

In conformity with physical laws discussed below, by forming air inlets and outlets in line with the eaves and the ridge, air flows between these two points even at stillness of air. This air flow causes the air core

- to reduce heat accumulation below the roof shell due to solar heat;
- to exhaust humidity arriving from inner rooms (kitchen, bathroom, etc.);
- to drain moisture coming from outside (rain, atmospheric humidity);
- to act as pressure equalizer in storm (wind suction or pressure);
- to about equalize temperatures in the lower and upper plane of the roof shell, to reduce thermal stresses in the material.

These important functions point to the significance of the aeration of the air layer. Its deficiency may result in the following major shortcomings:

- penetrating or circulating humidity persists under the roof shell for a longer period, endangering the roof structure and much reducing the efficiency of thermal insulation;
- roof shell keeps moist for long, so that – especially in winter – alternating freezing-thawing cycles may seriously damage roof tiles.

Hydraulic Processes in Oblique External Walls

Compared to air capacities of attics, aerated air layers in skew walls are infinitesimal. To have this minor space of ventilation meet the same necessity, definite air change ratio between aeration space and outer atmosphere has to be helped by elements of construction and roofing systems.

Air flow within the aeration space may be technically considered as flow in a pipeline. Driving motors of the flow process are

- thermal buoyancy (flue effect);
- wind effect.

Thermal buoyancy is due to the fact that with increasing temperature, air density is reduced. The more heights of vents at the eaves and the ridge differ the higher the acting pressure difference is. These height differences being related to the roof geometry, it can be concluded that the higher the roof slopes, the more active the thermal buoyancy is.

Further influencing factors of aeration flow velocity are friction typical of the given confining building material and, in particular, flow and deviation losses due to cross-section variations at inlets and outlets.

Flow is also affected by wind effect and by different warming up and cooling of the roof surface.

For well-designed and well-constructed roofs sloping at least 10°, a ventilation flow velocity of 0.10 to 0.30 m/sec may be reckoned with. Under poor features, e.g. partly blocked in- and outlets, this value may be significantly reduced. This situation is further impaired by the fact that the air flow volume, hence the product of flow velocity by the free cross-section is critical for the humidity exhaust required. For a minimum of cross-section and mean ventilation flow velocity, the air change is about 10 cu.m/h per meter of eaves. Hence obviously, even a narrow ventilating cross-section may contribute to the efficiency of a roof structure.

Heat Transfer Processes in Aerated Roofs

Under summer temperature conditions, the roof surface is much heated by insolation. Important warming of the roof surfaces induces heat flow from outside inwards. Temperature development within the roof cross-section is seen in *Fig.11*, pointing out the effect of the air space ventilated from below to shield insolation.

At the actual time of measurements, there was no wind effect, ventilating air flow velocities were due exclusively to thermal effects. At the sunny side, because of the prevailing temperature differences, a rather high ventilation flow velocity developed. At the outlet near the ridge, this velocity produces a high ram pressure so that – upon cooling of the air flow – a fraction is outlet at the opposite side, at the lower edge of the roof. Thus, ventilation flow from the top downwards may arise from other than wind effects.

Winter temperature conditions feature heat flow from inside to outside, due to heating in inner rooms.

Cooling by radiation of the roof surface compared to atmospheric temperature clearly appears on *Fig. 11*, showing temperatures in the roof cross section at two times of thermometry. In the nightly period, surface temperature of the roof is much lower than the atmospheric temperature. Upon insolation, the roof structure is warmed, so that in the morning, temperature rises above freezing point, while atmospheric temperature is kept permanently below freezing point. The roof surface undergoes a freezing-thawing cycle.

The process above may entrain condensation also within the aeration space if surfaces bounding it reach the atmospheric dew-point. At the inner surface of the ventilation space, condensate freezes to hoary. Later, upon insolation, this ice sheet melts down, likely to get into the inner space across thermal insulation it having no dampproofing of the roof structure.

From the aspect of cooling processes, development of differences between temperatures of ventilation space and atmosphere may be of interest. A fraction of measurement value pairs show ventilation space temperature to be below or near to atmospheric temperature. For most of measurement values, ventilation space temperature is much above atmospheric temperature. Temperature differences average 3°C, of importance also for economizing heating power and heating costs.

Ventilation of Heat-insulated Roofs

German technical standard DIN 4108/3 defines the ventilation rate of thermal insulated roofs required for the considered confining structure not in need of special humidity design, being exempt from the risk of soaking. The following rules have to be respected:

1/ The roof slope is at least 10°.

