ROOF STRUCTURE OVER NEW SWIMMING POOL IN ST. MARTIN, CROATIA

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Summary

The paper presents a new glulam structure over the swimming pool facilities in St. Martin, Croatia. The glulam structure supported by steel columns was built in spring 2005. The glulam structure is designed as wave-formed continuous beam with a Gerber hinge.

The structural and buckling analysis have been performed using COSMOSM software at the Faculty of Civil Engineering, University of Zagreb. The paper presents analysis details, as well as the structure details. The photographs show the course of construction and the finished structure.

1. Introduction

According to the design papers and drawings, the adaptation of the existing facilities and the roofing up the outdoor pools in St. Martin thermal spa resort was conducted in a very short period. The thermal spa exists since 1911, when thermal waters were discovered during the exploration of oil wells in this area.

In order to enable the spa resort use throughout the year, the new investor decided to make a roof over the existing pools with the timber structure and to add new outdoor pools. The surface area covered by the new structure is approximately 1650 m^2.

The paper presents details of the analysis of this complex structure, modelling and results of the static and buckling analysis. It also presents the details of the assembly and erection works in spring 2005 as well as the finished structure. The spa has been in function since mid of June 2005.

Architects were Vedran Pedišić and Prof. Emil Špirić, Ph.D.

Structural design was performed by Tanja Baljkas, Civ.Str.Eng., Miljenko Haiman, Ph.D., Civ.Str.Eng. and Prof. Boris Baljkas, Civ.Str.Eng.

2. 3D structural analysis model

The structure has been designed of the main wave-formed laminated roof girders made of European spruce wood, supported by the steel columns. The seven main roof beams are glulam girders spaced at intervals 7.02 m that span from 23.25 m (max) to 10.14 m (min).The cantilever part of the glulam beam is approx. 3.5 m.

For lateral stabilisation of the main girders the structure is provided with two bracings consisting of vertical secondary glulam elements and steel tensile diagonals.

The roof cover consists of high corrugated steel sheets with the bearing capacity at 7 m span, mineral wool as thermal insulation and Sika foil layer as the weather conditions protection.

The bearing structure consists of five different girder types marked with numbers 1 to 5 on Fig. 1., from the upper side of the axonometric scheme.

