

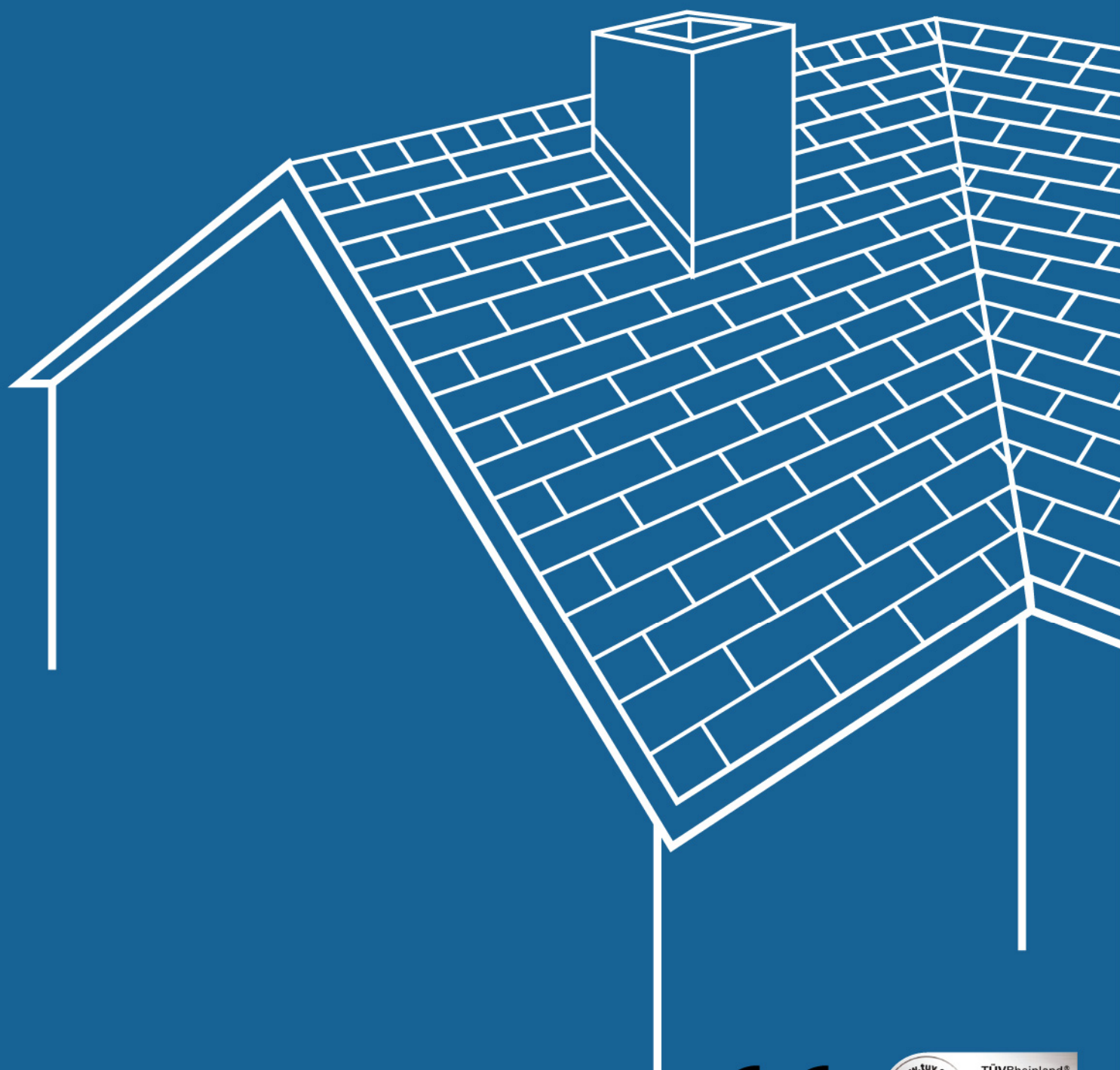
Informational Brochure

Izodom 2000 Polska



Roofs - rules of using thermal insulation on rafter
and flat reinforced-concrete roofs

No7



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Roofs - rules of using thermal insulation on rafter and flat reinforced-concrete roofs.

The extracts from studies and other own materials prepared by Department of Concrete Structures of Technical University of Lodz (a team composed of prof. dr hab. inż. Artem Czekwianianc, doc. dr inż. Jan Kozicki, mgr inż. Jacek Filipczak) were used in this publication.

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List of available publications:

Issue No. 1: Basic information on material and erection technology of "Izodom 2000 Polska" system

Issue No. 2: Design and calculation guidelines for walls of "Izodom 2000 Polska" system. "Richtlinien für die Berechnung und Konstruktion der Wände im System Izodom 2000 Polska"; [German version of Issue No. 2, based on German National Standards]

Issue No. 3: Floors of "Izodom 2000 Polska" system

Issue No. 4: Halls, cold stores, warehouses of „Izodom 2000 Polska” system

Issue No. 5: Design and calculation guidelines for tiny aggregate concrete walls of „Izodom 2000 Polska” system.

Issue No. 6: Design and calculation guidelines for swimming pools of "Izodom 2000 Polska" system.

Issue No. 7: Roofs - rules of using thermal insulation on rafter and flat reinforced-concrete roofs.

Issue No. 8: Foundation slabs of „Izodom 2000 Polska” system

Issue No. 9: Applying „Izodom 2000 Polska” wall system in regions of seismic risk.

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Table of content

1	General.....	4
2	Wind action on pitched and flat roofs according to PN-EN 1991-1-4.....	5
3	Rafter roofs.....	7
3.1	Rafter roof covered with ceramic or cement tiles.....	7
3.2	Rafter roof covered with metal sheet tiles or corrugated sheet.....	11
3.3	Rafter roof covered with torach-on membrane.....	14
4	Reinforced-concrete flat roof.....	15
5	Summary	17

1 General

Large-size roof boards made of foamed material are used mainly as thermal insulation of wooden rafter-type roofs. They can also be used on flat reinforced-concrete roofs (cast-in-situ or beam and block roofs).

Taking into account the production capacity of the plant, and above all easy transport and installation of the boards, following in-depth analysis it was finally decided that the board dimensions will be 900×1900mm net (1000×2000mm overall). The boards will be made of a classic EPS with the 20kg/m³ density and a very good heat transfer coefficient of 0.032W/m²K, which at the 220 or 250 mm thick boards ensures good thermal comfort of the buildings. An additional advantage of the boards is locks joining them and forming a uniform insulation layer. On one hand, such locks make installation accurate, and on the other hand they prevent the occurrence of thermal bridges.