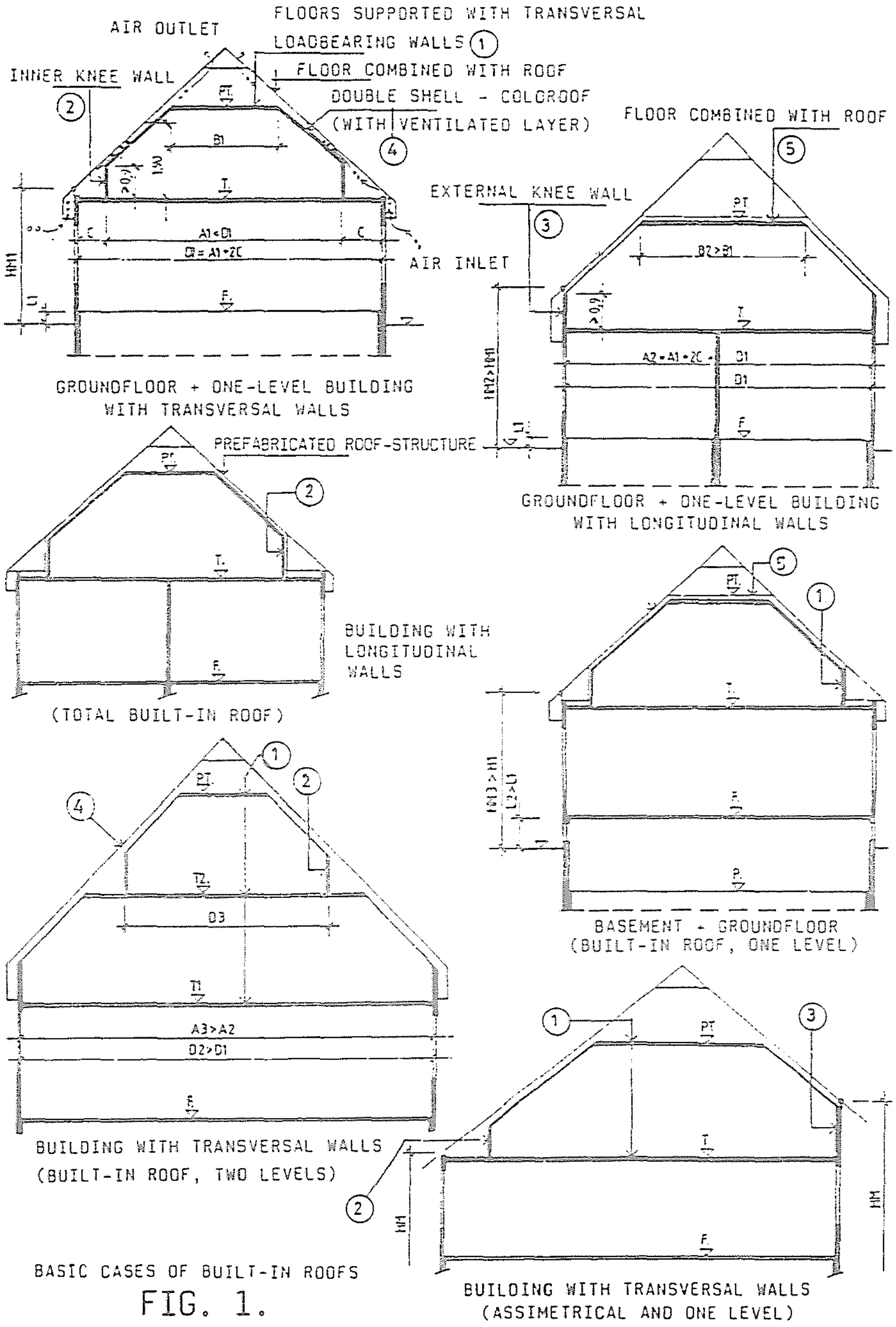
2/ The vent at the eaves is at least 2 thousandth parts of the ventilated surface, at least 200 sq.cm for every meter of eaves.

3/ At the ridge and in the gable wall, the vent is at least 0.5 thousandth part of the ventilated surface.

4/ In a current surface of a sloping roof, the vent cross-section is min. 200 sq.cm/m but the open height – inobstructed cross-section – must nowhere be less than 2 cm.

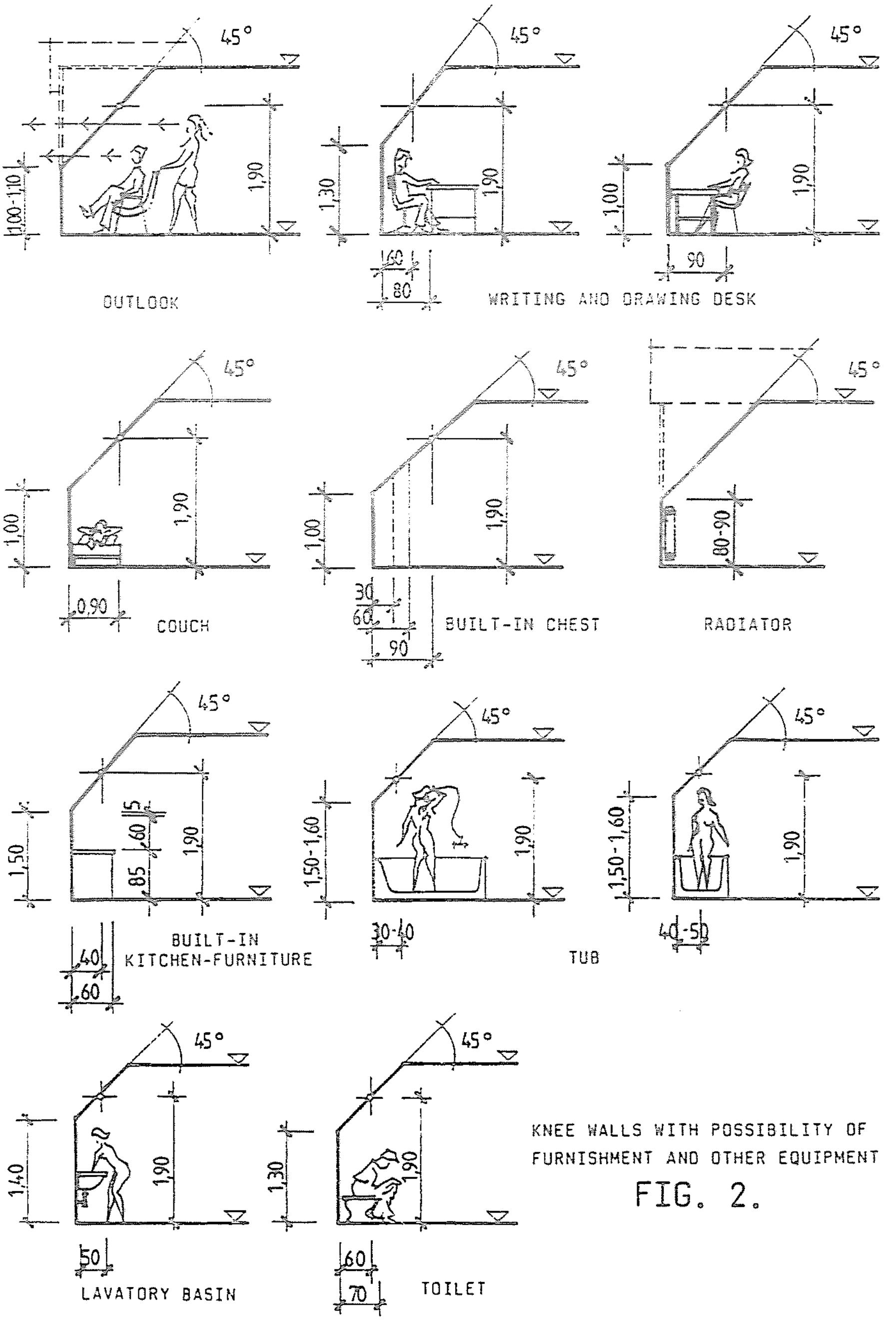
5/ Minimum resistance to humidity transmission of the structure is function of the rafter length. The built-in vapour barrier layer has to be on the warm side of the structure.