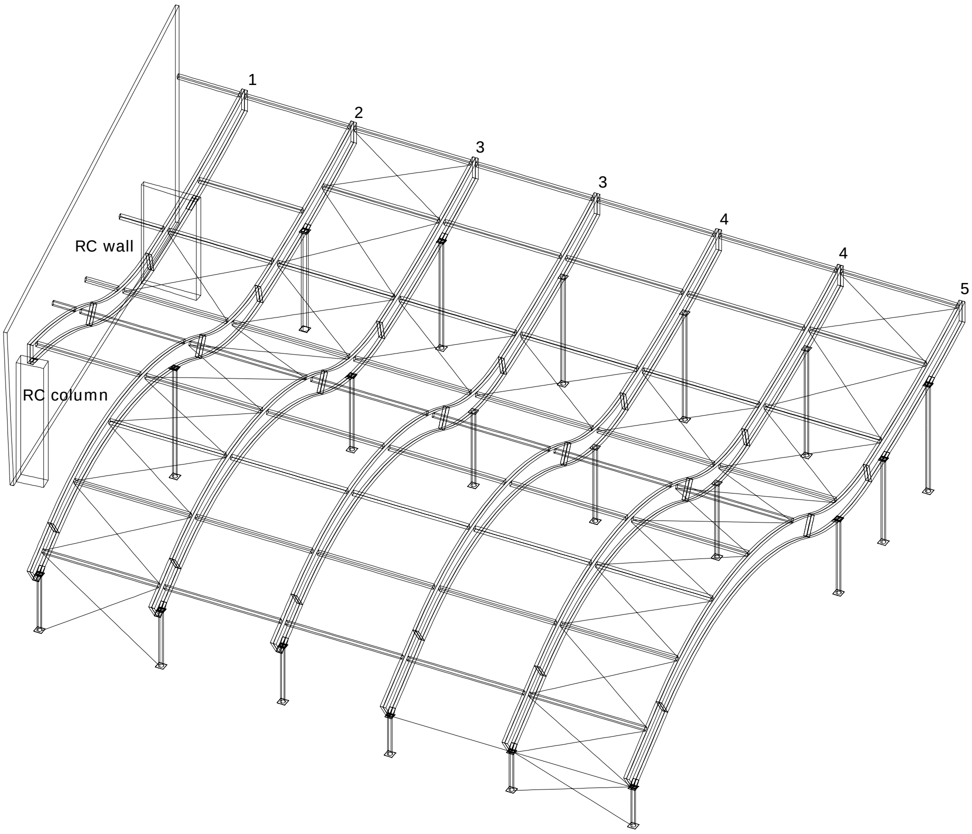

Fig. 1. *Isometric structure scheme*

The difference is in the number of columns and spans. Type 1 is supported on two RC walls, type 2, 3 and 4 are supported by 3 steel columns and type 5 by 4 steel columns (Fig. 1).

COSMOSM FE model of the structural analysis is presented on Fig. 2.

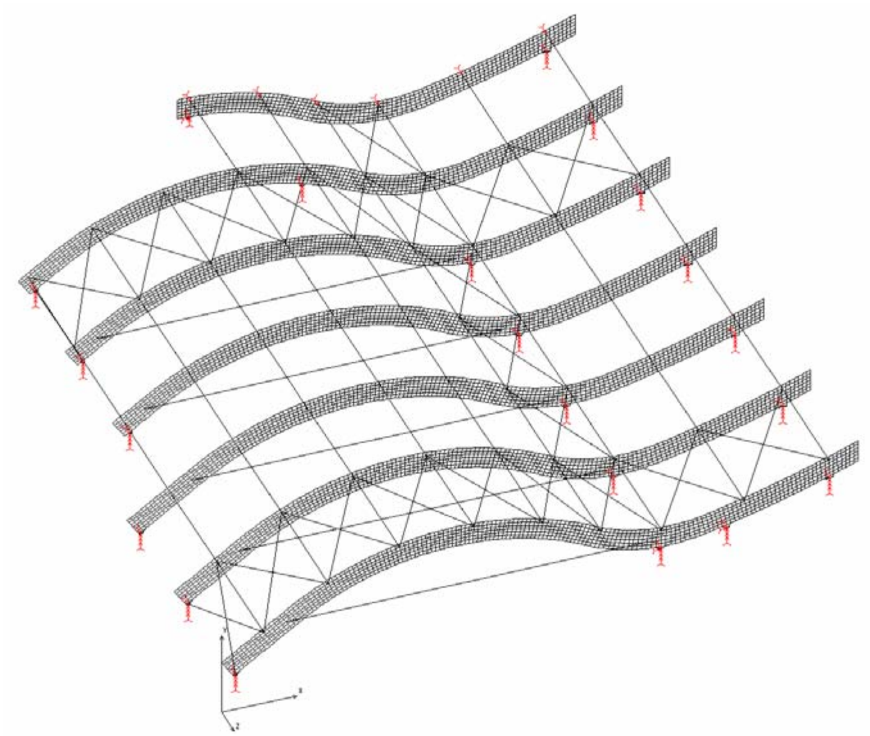

Fig. 2. *FE model of glulam and bracing structure. Red arrows mark the support conditions.*

Main girders 2 x 16/120 cm, are modelled with SHELL4L orthotropic finite elements with the thickness of SHELL elements 2 x 160 = 320 mm and SHELL3L elements for details in the connecting area.

SHELL4 isotropic elements were used for steel bearings (S235). For tie rods connection details, RBAR model elements were used to transfer the load from the tie rod equally to the girders. In reality, these details were made as flat steel sheet elements between the two main girders. These elements are connected with glulam elements with bolts.

Tie rods are modelled with TRUSS3D elements, and the secondary structure of bracing verticals for lateral stabilisation by means of BEAM3D elements. The bracing tie rods are modelled with PIPE elements to accept tension forces only.

Material characteristics - wood orthotropic material of European spruce:
EX = 11500 MPa, EY = 600 MPa, EZ = 450 MPa,
NUXY = 0.027, NUYZ = 0.6, NUXZ = 0.033
GXY = 600 MPa, GYZ = 60 MPa, GXZ = 650 MPa, DENS = 6.0e-6 N/mm^3.

