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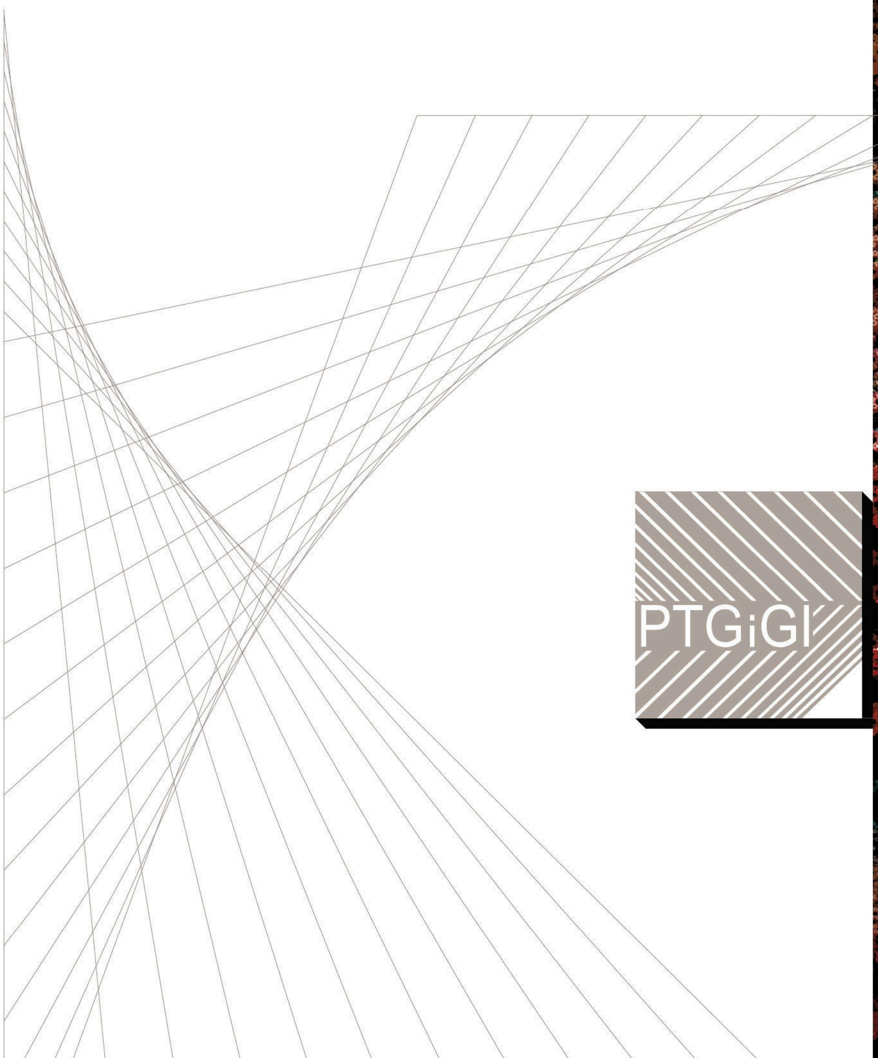

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GEOMETRICAL ASPECTS OF ATTIC MANAGEMENT

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Abstract: The work has shown that the cubic lattice of the usable attic space of the gable roof does not depend on the measure of the slope angles of the hipped roof ends, but only from the height of the ridge position. The surface of the hipped roof ends is the smallest when the slope angles are the same.

Keywords: multi-hip roof, gable roof, saltbox form of roof, attic space, optimization

1 Introduction

Among the buildings constructed especially in the earlier period, now less often, we encounter detached houses with a gable roof with different slopes of hipped roof ends (Photo. 1). It is difficult to say what were the main aims of the investor or designer. The analysis carried out in this paper proves that with certain (perhaps) advantages of this solution, it certainly does not yield a larger usable area. On the other hand, a larger roof area is to be covered. There is probably a question of aesthetics, which is already a matter of more subjective evaluation.