The boards are made of EPS with very low water absorption. Nevertheless, the boards feature longitudinal channels to drain the water which can get inside as a result of possible lack of roof tightness or formed as a result of vapour condensation. The channels are 10 mm wide and spaced every 100 mm. Their inclination is 11°, meaning that water drainage is possible when roof inclination is greater than this angle.

In rafter roofs, the boards will be fixed to wooden battens. Maximum batten dimension is 40 x 40 mm. The grooves on the bottom side of the boards are 40x50 mm, so there is a 10-mm tolerance for possible errors in batten location and straightness. The batten spacing is 300 mm. At this spacing and with the board thickness of 220 or 250 mm, even at the most unfavourable location of the concentrated load (which can occur during installation), the board is subjected only to compressive loads, so there is no risk it will break.

Two board types have been designed: DPL-ZIG 1900×900×220mm for rafter roofs with ceramic or cement tiles and DPL-GLT 1900×900×250mm for roofs covered with metal sheet tiles, corrugated or trapezoidal sheet or roofing felt (membrane). The DPL-GLT 1900×900×250mm boards can also be used as thermal insulation of flat roofs. On their top surface, the DPL-ZIG 1900×900×220mm have special shapes for direct placement of the tiles, so it is not necessary to use battens and counter-battens.

It is possible to install additional thermal insulation made of ordinary expanded polystyrene boards, and then the total insulation thickness will be about 400 mm. At such insulation thickness, the roof will meet the requirements for a passive building, i.e. the building which practically does not need heating.

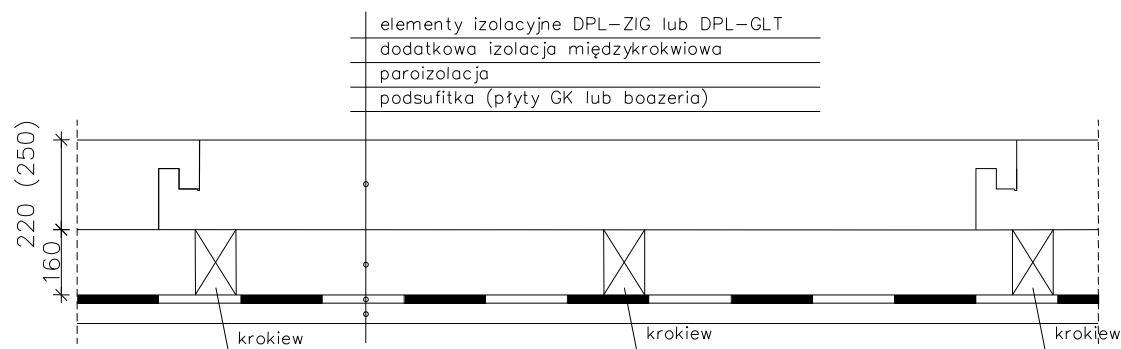


Figure 1. Additional thermal insulation; (*elementy izolacyjne DPL- ZIG lub DLP-GTL* - DPL-ZIG or DLP-GLT insulation boards; *dodatkowa izolacja międzykrokiowa* - additional insulation between rafters; *paroizolacja* - vapour barrier; *podsufitka (płyty GK lub boazeria)* - soffit (plasterboards or wooden panels); *krokiew* - rafter)

As shown on Figure 1, the top boards of the thermal insulation are laid on the roof structural elements. In case of the roofing felt, metal sheet tiles or corrugated sheet, these layers must be joined with the structure. Joining should ensure safe transfer of actions caused by wind suction. The connecting parts joining the roofing and the insulation should be dimensioned according to the European Standard. It was assumed that the building is located in the wind load zone 1 which covers 90 percent of Poland's area. If the wind load is greater than the one assumed for zone 1, the size of connectors should be correspondingly increased using the wind suction values according to PN-EN 1991-1-4.

2 Wind action on pitched and flat roofs according to PN-EN 1991-1-4

For central Poland (wind load zone 1) and for areas regularly covered with vegetation, built-on areas or areas with single obstacles spaced at maximum 20 their heights (such as rural or suburban areas, forests) i.e. for the terrain category III and the elevation up to $A = 500\text{m a.s.l.}$ and the building height up to 10 m, the tearing force according to PN-EN 1991-1-4. November 2008. Eurocode 1. "Actions on structures - General actions - Part 1-4: Wind actions", will be as follows:

- basic wind speed $V_{b,0}$ and wind speed pressure $q_{b,0}$

$$V_{b,0} = 22[1 + 0,0006(A - 300)] = 24,6\text{m/s}$$

$$q_{b,0} = 0,30[1 + 0,0006(A - 300)]^2 \frac{20000 - A}{20000 + A} = 0,376\text{kN/m}^2$$

- roughness coefficient $C_r(z)$ and exposition coefficient $C_e(z)$

$$C_r(z) = 0,8 \left(\frac{z}{10} \right)^{0,19} = 0,8$$

$$C_e(z) = 1,9 \left(\frac{z}{10} \right)^{0,26} = 1,9$$

- basic wind speed v_b

$$v_b = C_{dir} C_{season} v_{b,0}; \quad C_{dir} = 1,0; \quad C_{season} = 1,0$$

$$v_b = v_{b,0} = 24,6 \text{ m/s}$$

- average wind speed

$$v_{m(z)} = C_{r(z)} C_{0(z)} v_b; \quad C_{0(z)} = 1,0$$

$$v_{m(z)} = 0,8 \times 1,0 \times 24,6 = 19,7 \text{ m/s}$$

- turbulence intensity $I_{v(z)}$, $k_1 = 1.0$, $z_0 = 0.3 \text{ m}$

$$I_{v(z)} = \frac{k_1}{C_{0(z)} \ln\left(\frac{z}{z_0}\right)} = \frac{1,0}{1,0 \times \ln\left(\frac{10}{0,3}\right)} = 0,285$$

- peak value of wind speed pressure $q_{p(z)}$; $\rho = 1.25 \text{ kg/m}^3$

$$q_{p(z)} = \left[1 + 7I_{v(z)}\right] \frac{1}{2} \rho v_{m(z)}^2 10^{-3} = 0,726 \text{ kN/m}^2$$

- pressure acting on external surfaces of the structure w_e

$$w_e = q_{p(z)} C_{pe}, \text{ design value } w_{ed} = 1,5 w_e$$

Value of coefficient of external pressure C_{pe} for pitched roofs depends on the angle of inclination. Table 1 lists the maximum values of $C_{pe,1}$, i.e. the values of local coefficients used to calculate small elements' area of 1 m^2 or less and the connectors depending on the roof inclination angle, and on w_e and w_{ed} . The values conform to PN-EN 1991-1-4 and the intermediate values were interpolated linearly.