If the thermal insulation is sensitive to humidity, air layers both below and above the underlying dampproofing sheet have to be aerated, while for a thermal insulation not sensitive to humidity (closed-cell thermal insulations) a single ventilation layer suffices.



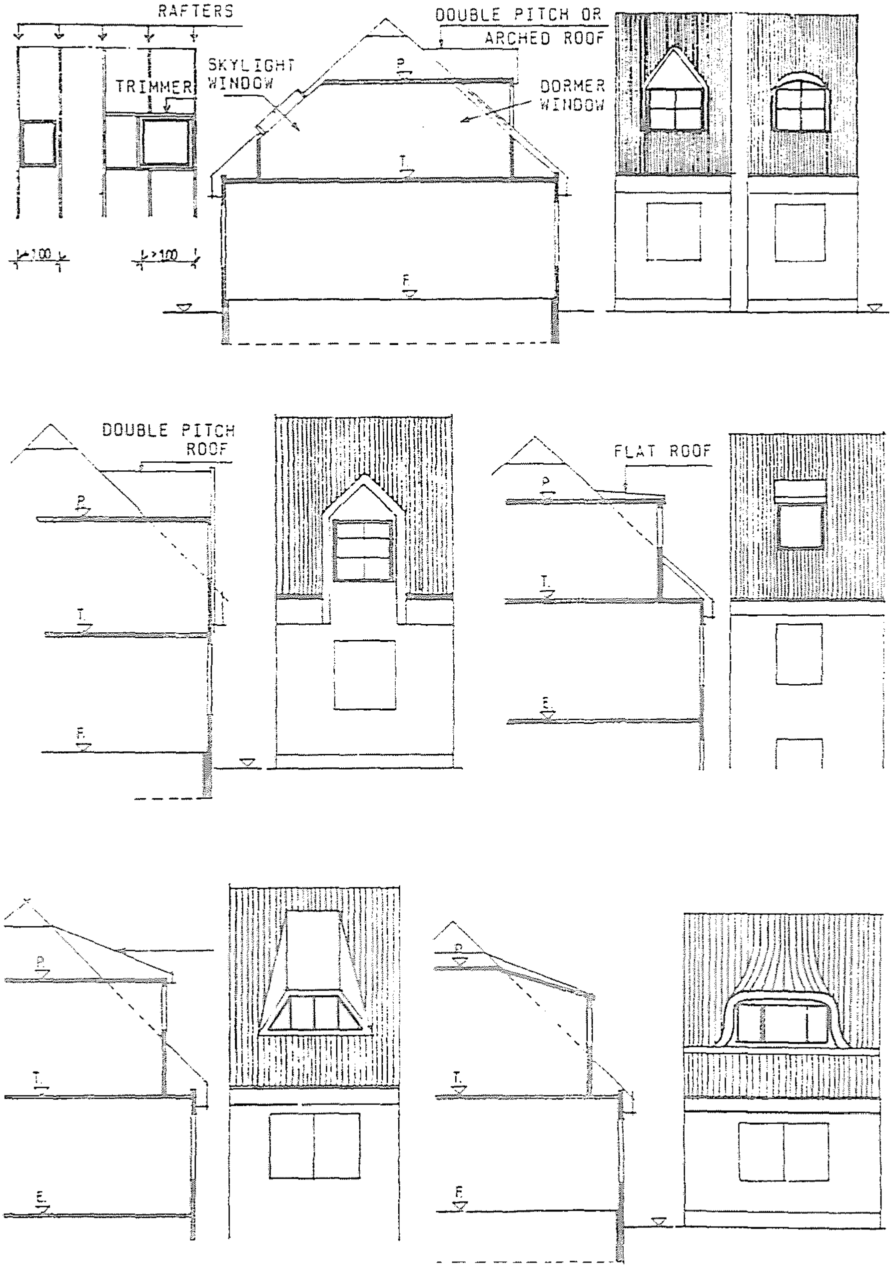
BASIC CASES OF BUILT-IN ROOFS

FIG. 1.