2 Importance of preliminary analysis of roof skeleton in building design - case study

When designing a multi-hip roof, it is worthwhile to make a preliminary analysis of the roof skeleton based on the outline of the building [2]. This will help to avoid unforeseen difficulties with the roof solution. Figure 1 shows the projection of the designed roof truss [1]. Regardless of how the building peaks will be resolved, when determining the building outline a mistake was made by failing to perform the preliminary analysis. Assuming that the slope of the roof is to be the same, it is necessary to adopt a locally symmetric arrangement (see Fig. 1b3). The necessity of implementing a short, irregular (118 cm) segment of the ridge line would be avoided (see Fig. 1b1÷b2). The same is true of the curvilinear structure of the roof slope in the form of a saddle surface which would be avoided (see Fig. 1c÷d). Correction of the dimensions of the building contour allowed the building to be symmetrically localized with a loss of approx. 4 m^2 of surface area (see Fig. 1c: Area=1943973357.8854 [mm^2], Perimeter = 217623.3146 [mm]; Fig. 1b3: Area = 1903476713.4383 [mm^2], Perimeter = 216089.6351 [mm]). The surface loss of approx. 4 m^2 can be compensated by increasing the dimensions by approximately 400 mm, from: 10592 to 11992 [mm] and from 15813 to 16213 [mm]. Although the deviations discussed will not have a significant impact on the roofing technique, and more so on roofing, but the precision in design taking into account such details will undoubtedly be a manifestation of the designer's skill and diligence [1].

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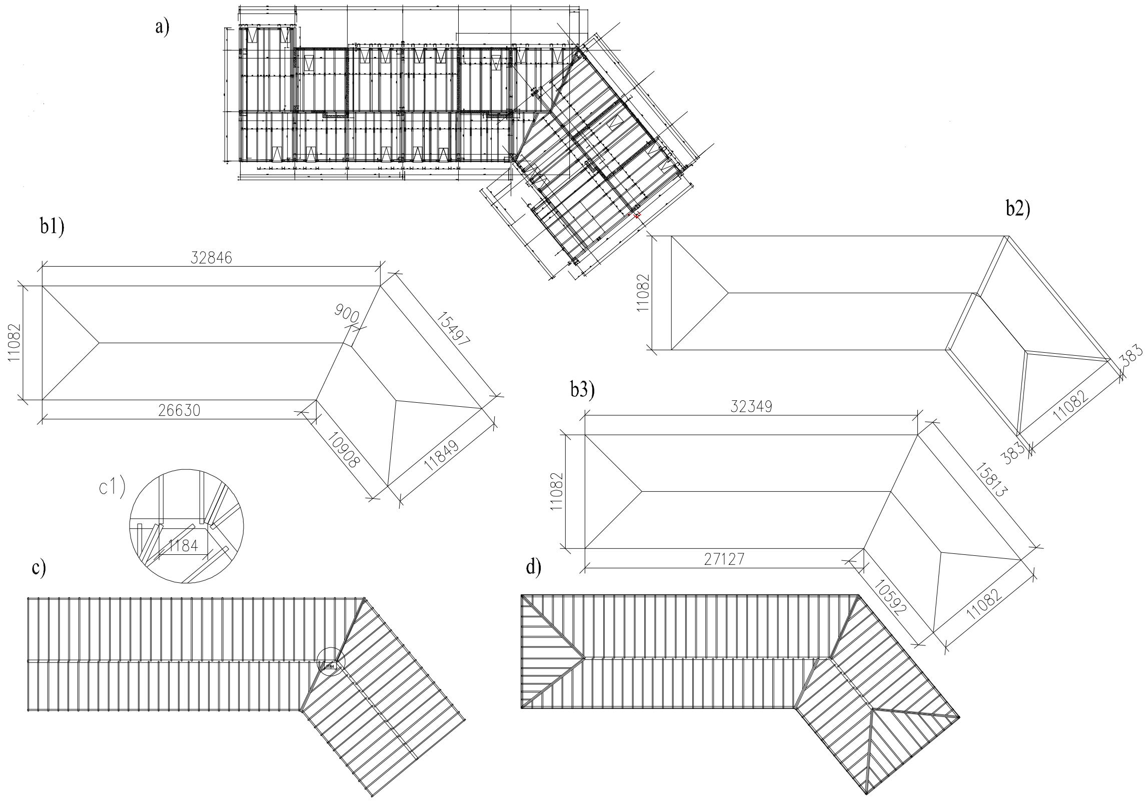