Maximum values of external pressure coefficient $C_{pe,1}$ for flat roofs, and the w_e and w_{ed} values are given in table 2.

Table 1.

α	$C_{pe,1}$	$w_e \text{ [kN/m}^2\text{]}$	$w_{ed} \text{ [kN/m}^2\text{]}$
15°	-2,00	-1,452	-2,178
20°	-1,75	-1,270	-1,905
30°	-1,50	-1,089	-1,634
35°	-1,00	-0,726	-1,089
40°	-0,50	-0,363	-0,545
45°	-0,30	-0,218	-0,327

(the “-” sign means wind suction)

Table 2.

roof type		$C_{ep,1}$	w_e [kN/m ²]	w_{ed} [kN/m ²]
sharp roof edges		-2,5	-1,815	-2,723
with parapet wall	$h_p / h = 0,025$	-2,2	-1,597	-2,396
	$h_p / h = 0,050$	-2,0	-1,452	-2,178
	$h_p / h = 0,100$	-1,8	-1,307	-1,961
rounded edges	$r / h = 0,05$	-1,8	-1,307	-1,961
	$r / h = 0,10$	-1,4	-1,016	-1,524
	$r / h = 0,20$	-0,8	-0,581	-0,872
mansard edges	$\alpha = 30^\circ$	-1,5	-1,089	-1,634
	$\alpha = 45^\circ$	-1,9	-1,379	-2,069
	$\alpha = 60^\circ$	-1,9	-1,379	-2,069

h_p – parapet wall height

h – building height without parapet wall

r – eaves rounding

α – mansard roof inclination angle

3 Rafter roofs

3.1 Rafter roof covered with ceramic or cement tiles

The thermal insulation above the rafters should be made of the DPL-ZIG 1900×900×220mm boards. Typical details of the roofing in the eaves area are shown on Figures 2a and 2b.

A 170mm high wooden block should be fixed to the rafter in the eaves area. Fixing can be made using a Simpson perforated strip made by Jutor spółka z o.o. which fastens the block to the rafter on both sides or by other means, but the connector should be dimensioned for force w_{ed} according to table 1 depending on the roof inclination angle.

The boards for flashing and gutter fixing are nailed to the block and the rafter. The block height allows free water flow from under the roof tiles directly on the flashing (water that got inside as a result of lack of tightness or formed in the process of vapour condensation). The location of flashing in relation to the DPL-ZIG 1900×900×220mm board is shown on Figures 2a and 2b. This solution has two variants. In the first one, the edge tile rests on a protruding fragment of the EPS board, and the bottom part of the board with the lock should be cut off (Figure 2.a). In variant two, the EPS board is placed at the block, but this requires using a steel profile supporting the edge tile (Figure 2.b). The profile is fixed to the board using the distance washers to allow free water flow from under the roofing onto the flashing.

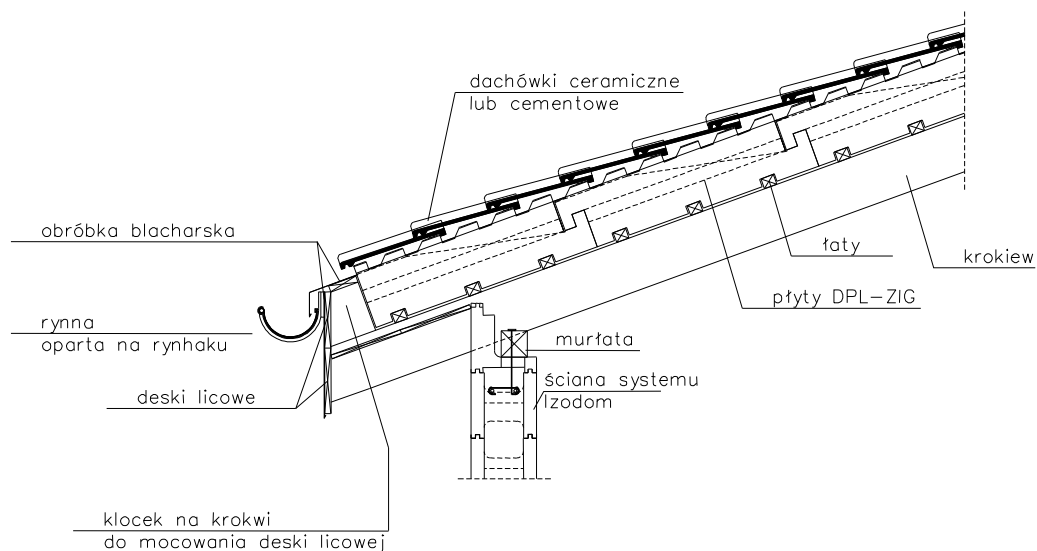


Figure 2.a. Rafter roof – ceramic or cement tiles in the eaves area (DPL-ZIG board, variant with bottom lock cut off)

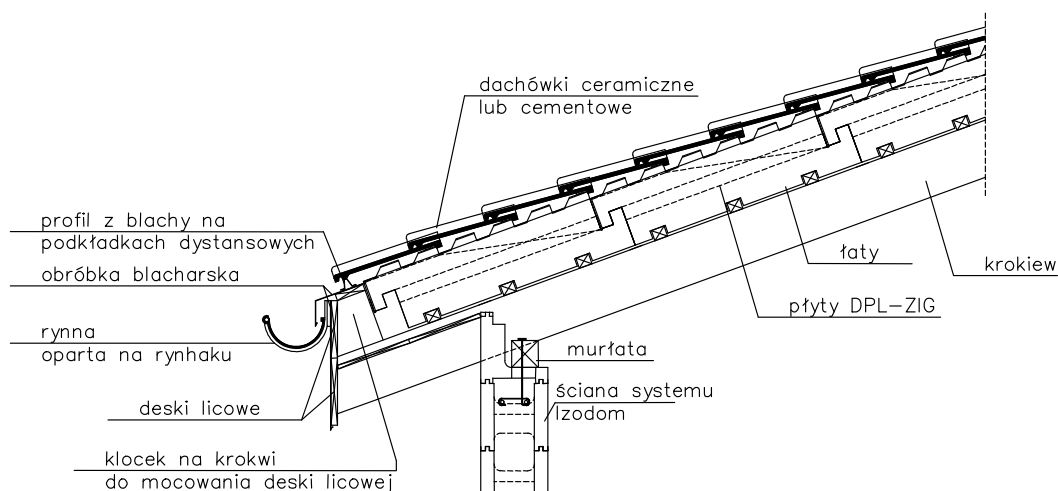


Figure 2.b. Rafter roof – ceramic or cement tiles in the eaves area (DPL-ZIG board, variant without cutting off the bottom lock); (dachówki ceramiczne lub cementowe - ceramic or cement tiles; obróbka blacharska – flashing; rynna oparta na - gutter resting on its bracket; deski licowe - facing planks; łąaty – battens; krokiew – rafter; murłata - top plate; klocek na krokwi do - block on the rafter to fix the facing board; płyty DPL - ZIG - DPL-ZIG boards; ściana systemu Izodom - Izodom system wall; profil z blachy na podkładkach dystansowych - steel profile on distance washers).