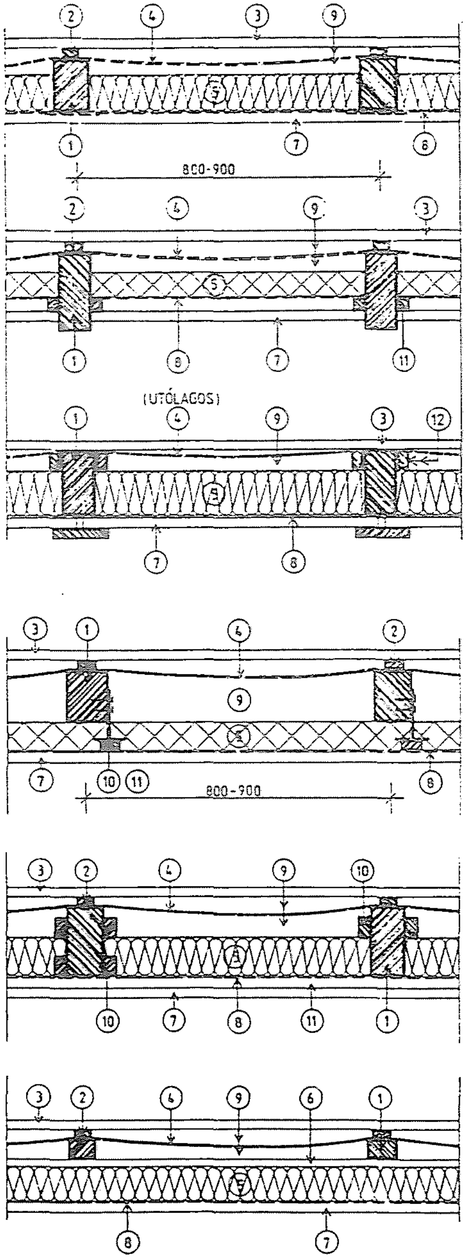


KNEE WALLS WITH POSSIBILITY OF FURNISHMENT AND OTHER EQUIPMENT

FIG. 2.

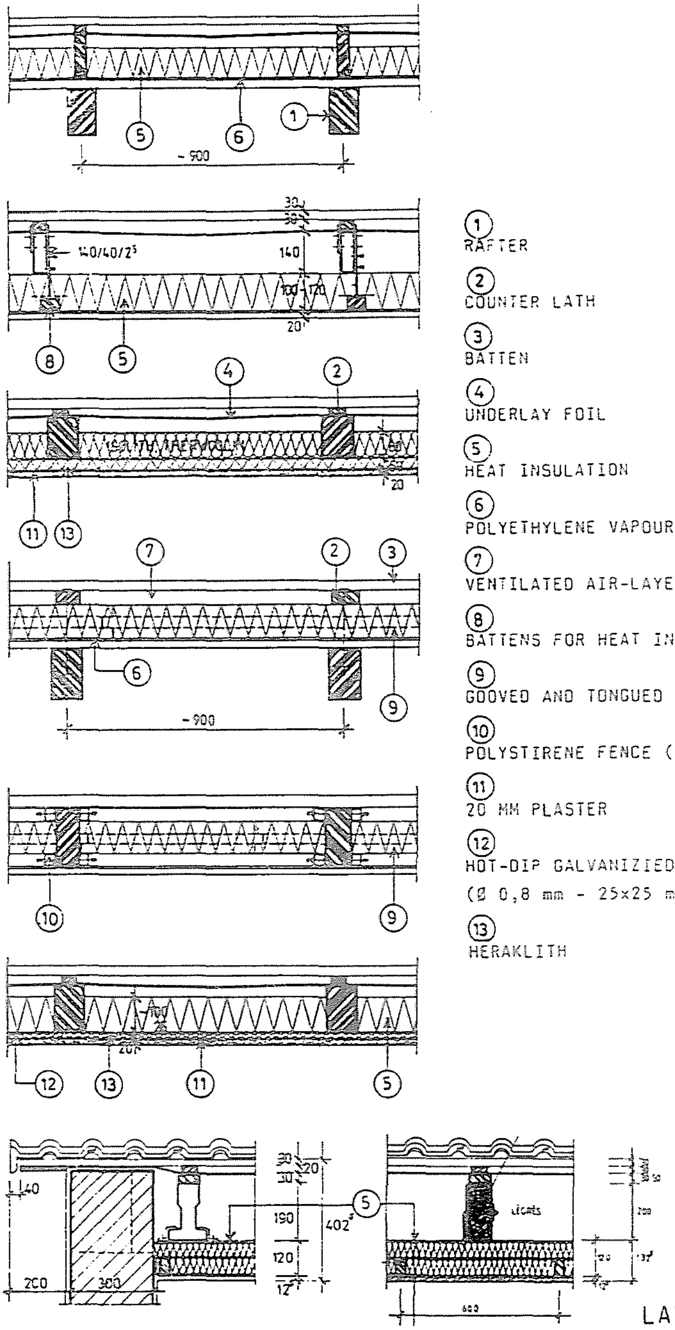


ATTIC WINDOWS FIG. 3.



① RAFTER
② COUNTER SLAT
③ BATTEN
④ UNDERLAY FOIL
⑤ HEAT INSULATION
⑥ PURLIN
⑦ INNER FINISH
⑧ POLYETHYLENE VAPOUR BARRIER FOIL
⑨ VENTILATED AIR-LAYER
⑩ BATTENS FOR HEAT INSULATION
⑪ BATTENS FOR INNER FINISH
⑫ FOIL

LAYERS OF ROOFS FIG. 4.



