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STRUCTURAL BRACING OF WOODEN ROOFS UNDER THE EXTREME WINDS

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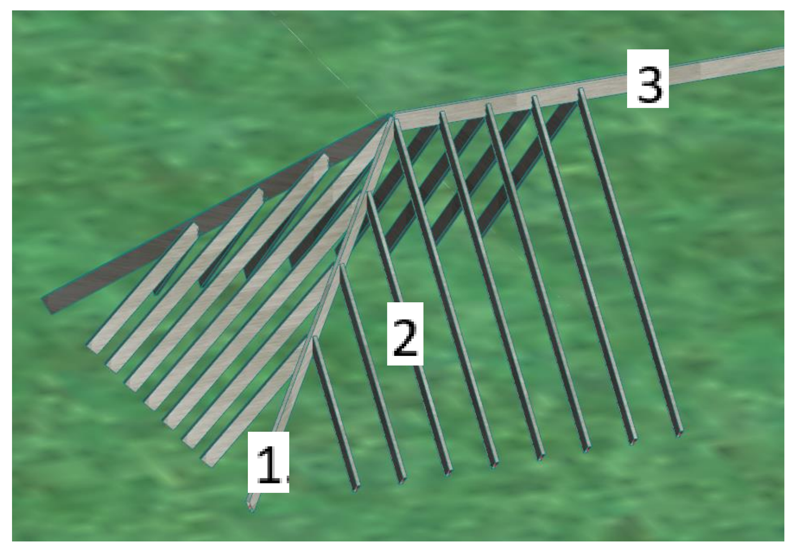
Introduction

The buildings are crowned with a roof that provides protection against weather conditions. Important factors are the shape of the roof, the type of roofing and the slope. Supporting structures in residential buildings are most often made of wood. There are several basic types of roof structure. Depending on the type of the wood framing, it may include the following elements: hip, ridge and rafter (Fig. 1). The most common cause of failure is the effect of strong winds, e.g., during hurricanes. Based on the observation of damaged structures, it can be concluded that the cause of damage is too long unsupported lengths of the elements. Recent studies have recommended tight hip bracing. The aim of the work is to analyze the position of the ceiling struts for the corner element in the ceiling in terms of the ultimate limit state and the serviceability limit state, in various variants of the structure.



1. HIP
2. Rafter
3. Ridge

Fig. 1 Frame structure of a multi-slope roof

Material and Methods

Based on the finite element analysis, a basic model of a multi-slope roof was created, consisting of two ridge tiles, six corner rafters and two valley rafters (Fig. 2). The work focuses on the support conditions of the corner element called HIP, by adding or changing the spacing of adjoining rafters (Fig. 3). The model was loaded in a manner typical for Central European and North American conditions (Fig. 4a, 4b). The structure is tested in various variants: with different spans, sections and for different inclinations, under the influence of standard and extreme wind speeds. The main criteria taken into account when choosing solutions were the values of forces and displacements. Based on the known strength of the wood, efforts were made to find the maximum unsupported length of the HIP and check the effect of support when this length is increased.