Flashing details in the eaves area are shown on Figure 3a and 3b.

A typical detail in the ridge area is shown on Figure 4. In this case, an EPS wedge can be used in the ridge axis or – if allowed by the board width – the neighbouring boards in the ridge can be cut at an appropriate angle.

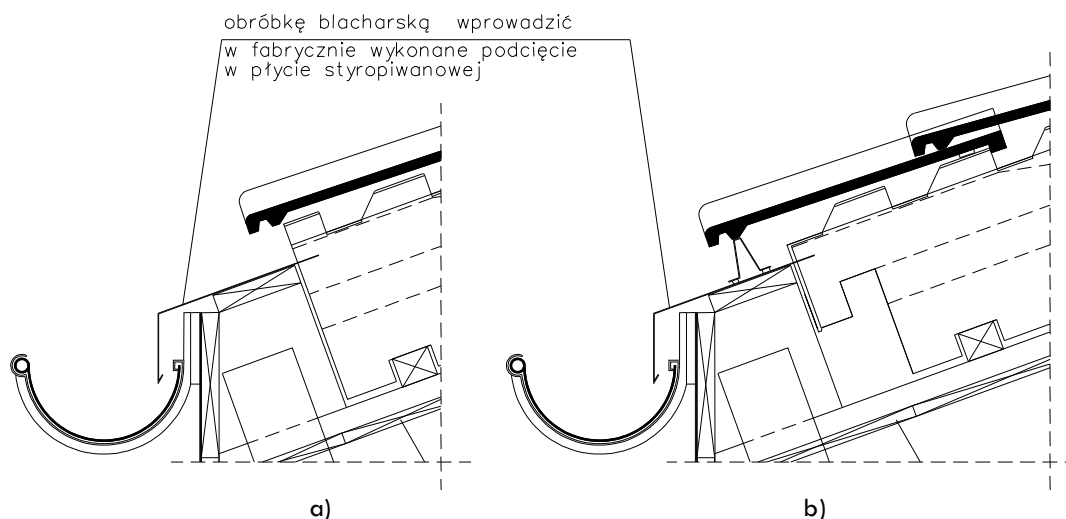


Figure 3. Eaves of the rafter roof covered with ceramic or cement tiles. Fixing the wooden block to the rafter:
a) bottom part of the board with lock cut off, b) full board pressed against the edge block. (obróbkę blacharską wprowadzić - flashing to be placed in the factory-made undercut in the EPS board)

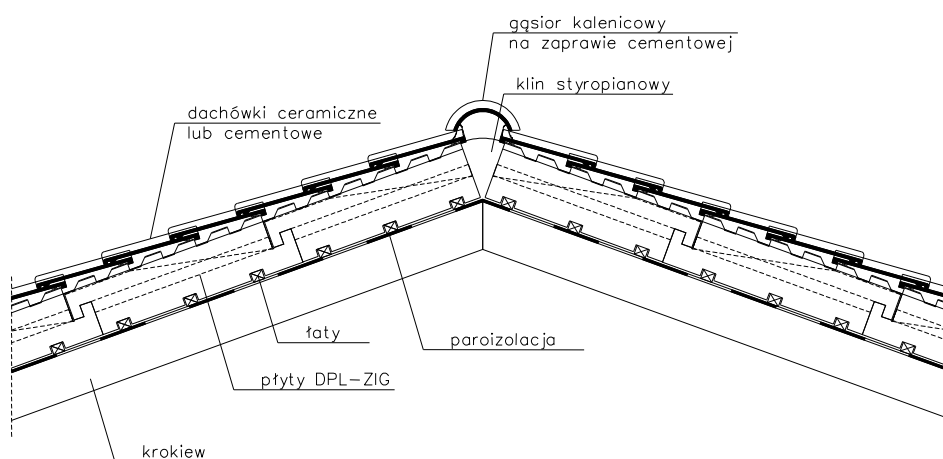


Figure 4. Rafter roof – ceramic or cement tiles in the ridge area (dachówki ceramiczne lub cementowe - ceramic or cement tiles; gqsior kalenicowy na - ridge tile on cement mortar; klin styropianowy - EPS wedge; paroizolacja - vapour barrier; łaty - battens; krokiew – rafter; płyty DPL – ZIG - DPL-ZIG boards)

Start the placement of boards on the right-hand side, in the first lowest bottom row parallel to the eaves. Cut off the lock on the right-hand side of the board. Then place successive boards, checking connections between them. In the next, higher row, cut the first board into halves and connect the left-hand half with the bottom row board. Continue by placing full boards. The placement method is shown on Figure 5. Third, fifth and successive rows (odd rows) are made using full boards. The even rows start with half boards. Such offset placement of the boards provides better and tighter roof insulation. Cut vertically all rows of the boards on the left-hand side of the roof to obtain the roof shape as per the design.

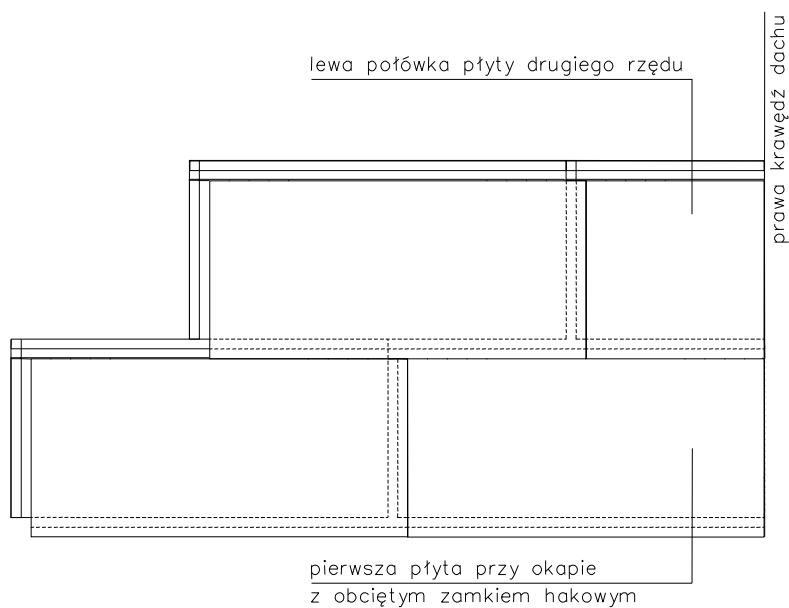


Figure 5. Start of the boards placement (lewa połówka płyty - left-hand half of the second row board; pierwsza płyta przy okapie - first board at the eaves with the lock cut off; prawa krawędź dachu - right-hand side edge of the roof)

Start placement of tiles on the eaves on the right-hand side. The first row of the tiles should be at the distance of 50 – 100 mm from the eaves edge. A typical solution in the gable wall area is shown on Figure 6.