① RAFTER

② COUNTER LATH

③ BATTEN

④ UNDERLAY FOIL

⑤ HEAT INSULATION

⑥ POLYETHYLENE VAPOUR BARRIER FOIL

⑦ VENTILATED AIR-LAYER

⑧ BATTENS FOR HEAT INSULATION

⑨ GOOVED AND TONGUED POLYSTIRENE ELEMENT

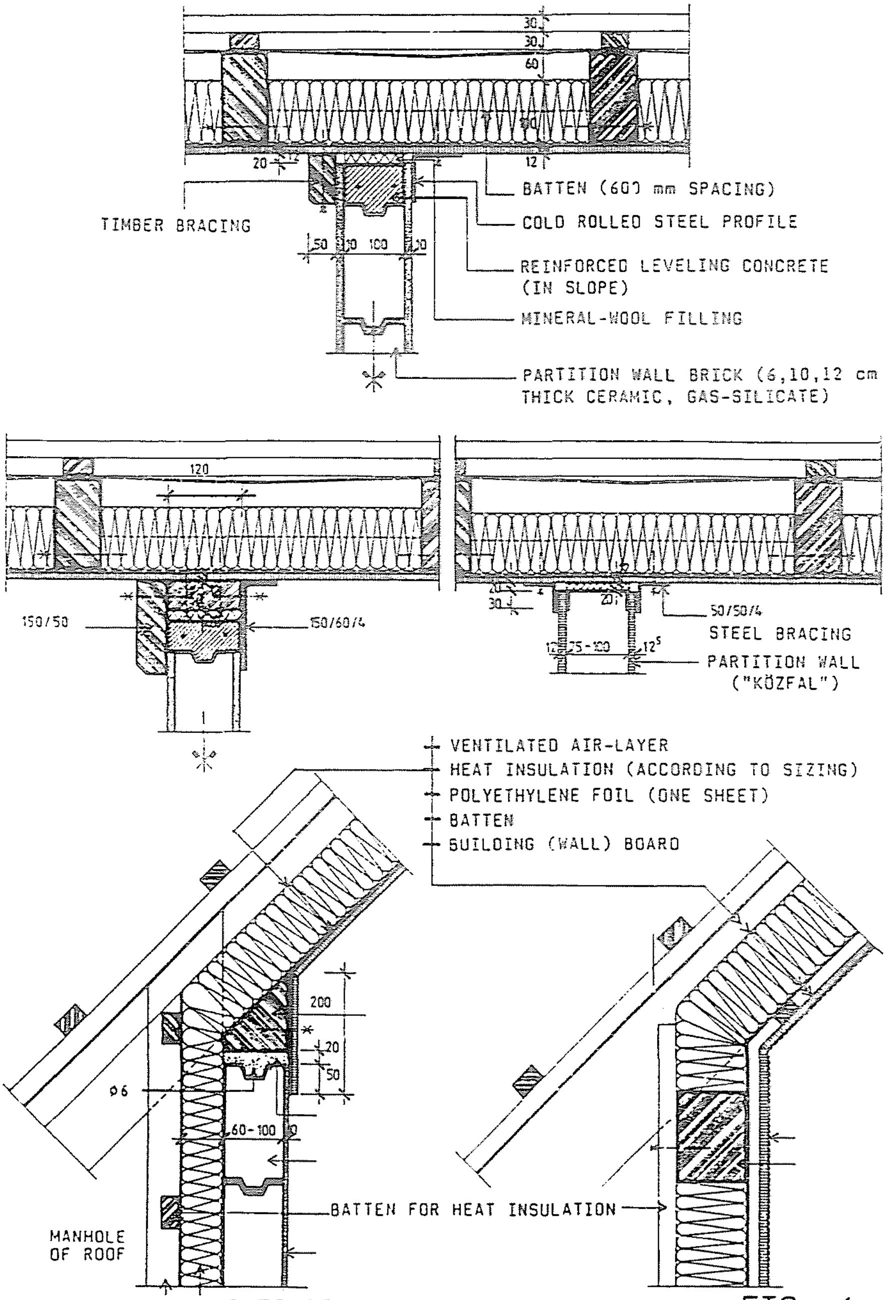
⑩ POLYSTIRENE FENCE (OUTSIDE AND INSIDE)

⑪ 20 MM PLASTER

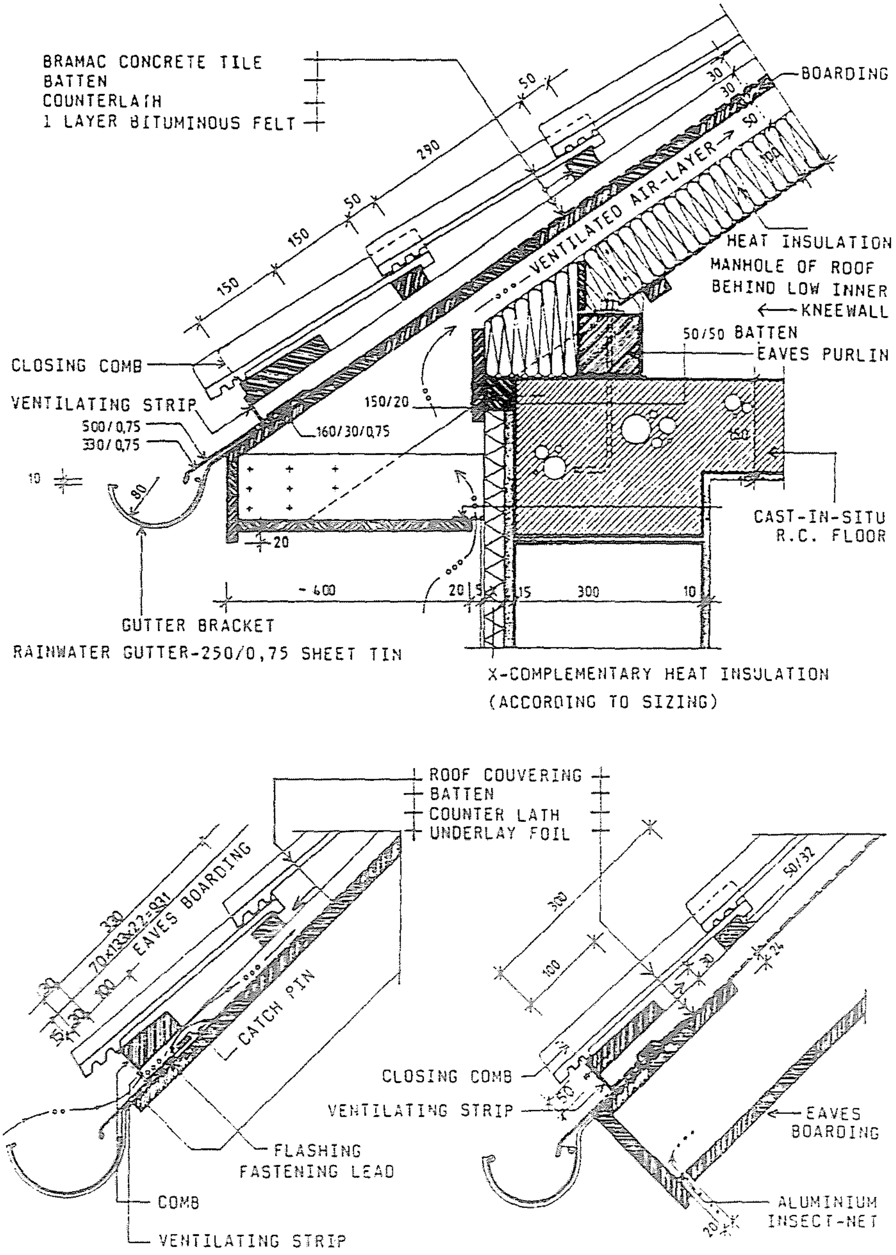
⑫ HOT-DIP GALVANIZIED, SEAM WELDED NET
(Ø 0,8 mm - 25×25 mm SIZE OF MESH)