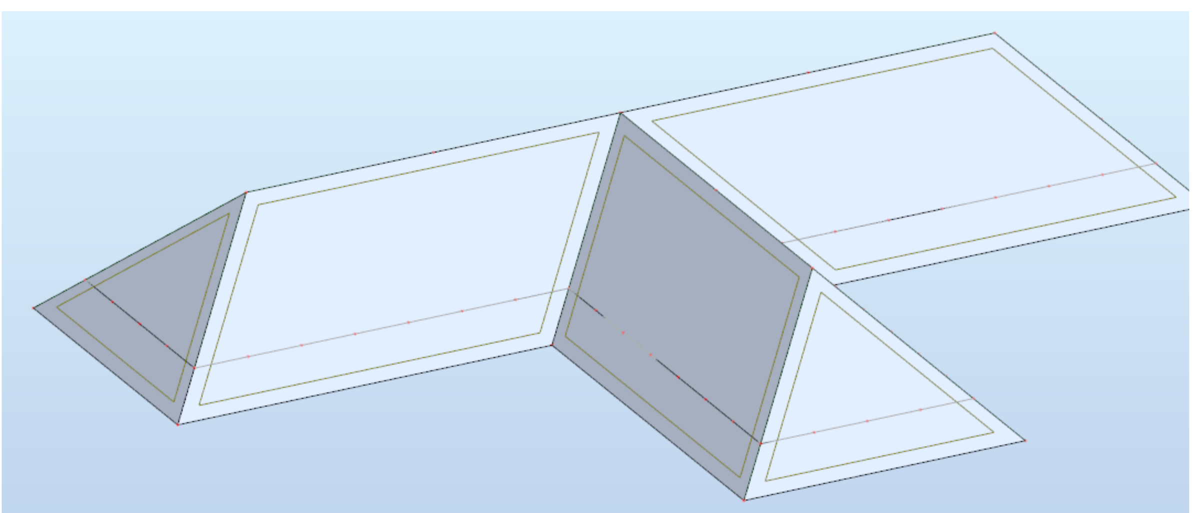


Fig. 2 Basic 3D model of a multi-slope roof

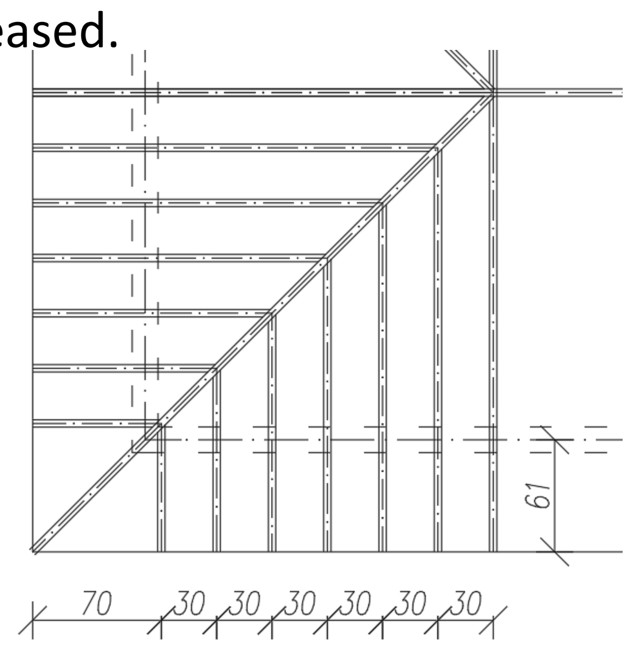


Fig. 3 Roof rafters adjacent to HIP

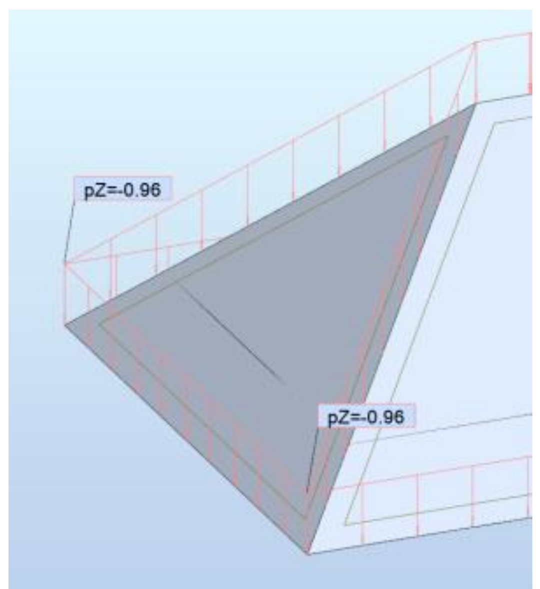
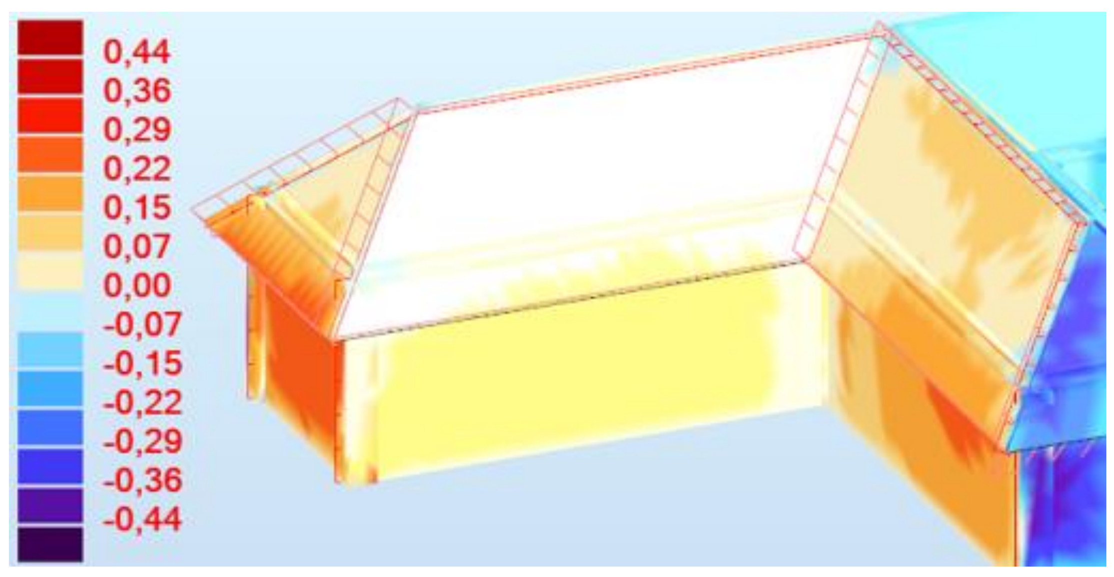


Fig. 4a Diagram of live and dead load



4b Diagram of pressure and wind load

Results

The starting point was the research carried out earlier, based on the observation of damage and specialized computational programs. The article attempts to reproduce the conditions for an object located in Europe, based on Polish standards. The first step in finding the total unsupported length (TUL) was to select the appropriate beam cross-section and roof slope, typical for the assumed conditions. Then, many models were made based on the basic model (Fig. 2) with different spans, but with a constant overhang length. The models were loaded in the same way and the internal forces were compared. The last stage was adding additional rafter supports to models with a larger span. It was necessary to find a suitable way of introducing the rafters so as not to disturb the place of extreme forces. The results of the forces obtained are summarized in Table 1.

Table 1 Obtained results and comparing them to models of the corresponding unsupported length

Case (summary)	HIP length [m]	Total unsupported length	Load type	σ [Mpa]	M [kNm]	T [kN]	u [mm]
I	2,26	2,26	Surface	3,95	0,82	1,76	0,90
			Wind 22	2,38	0,18	0,39	2,90
			Σ for 22:	5,12	0,83	1,79	3,00
V	2,67	2,26	Surface	4,17	0,83	2,19	1,50
			Wind 22	2,59	0,19	0,50	3,10
			Σ for 22:	5,79	0,85	2,26	3,20
VI	3,20	2,26	Surface	3,30	0,69	1,60	1,60
			Wind 22	1,85	0,15	0,35	2,20
			Σ for 22:	4,17	0,71	1,65	2,30

