Experiences in design, construction and maintenance of timber shell roofs in Estonia

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Abstract Two-layer hypar-type timber shell roofs were first used in Estonia in 1960. Up to that time about 50 shell roofs had been designed and constructed. Older roof shells have been in maintenance nearly for 40 years. These shells are rectangular hypars consisting of two or three-layer timber boards with an edge element in plane about 10 x 10 meters. Some of them are combined from 2 to 8 hypars. Before design and construction, the behaviour of the structures was examined by testing numerous model structures and theoretical analysis during several years. Experiences in the study, design, construction and maintenance are presented.

Keywords timber saddle-shaped (hypar-type) shell roof, hypar shell, structure models, experimental investigation, actual behaviour of structure, composite structures

EXTEND ABSTRACT

The first two-layer dome-shaped timber shells were designed and built by the engineer Theodor Kalep as early as 1908-1909 in Riga. Those shells maintained for about 40 years were square and of 18 m span.

Timber shell (TS) structures are now being erected all over the world. Many authors have carried out experimental and theoretical studies on TS work. For over 40 years the work of different TSs has been investigated in the Estonia. Flat two- and three-layered timber shells are being analysed through experimental investigation, testing of models and calculations. The work of cylindrical, conoidal and in particular, various in plan square saddle-shaped (H-type) shells, has been studied.

The TSs concerned consisted of two- or three-board layers, placed parallel to the shell diagonals. When a third layer was used, it was placed at 45° to the other two layers. Some shells were strengthened by glass-reinforced plastic , prestressed steel cable network or by ribs. The latter was placed parallel to the contour beam. Timber boards of different layers were connected by nails.

First, loading tests were carried out on the models. Model dimensions in plan were 1.8 x 1.8 up to 3.5 x 3.5 m, contour elevations usually 1/5 and surface thickness 1/200 until 1/340 from plan measure. The models were loaded with evenly and unevenly distributed vertical loads up to 6 kN/m2. Some models were loaded to the collapse.

The surface of H-type TSs corresponded to the hypar or to another saddle-shaped surface. It was shown that saddle-shaped shells have advantages over other types in terms of bearing capacity.

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Saddle-shaped surfaces satisfy even in the circumstances of the contour freely deforming in the horizontal direction.

Two-layer hypar-type timber shell roofs were first used in Estonia in 1960. Up to that time about 20 shell roofs had been designed and constructed. Older roof shells have been in maintenance nearly for 40 years. These shells are rectangular hypars consisting of two- or three-layer timber boards with an edge element in plane about 10 x 10 meters. Some of them are combined from 2 to 8 hypars. The behaviour of H-type shells, specifically of those under maintenance, were also investigated under sustained loads.

One of the studies focused on the behaviour of an elliptical in plan roof, a composite structure consisting of prestressed cable network and a three-layer timber shell with a contour from steel tube freely deforming in the horizontal direction was examined theoretically and by testing the model structure. In this case the timber shell was connected to the contour tube through a steel edge element by bolts and to the network in every knot by clamp joints. This type of the structure was erected in 1992 as the roof of the Song Festival Tribune in Tartu, Estonia (diagonal measures 42 and 54 m). Observation of the actual behaviour of this structure was also carried out.

CONCLUSIONS

Saddle-shaped two- or three-layer TSs constructed from boards can be used as a carrying structure for different roofs with moderate spans, especially in rural areas. Local builders can construct such roofs with straight edge elements quite easily and quickly. In cases of larger spans it is necessary to strengthen the TS with ribs or to use composite structures consisting of two- or three-layer TS and cable network.