⑬ HERAKLITH

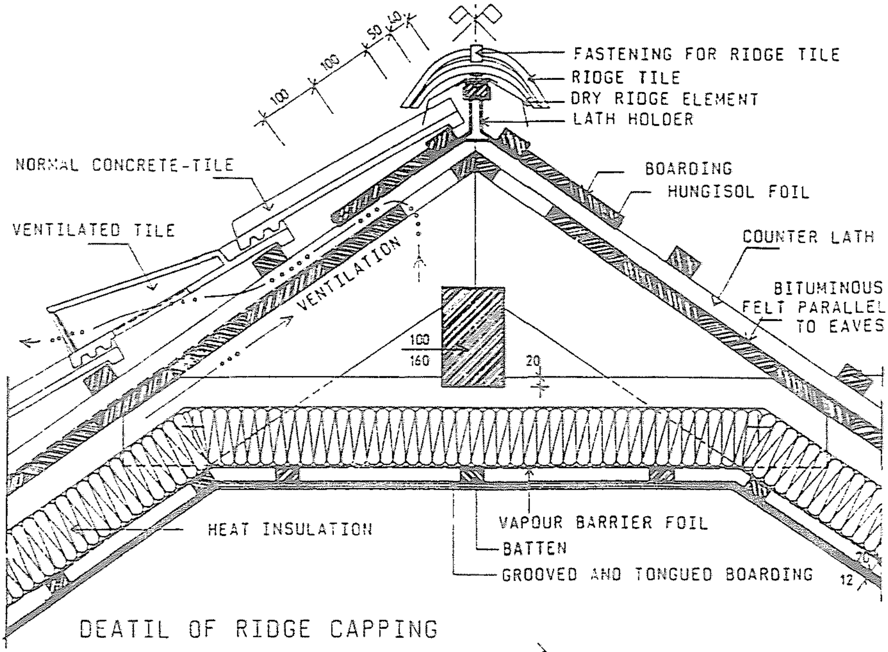
FIG. 5.
LAYERS OF ROOFS



JOINTS OF PARTITION WALL AND ROOF FIG. 6.



ROOF OVERHANG DETAILS FIG. 7.