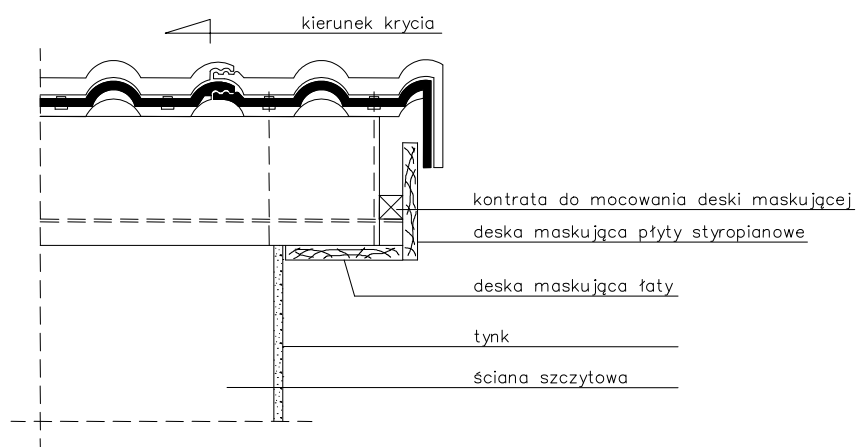


Figure 6. Rafter roof – ceramic or cement tiles in the gable wall area (kierunek krycia - ridge placement direction; kontrata do mocowania - counter-batten to fix the covering plank; deska maskująca płyty - plank covering the EPS boards; tynk – plaster; ściana szczytowa - gable wall)

Two covering planks were used in this case – one on the bottom nailed to the wooden battens, the other on the side nailed to the bottom plant and the wooden counter-batten.

3.2 Rafter roof covered with metal sheet tiles or corrugated sheet

The DPL-GLT 1900×900×250mm boards should be used for thermal insulation above the rafters. Also in this case, the boards' placement should start as described in section 3.1. Typical roofing solutions in the eaves and ridge areas are shown on Figure 7, and the sheet fixing details are shown on Figure 8.

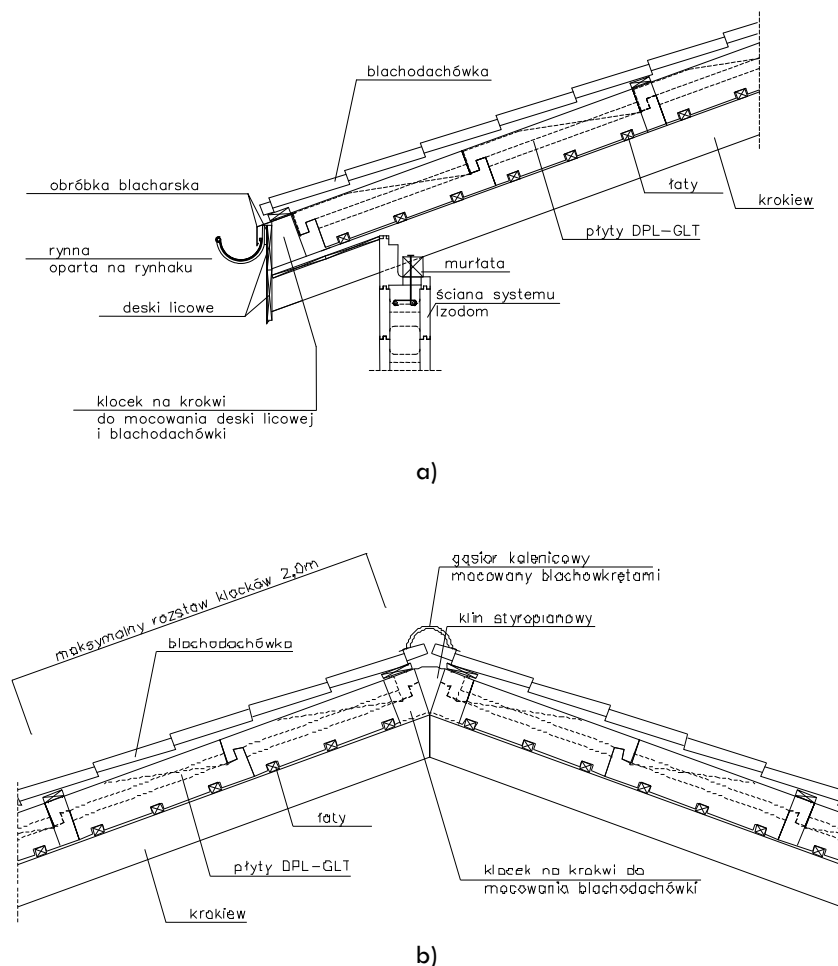


Figure 7. Rafter roof – sheet tiles or corrugated sheet in the eaves and ridge areas (blachodachówka - metal sheet tile; obróbka blacharska – flashing; rynna oparta na - gutter resting on its bracket; deski licowe - facing planks; łaty- battens; krokiew – rafter; murlata - top plate; klocek na krokwi do - block on the rafter to fix the facing plank and metal sheet tiles; płyty DPL – GLT - DPL-GLT boards, ściana systemu Izodom - Izodom system wall; gqsiar kalenicowy - ridge tile fixed with sheet metal screws; klin styropianowy - EPS wedge; klocek na krokwi do - block on the rafter to fix the metal sheet tiles; maksymalny rozstaw - maximum block spacing 2.0 m)