Figure 1: Dimensional analysis of the shape of the roof:

a) a designed roof truss;

b1) the skeleton of the roof with a specified outline of the building (ninety-centimeter section of the ridge, which makes it difficult to design a ridge purlin or ridge beam);

b2) the correction of building contour (shift of two lines of the building plan by 383 mm);

b3) a locally symmetric building plan after correction;

c) a roof with gable walls (with restriction), containing a segment of the saddle surface;

c1) one hundred and eighteen centimeters of ridge purl, oblique to the straight line of the eaves, "forcing" the adoption of a segment of the saddle surface in the roof solution;

d) multi-deck roof (hip roof), with sections in the upper part of the building and a section of the saddle surface

3 Geometrical aspects of attic management

Among the buildings built in previous years, we often encounter gable roofs with different slope of hipped roof ends [3], but they are not saltboxes (Fig. 1, [4]). It is hard to point out the motives of such solutions. Sufficient justification could be an aesthetic motivation. The slope of the hipped roof end is similar to the sloping roof [3] and hence the roof window is almost vertical. The functionality of the premises would be less justified. It would be unreasonable to claim that we get a larger attic space.

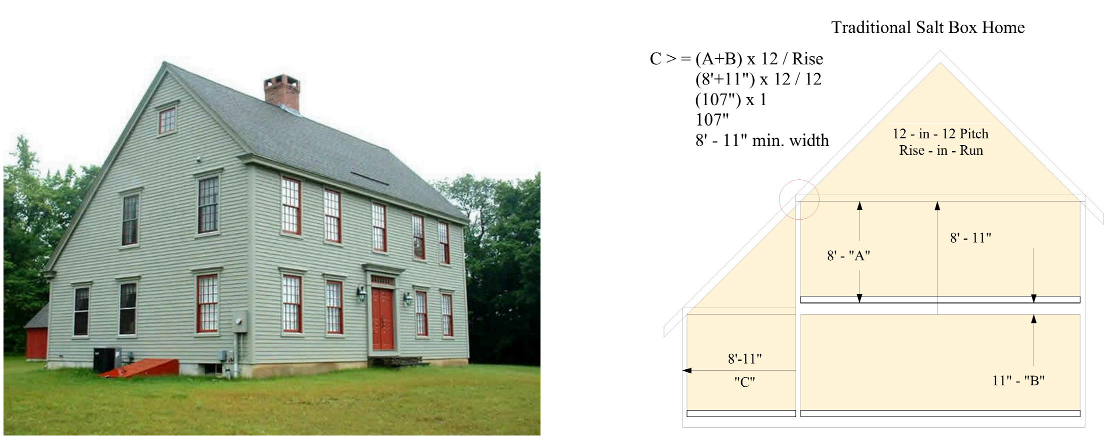

Figure 2: Traditional saltbox roof. Historically - adding a single-story lean-to shed to the back of a 1.5 or 2 story & one-room deep house was the most practical method of gaining more space. The resulting shape of this new house was the shape of a wooden box used to store salt in Colonial times, that's why we call them saltboxes [4]

We will prove that if the height of all walls is the same (the eaves are on one level), after determining the height of the roof truss from the ceiling, then the slope angles of the hipped roof ends (obviously acute) do not affect the volume of the usable attic height induced by the height h_1 (Figure 3). Naturally, the attic cubicle depends only on the assumed height h of the roof and, of course, the width x of the building (Figure 3). On the basis of the assumptions, which refer to the designations given in Figure 3, based on the similarity of the corresponding triangles, we obtain the equation x_1=x_1*. Thus, the amount of space at a certain height h_1 in the attic in both cases is the same. However, it is different in the case of the size of the roof area. Let us represent the circumference P of the triangle (see Fig 3b), as a function of the parameters φ and ε defined in the following way.