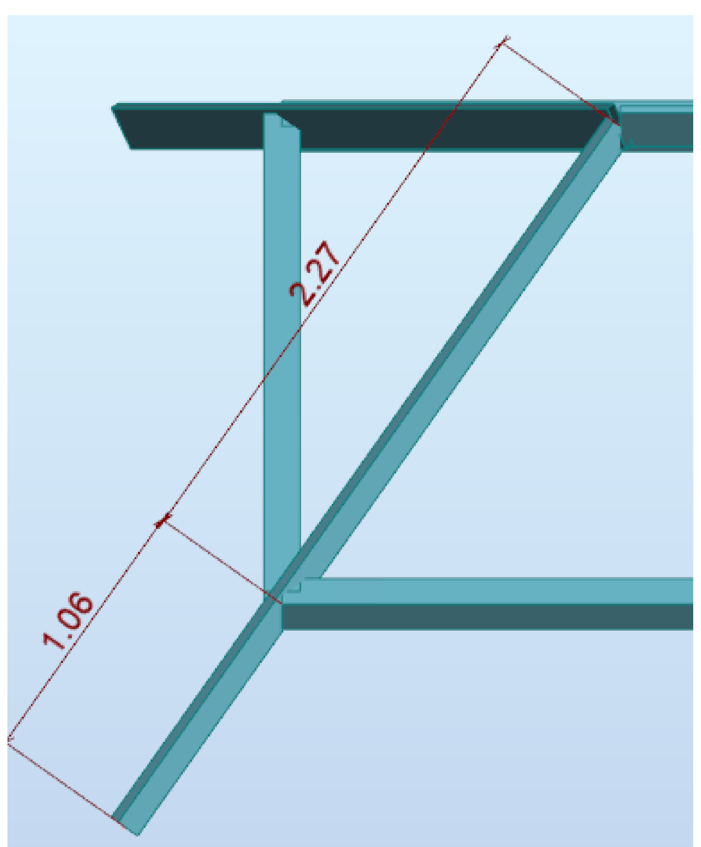


Fig. 5 Models with a TUL depending on the roof span

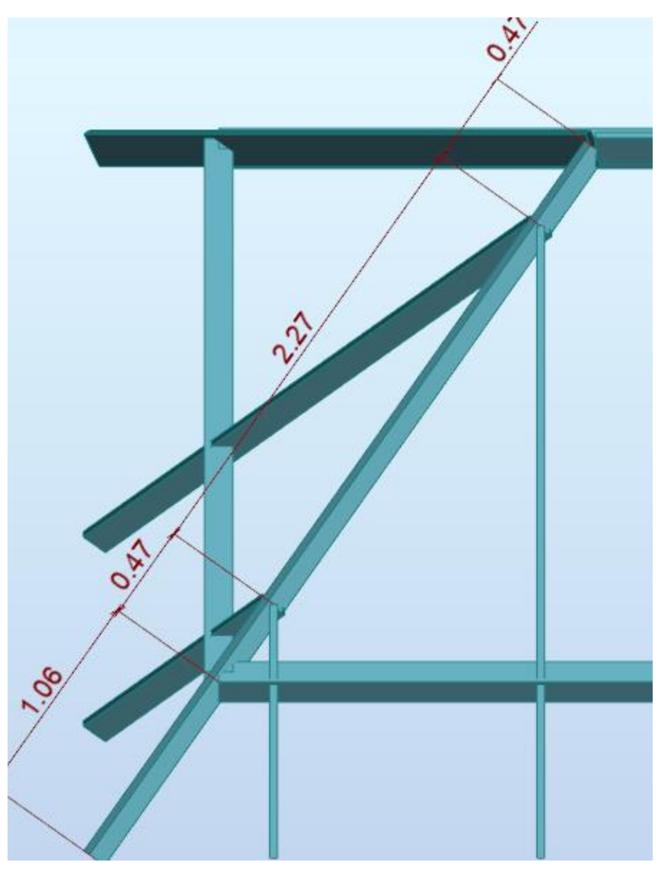


Fig. 6 Larger span models, reduced by adding rafters

Discussions & Conclusions

The obtained results were compared with models of the corresponding unsupported total length (Fig. 5). For hip, smaller internal forces and displacements were obtained for the schemes shown in figure 6 due to the support of the hip in the place of the highest loads. The comparable internal forces and deflections for the valley result from the comparable values of the loads acting on the valley. The conducted analysis shows that it is necessary to support the hips, apart from the ridge and the support on the wall, in the case of roof slope of 45°, the length of the element longer than 2.26 m and for the tile roofs, under dead, live and wind loads. In the case of extreme wind load of 40 m/s the bracing in the distance of 2.26 is insufficient and will be the subject of further analysis, the results of which will be presented in the next article.

Acknowledgements

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