DEATIL OF RIDGE CAPPING

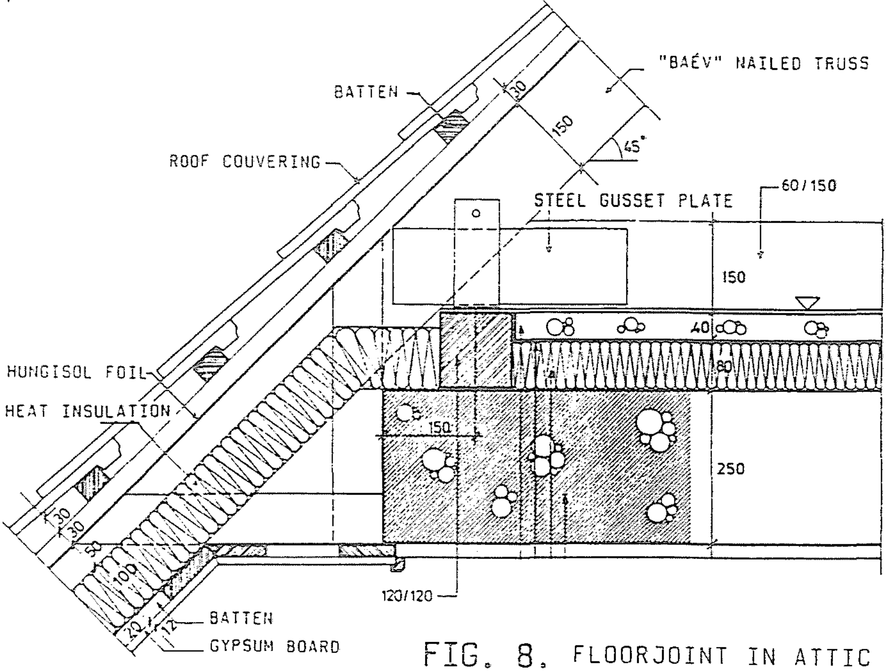
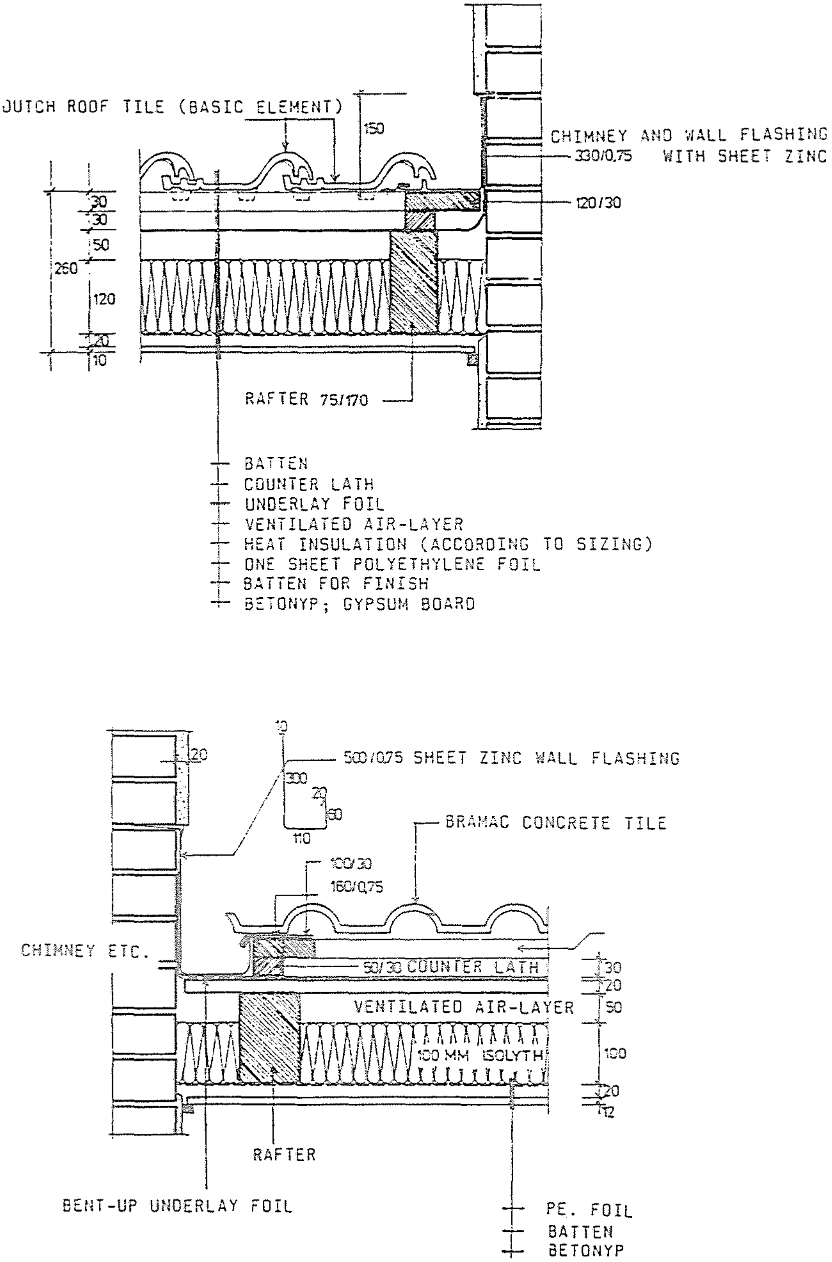
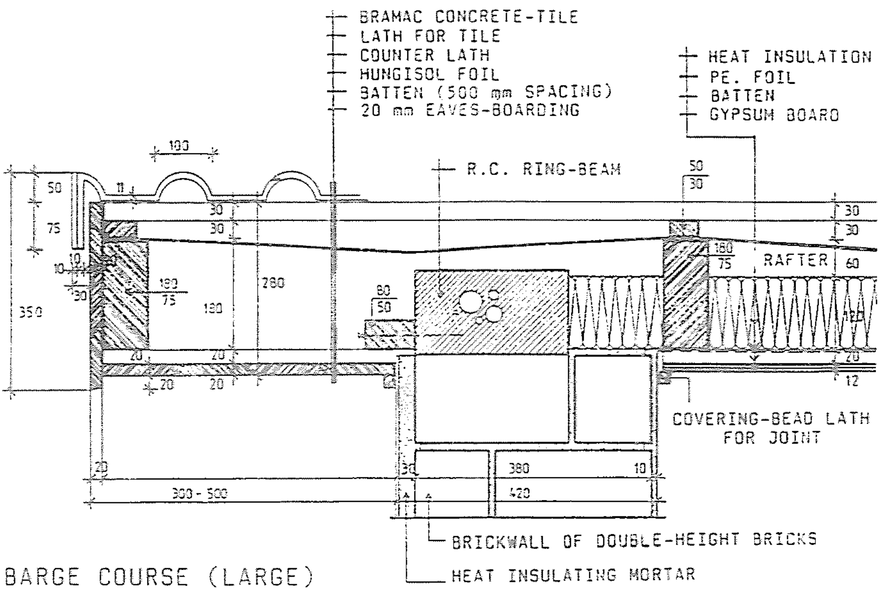


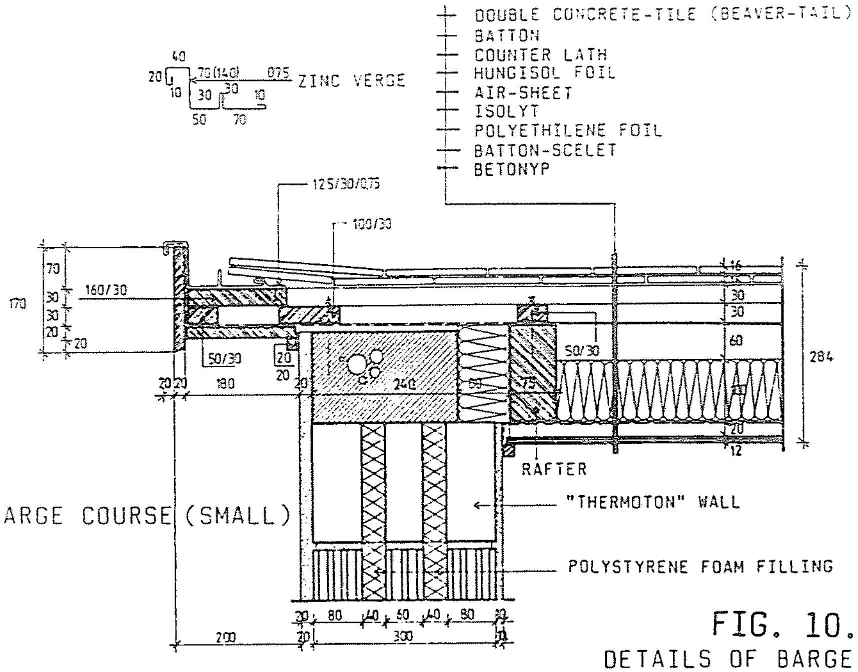
FIG. 8. FLOORJOINT IN ATTIC



FLASHING FOR SUPERSTRUCTURES OF ROOF FIG. 9.



