Dome Structures. Saldome 2.

Christoph Häring

MSc Swiss Federal Institute of Technology Zurich, President of the Häring Group's Management Board, Pratteln, Switzerland
chris.haring@haring.ch

ABSTRACT

The development of Saldome 1 and Saldome 2 is presented. General consideration of cost-efficient storage of huge quantities of salt and other bulk materials is outlined. The geometrical background of the Haring ENSPHERE net structure is shown. The foundation concept, assembly method and roof skin concept for Saldome 2 is presented.

KEYWORDS: GLULAM, ENSPHERE, TIMBER DOMES

1. HISTORICAL REVIEW ON TIMBER DOME STRUCTURES

Large timber dome structures have been erected in the USA in the nineteen-seventies and eighties – mostly as multi-purpose halls or sport stadiums. The geometry of the structural framework was usually based on the geodesic dome, the application of which is strongly connected to the name of Buckminster Fuller. His most famous work was the Montreal Biosphère, a spherical steel structure measuring 76 meters in diameter and 62 meters in height.

2. BACKGROUND OF THE SALDOME CONCEPT

2.1. Saldome 1

In the mid-nineties of the twentieth century the Swiss Federal Rhine Salina started looking after construction forms allowing considerable larger storage volume than the traditional storehouses with three-pin arch-frame supporting structures. However the traditional timber construction storehouses showed a remarkable durability even after 40 years of service in a very aggressive corrosion climate. Augmented storage volume and reduced storage cost per tonne could then only be provided by the use of a more efficient supporting structure spanning a larger bulk volume. The sphere is the intuitively right choice providing a material optimized cover of a free space. The spherical calotte protects a salt cone with maximized ground area and minimized surface against weather conditions. Furthermore the rotational storage concept provides operational simplifications concentrating the mechanical devices necessary for loading and unloading. The concept was first applied in 2005 and resulted in the construction of the Saldome 1, a timber dome structure measuring 90 m in ground diameter and 30 m in height.
2.2. Saldome 2

Change of the climate conditions with more temperature cycles around the melting and freezing point respectively combined with an extended demand of snow clear roads throughout the whole year led to considerable problems providing de-icing salt supply in hard winters. The completion of Saldome 2 with its additional 110'000 to 120'000 tons of salt storage capacity will enable the supply guarantee of de-icing salt for Switzerland in future winters. The diameter of 120 m and height of 32.5 m makes Saldome 2 the widest spanning timber dome built in Europe.

2.3. Planning and realisation

Although the timber dome is respected as heartpiece of the work to be realised its contribution to the total cost is only one third of the overall cost. Alongside the entire work basically consist of the logistic facilities, traffic development and drainage system. Development and engineering works started April 2010, the construction permit has been received in early 2011. Construction works started in June 2011 and will be completed end of April 2012. Erection of the primary and secondary timber structure started in October 2011 and was completed 9 weeks later. The roof was completed in February 2012.

Figure 1 – Cross-section along apex connection of Saldome 1 and Saldome 2.

Figure 2 – Ground plan of Saldome 1 and Saldome 2 area.
3. STRUCTURAL CONCEPTION

3.1. Net Geometry

Both Saldome structures use the ENSPHERE net geometry. The knots and bars are generated starting with a virtual plane to be imagined above the final sphere containing a regular net of equilateral triangles which are projected at the spherical surface using a multistage algorithm.

Figure 3 – Nocturnal impression of the illuminated Saldome 2 structure.

Figure 4 – Creation of the spherical ENSPHERE net.
Neglecting minor irregularities in the abutment zones the three interlocking arch systems being generated have an impressive natural aesthetic appeal and are clearly effective as supporting structures.

Minor irregularities in the net geometry in the abutment zones are being accepted allowing to set constant the distance between the 48 supports.

Each structural element lies on an individual meridian of the sphere whose center lies 40 m below ground level in the case of Saldome 2. Concerning the glulam production this provides a notable simplification as each curved structural element has a constant radius of about 72 m and is being press sized using the same settings.

Furthermore the cuts at the bar ends are oriented to the spherical center thus being perpendicular to the bar axes.

The net geometry requires only two variables defining the structural elements. The first variable describes the bar length. The three interlocking arch systems create 6 sectors of identical geometry. The total number of 534 bars separate 89 types of bars. The second variable consists in the angles the structural elements span to each other. The 163 crossing knots are divided in 28 types with individual attachment angle configuration.

The fixation of a constant dimension of the glulam beams of 200 x 943 mm allows to use a identical connection design for each beam end.

3.2. Ring Foundation

With arch or dome constructions high radial stiffness of the supports is crucial for the formation of the load carrying action one strives for. For large diameter to height ratios this correlation gains additional importance.

The foundation of Saldome 2 is provided by a combination of single foundation blocks acting against the concentrated vertical forces and a circular beam tie in reinforced concrete to resist horizontal forces.

Figure 5 – cantilevering assembly process; (a) attachment of a prepared A-type subassembly; (b) lifting in position of the A-type subassembly – no scaffolding was necessary
The use of single foundation blocks allows clamping of the beams and hence to assembly the structural elements using the cantilever method. In Saldome 2 the cantilevering assembly process worked to its pure form as no scaffolding was necessary at all.

3.3. Roof Skin Elements

Considerable optimization from Saldome 1 to Saldome 2 consisted in the formation of the roof skin. It is a challenge for every roof with double curvature to find a convincing approximation of the surface built with the only single bendable engineered wood products.

In Saldome 2 the primary structural net has been refined with secondary beams to reduce the inherent spans so that the elementation of the roof surface with no reference to the primary and secondary structure was possible. The joints of the roof skin elements could be realised lying between the primary and secondary beams.

The 13 m long and 2 m wide slightly conically cut macro roof skin elements were industrially produced in series with a lengthwise curvature.

Waterproofing is provided by coating the elements in factory with a novel liquid plastic with schistose granulate dispersed on. The lasting gaps at element margins are in-situ filled with the same material providing flexible joints.

Figure 6 – Elementation of the roof skin.