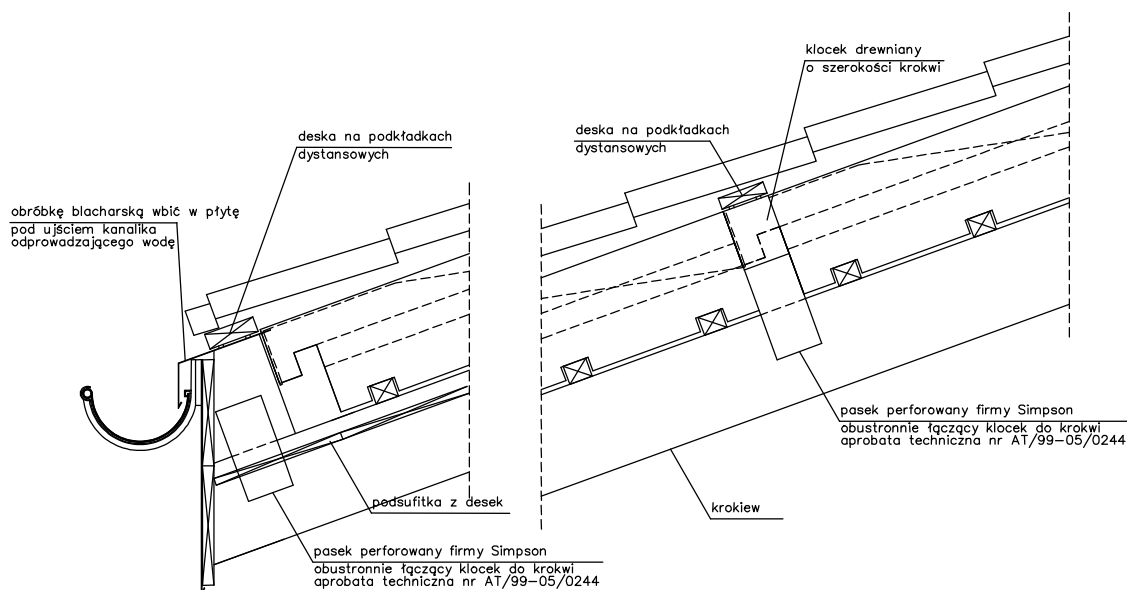


Figure 8. Sheet fixing to the structure – detail (obróbkę blacharską wbić w płytę - flashing to be hammered into the board under the outlet of the water drainage channel; deska na podkładkach dystansowych - wooden plank on distance washers; podsufitka z desek - soffit made of wooden planks; pasek perforowany firmy Simpson - Simpson perforated strip fixing the block to the rafter on both sides; technical approval No. AT/99-05/0244; klocek drewniany - wooden block of the rafter width; krokiew – rafter)

This design solution assumes that the roofing metal sheet is fixed to the structure through longitudinal planks which are fastened to the blocks placed on the rafters. The best location of wooden blocks is in the lock area, and in this area the EPS board should be suitably cut. The planks must be placed in the eaves and ridge areas, and should be evenly spaced on the roof with maximum distance between them equal to 2.0 m. The planks are nailed to the blocks using the distance washers to allow free flow of condensed vapour under the metal sheeting.

Sheet tiles or corrugated sheet can be fixed to the structure by means of the WFD mechanical fasteners for wooden bases manufactured by PPHU Wkręt-Met-Klimas. The connectors fix the sheet to the plank of minimum 25 mm in thickness. The blocks can also be fixed to the rafters using the Simpson perforated strips. All elements must be fastened to the structure in such a manner as to safely transfer the wind suction forces which depend on the roof inclination angle, as per table 1.

The detail of the roofing in the valley is shown on Figure 9. In this case, all neighbouring EPS boards in the wall should be cut so as to ensure contact between their side surfaces.

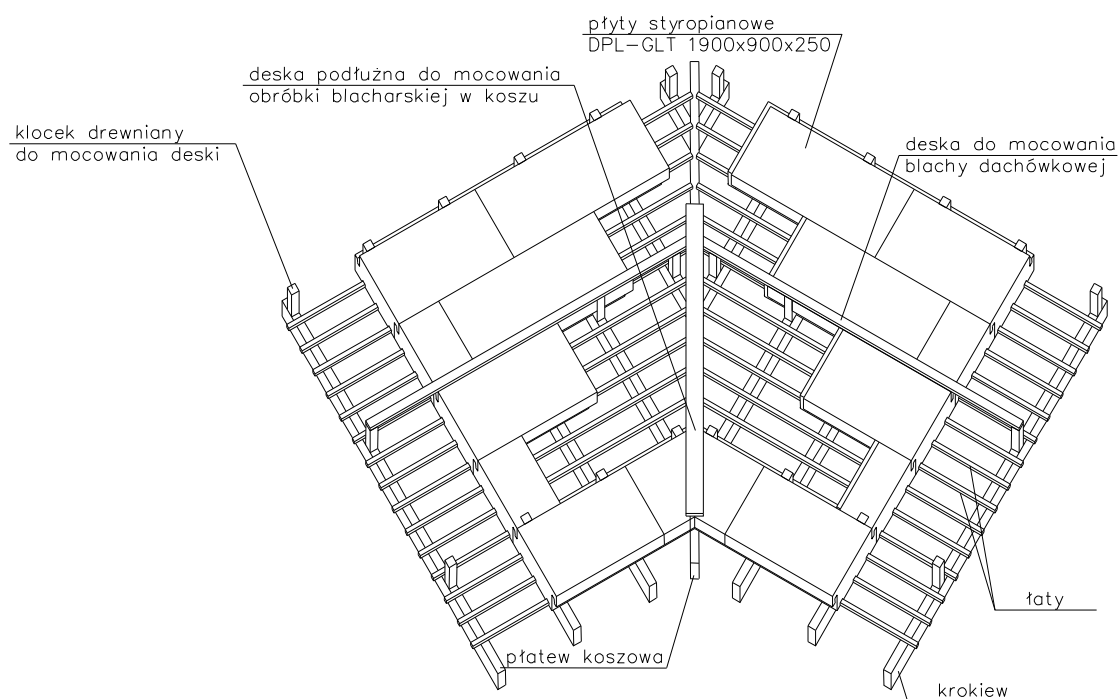


Figure 9. Solution detail in the valley area (klocek drewniany do - wooden block to fix the plank; deska podłużna do mocowania - longitudinal plank to fix the flashing in the valley; płyty styropianowe - EPS boards; deska do mocowania blachy - plank to fix the roof sheeting; łaty – battens; krokiec – rafter; płatew koszowa - valley rafter).

Place the 25 mm thick plank along the valley on the EPS boards and connect that plank with the sheet fixing planks. The valley flashing should be rolled under the roof sheets and fixed to the longitudinal plank.