Photo 1: Detached house with different angles of slope – little bit reminiscent of saltbox form of a roof (photo: E. Koźniewski)

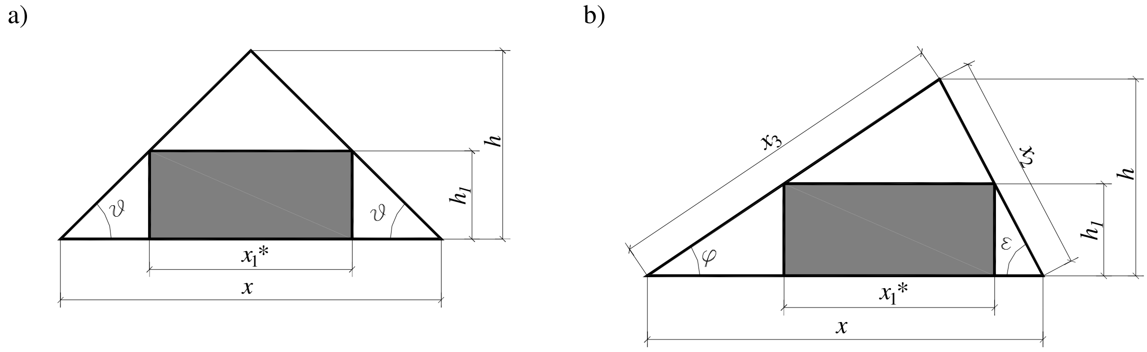

Figure 3: Cross section through the attic: a) with the sides forming the same angle ϑ with the polygon of the eaves, b) with different angles of inclination φ and ε to the plane of the polygon of the eaves (saltbox form of roof)

As shown in Figure 3b we can write:

$$\mathrm{P}=x+x_2+x_3=x+\frac{h}{\sin\varphi}+\frac{h}{\sin\varepsilon} \tag{1}$$

for the input data x i h which at the same time satisfy the condition

$$\cot\varphi+\cot\varepsilon=\frac{x}{h}. \tag{2}$$

From the equality (1), due to (2), since the values x and h are known, we can write

$$f(\varphi)(=\mathrm{P}-x)=h\left(\frac{1}{\sin\varphi}+\sqrt{1+\left(\frac{x}{h}-\cot\varphi\right)^2}\right). \tag{3}$$

The function $f(\varphi)$ is decreasing because the derivative

$$f'(\varphi)=-\frac{1}{\sin^2\varphi}\left(\frac{\sqrt{1+\left(\frac{x}{h}-\cot\varphi\right)^2}+\left(\frac{x}{h}-\cot\varphi\right)}{\sqrt{1+\left(\frac{x}{h}-\cot\varphi\right)^2}}\right) \tag{4}$$

in the range [arccot$\frac{x}{h}$, ϑ] takes negative values. In fact, with the shift of the upper vertex of the triangle (Figure 3a) from left to right (Figure 3b), the argument φ decreases from ϑ to arccot$\frac{x}{h}$. Thus, the sum of the lengths of the sides of the triangle increases. The boundary value of the angle φ is arccot$\frac{x}{h}$ because (naturally) it should be assumed that the angle ε should not be obtuse. As a result of the application of this property in the design of the building, through the cross-section, we obtain a conclusion of the optimum (minimum) of the roof framing dimensions and the size of the roof covering for the same slope of the hipped roof ends. Of course, as we have already said, this is a situation in which the walls of a building are of equal height, i.e. the polygon of the eaves (the base of the roof) is planar and lies in a horizontal plane.