BARGE COURSE (LARGE)



BARGE COURSE (SMALL)

FIG. 10.
DETAILS OF BARGE

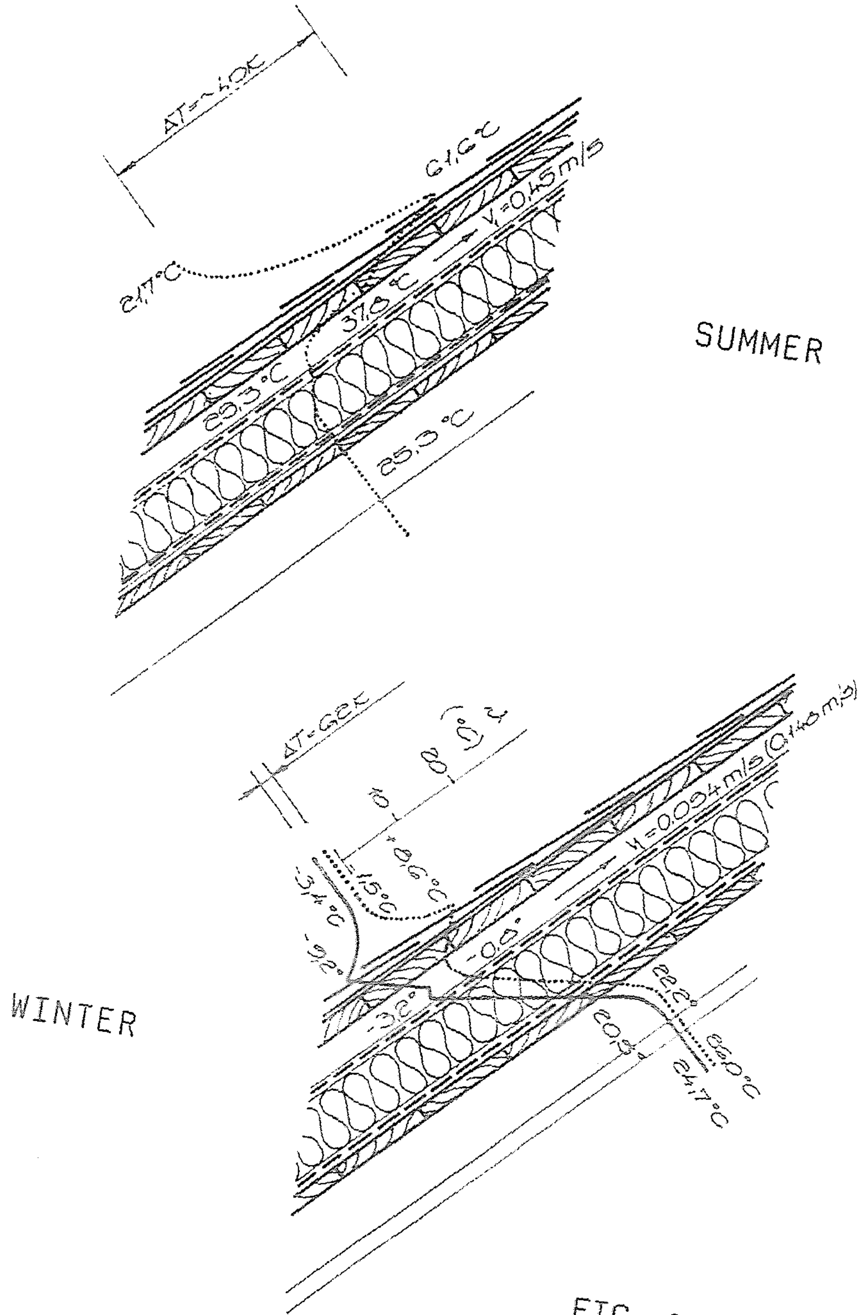

ΔT=~40K
61,6°C
v1=0,45m/s
21,7°C
37,8°C
25,3°C
25,3°C
SUMMER
ΔT=22K
0
20
t (°C)
-3,4°C
-1,5°C
+6,6°C
v1=0,094 m/s (0,140 m/s)
-2,6°
-0,0°
-3,2°
22,2°
20,5°
22,0°C
24,7°C
WINTER

FIG. 11.

References

LOCHNER, D. (1983): Garret-Space Building-Up. Budapest, Műszaki Könyvkiadó (in Hungarian).

JAKAB, I. (1981): Garret-Space Apartment. Budapest, ÉTK. (in Hungarian).

NOVÁK-VARGA-MAKÓ (1985): Rudiments of Garret-Space Building-Up. Budapest, Műszaki Könyvkiadó (in Hungarian).

KÓSZÓ, J. (1990): Pitch Roofs. Budapest, Műszaki Könyvkiadó (in Hungarian).

KARÁCSON, S. – VALISKÓ, J. – LIEBHAUSER, J. (1989): Renewal of Pitch Roofs. Report to Industrial and Com. Ministry (in Hungarian).

VÁÉV Bramac Roof System, (1987), Veszprém (in Hungarian).

Therwoolin Technology Manual. Salgótarján.

Heraklith-Heratekta Information. Heraklith-Hungaria Ltd. Zalaegerszeg (in Hungarian).

Hungvelux Garret-Space Windows, Information. Fertőd-Budapest (in Hungarian).

Eternite Corrugated and Flat Slab Products of Eternite Ltd. (1990): Budapest, TS, É-75. TTI (in Hungarian).

LIERSCH, K.: Aerated Roof and Wall Constructions. Vol 3: Roofs. Bauverlag GmbH. (in German).

DIN 4108. (in German).