3.3 Rafter roof covered with torch-on membrane

In this case, the thermal insulation should be made with the DPL-GLT 1900×900×250mm boards, which should be placed starting from the eaves and the right-hand side. The boards should be placed in an offset pattern as shown on Figure 5. The ridge boards should be cut at a suitable angle to ensure that their side surfaces touch each other. The details of the membrane roofing in the eaves and ridge areas are shown on Figure 10. In this case, the membrane is placed directly on the EPS boards which makes the condensate drainage through the channels impossible. If the drainage through the channels is required, the flashing in the eaves area should be made as shown on Figure 11.

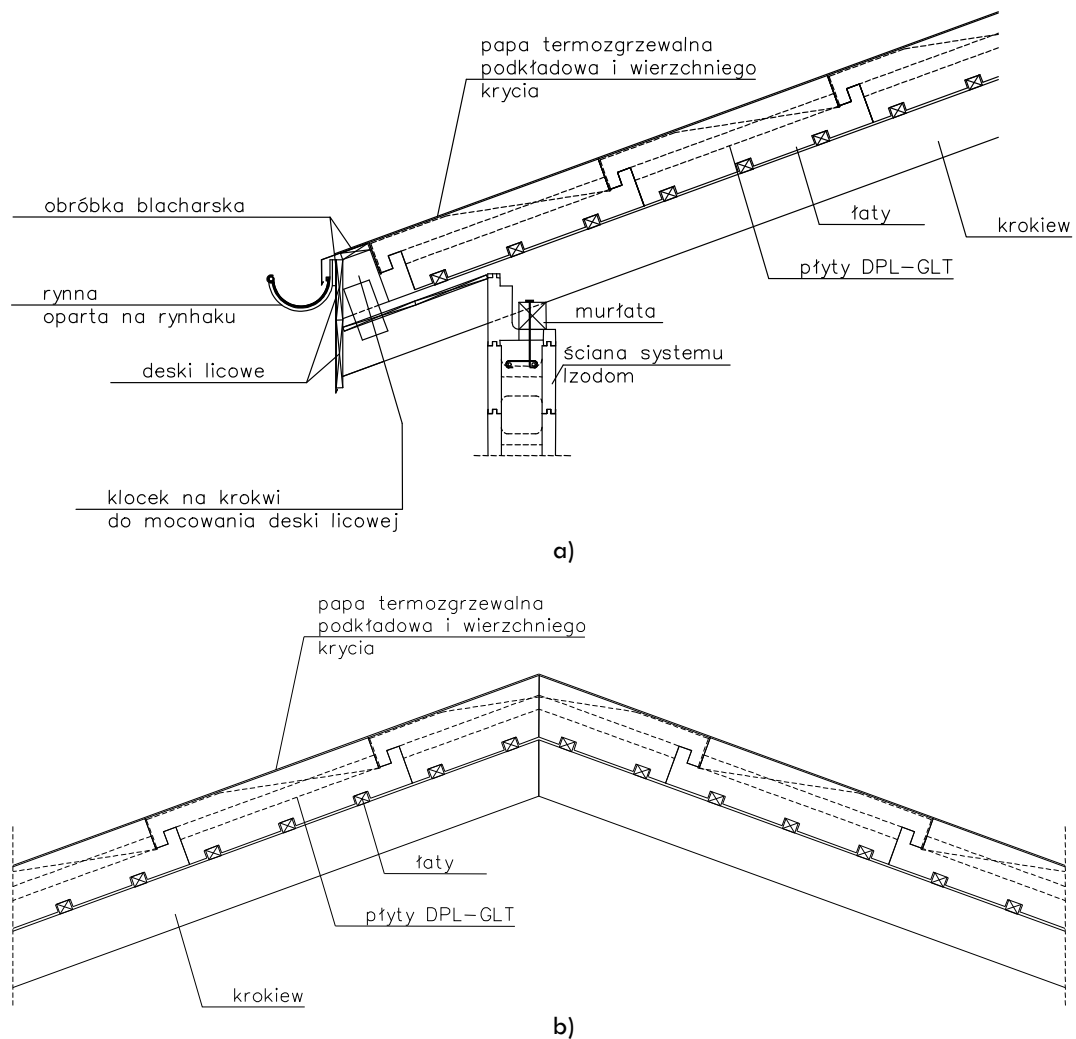


Figure 10. Rafter roof covered with membrane – details in the eaves (a) and ridge areas (b); (papa termozgrzewalna podkładowa - torch-on membrane, base layer and top cover; obróbka blacharska – flashing; rynna oparta na - gutter resting on its bracket; deski licowe - facing planks; łaty – battens; krokiew – rafter; murlata - top plate; klocek na krokwi do - block on the rafter to fix the facing board; płyty DPL – GLT - DPL-GLT boards; ściana systemu Izodom - Izodom system wall; klocek na krokwi do mocowania - block on the rafter to fix the facing plank).

Taking the wind suction into account, in this case the EPS boards should be fixed directly to the rafters. The connectors should be dimensioned according to the wind suction force – see table 1.

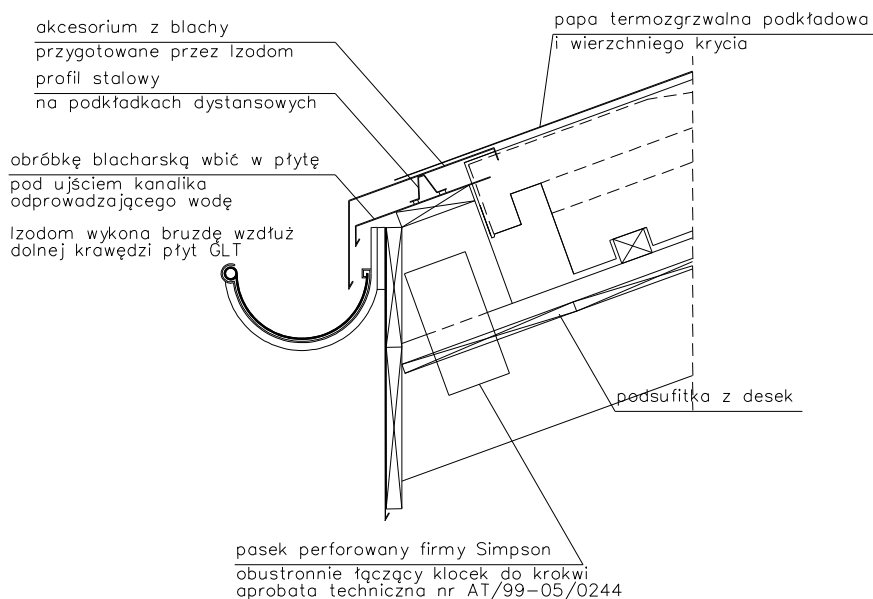


Figure 11. Flashing in the eaves area – water drainage from under the membrane possible (papa termozgrzewalna podkładowa - torch-on membrane, base layer and top cover; akcesorium z blachy - sheet accessory prepared by Izodom; profil stalowy na - steel profile on distance washers; obróbkę blacharską wbić w płytę - flashing to be hammered into the board under the outlet of the water drainage channel; Izodom wykona bruzdę - Izodom to make the groove along the bottom edge of GLT boards; podsufitka z desek - soffit made of wooden planks; pasek perforowany firmy Simpson - Simpson perforated strip fixing the block to the rafter on both sides; technical approval No. AT/99-05/0244).