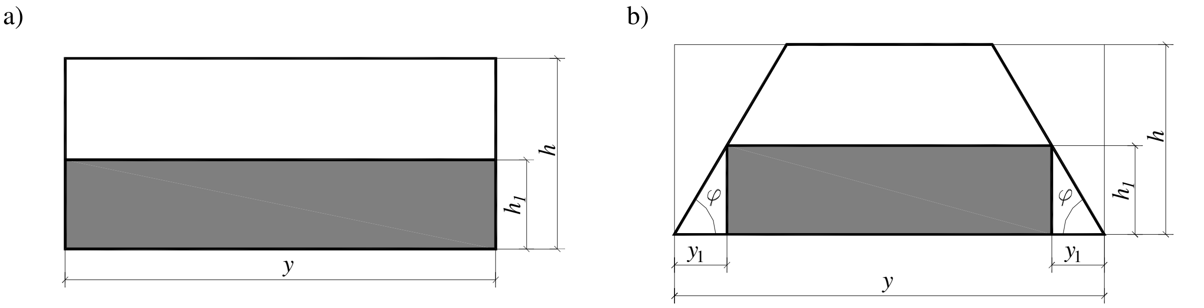

Figure 4: Longitudinal section through the attic: a) with gable walls, b) with angles forming the angle φ with the polygon of the eaves

A designer who creates design concepts of a building must consider what a designed roof should be. So, he must answer the questions: should one design a multi-hip roof without restrictions, so without the gable walls – then each side of the polygon of the base is an eaves Figure 5a) or such that some sides of the polygon do not have hipped roof ends (Figure 5b), or finally, a roof where that all the gable parts are walls, i.e. they do not have hipped roof ends (Figure 5c)?

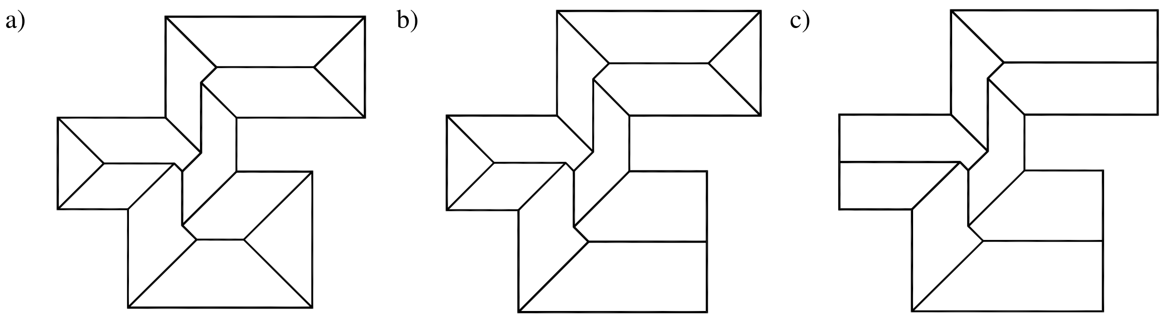

Figure 5: Example of a multi-hip roof [2]: a) without restrictions, b) one of the gable walls does not have hipped roof ends, c) no gable wall has a hipped roof end

Here the answer is obvious - profit and loss analysis. What is profit? Aesthetics, harmony of roofline, reluctance to apply solutions which involve a usable attic. The benefit is undoubtedly the increased floor area of the usable attic. The angle of inclination of the hipped roof ends is an important element of the building's shape and should be considered in three aspects: functional, climatic and economic and possibly fourth: aesthetic.

4 Conclusion

The analysis of the shape of the roof should precede the design of the building to interactively select the optimal solution. The natural symmetry of the form of the hipped roof ends, including the slope angles of the hipped roof ends, leads to the most favourable solution.

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GEOMETRYCZNE ASPEKTY ZAGOSPODAROWANIA PODDASZA

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