4 Reinforced-concrete flat roof

In buildings with reinforced concrete, cast-in-situ, prefabricated or beam and block flat roofs, the thermal insulation is made using the DPL-GLT 1900×900×250mm boards. The details of this solution with the outside and inside gutter are shown on Figures 12, 13 and 14. Only in this case condensate drainage from under the roofing is not possible because the flat roof inclination is usually below 11°.

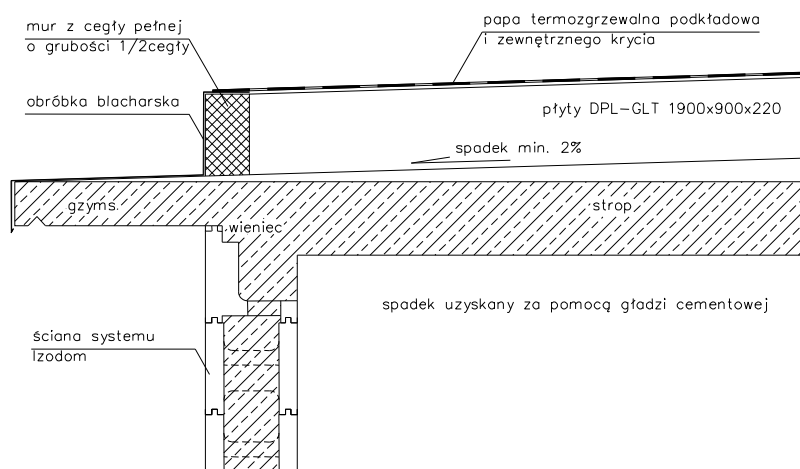


Figure 12. Reinforced-concrete flat roof with outside gutter – details (mur z cegły pełnej - full brick wall, 1/2 brick thickness; papa termozgrzewalna podkładowa - torch-on membrane, base layer and top cover; obróbka blacharska

– flashing; płyty DPL - DPL boards; spadek - slope min. 2%; gzyms - cornice; ściana systemu - Izodom system wall; spadek uzyskany za - slope obtained by means of cement topping; wieniec - tie beam; strop – slab).

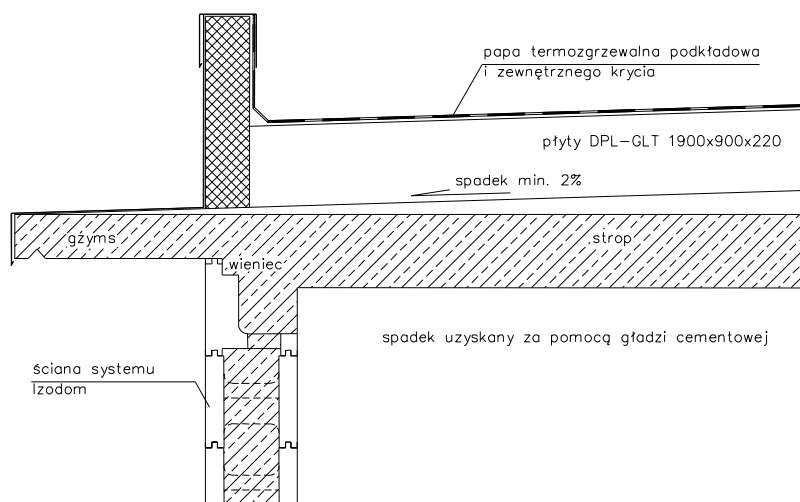


Figure 13. Reinforced-concrete flat roof with parapet wall – details

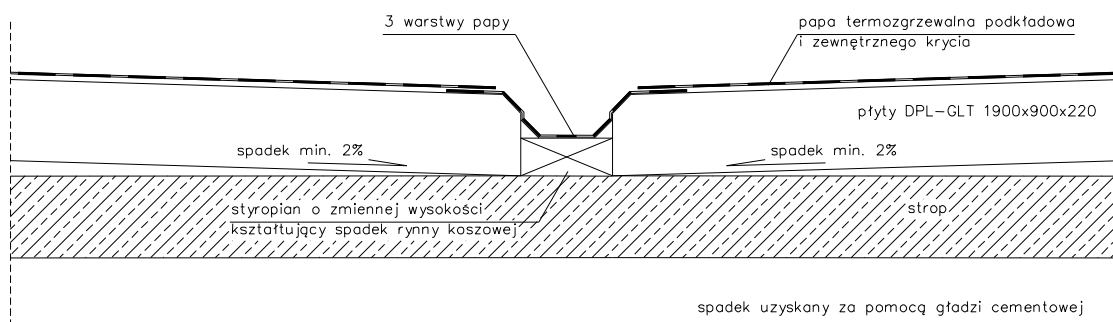


Figure 14. Reinforced-concrete flat roof, valley gutter – details (papa termozgrzewalna podkładowa - torch-on membrane, base layer and top cover; obróbka blacharska – flashing; gzyms – cornice; wieniec - tie beam; ściana systemu - Izodom system wall; płyty DPL - DPL boards; spadek - slope min. 2%; 3 warstwy papy - 3 layers of membrane; styropian o zmiennej - EPS with a variable height to ensure the valley gutter slope; strop – slab; spadek uzyskany za - slope obtained by means of cement topping).

The EPS boards should be fixed to concrete using the Lim Wkręt-Met plastic connectors [4] [5]. These connectors can be used to fix the EPS boards up to 150mm in thickness. In case of the DPL-GLT 1900×900×250mm board (thickness 250mm), use the connectors with minimum length of 300mm because the minimum anchoring in the concrete is 50mm. The number of connectors per 1m² should be specified according to w_{ed} in table 2.

5 Summary

Large-size boards made of a foamed material are a versatile insulating element. They can be used as thermal insulation on the wooden roofs covered with ceramic or cement tiles, metal sheet tiles, corrugated sheet or membrane. They can also be used as thermal insulation on flat reinforced-concrete roofs. An advantage of this solution is easy installation and – due to the locks – precise placement and absence of thermal bridges.