The structure is analysed for 6 basic load cases + COMBINATIONS
LC1 CONSTANT + DEAD LOAD
LC2 SNOW LOAD all over the roof according to local code (1.25 kN/m^2 of the ground plan)
LC3 SNOW LOAD 1 assumed as accumulation of snow in the groove (2.0 kN/m^2 of the ground plan, although the roof structure has heaters preventing such a load. The assumption is that the heating system of the roof surface may be in dysfunction at the most inconvenient moment.
LC4 WIND LOAD -X direction
LC5 WIND LOAD +X direction
LC6 WIND LOAD sideways to the structure in Z direction
LC7 LC1 + LC3 (for buckling analysis)
LOAD COMBINATIONS
LC51 = 1 + 2 + 6
LC52 = 1 + 3 + 6
LC53 = 1 +2 + 4 + 6
LC54 = 1 + 4
LC55 = 1 + 5.

The structural analysis model consist of 6069 elements and 7018 nodes.

3. Results of structural analysis

Structural analysis has shown the maximum stresses for load LC51 combination. Maximum stresses range from 8.63 MPa in tensile zone to -9.77 MPa in compressive zone. The ultimate stress values are up to 11.0 MPa.

Maximum stresses SIG-X for timber elements only are shown on Fig. 3.

In order to avoid excessive deformations of the main wave-formed girder we decided to connect the main span supports with steel rod as bottom chord. That results with the smaller main girders dimension and displacements and as well with no horizontal force at the top of the steel columns and consequently with smaller column section. The bottom chord consist of BESISTA connections and tie rods Ø27 mm.

Maximum deformations for load LC7 are shown in Fig. 4.

Maximum deflection is L/360, which is far less than the allowed L/200 for total load.

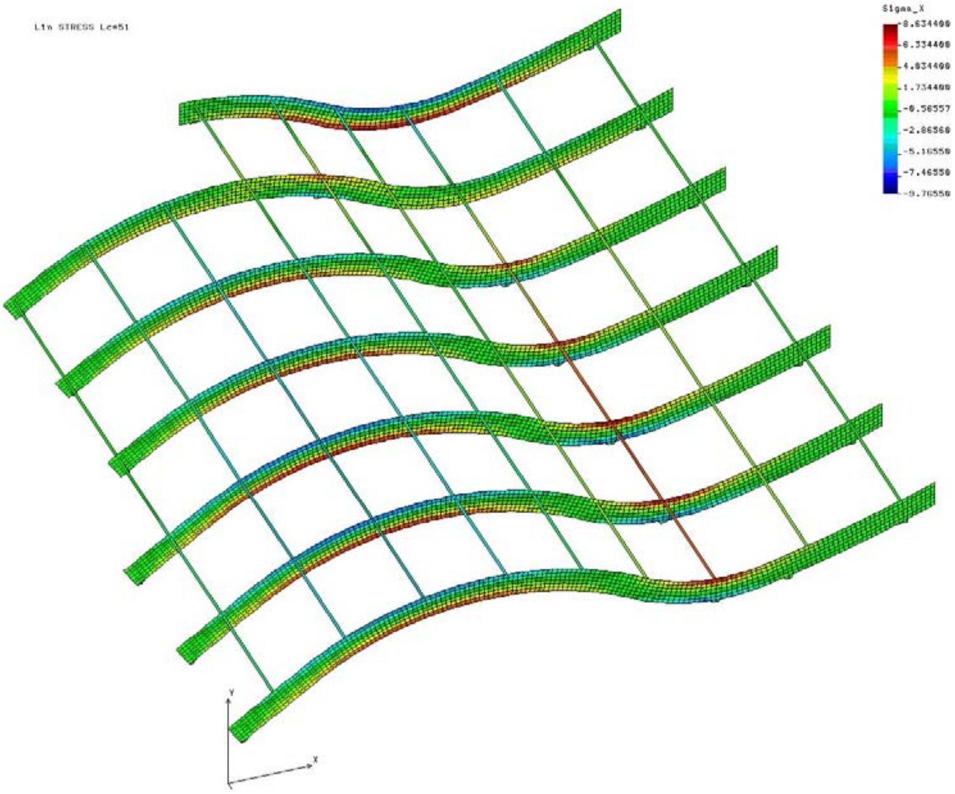

Fig. 3. *Maximum SIG-X stresses of glulam structural elements*

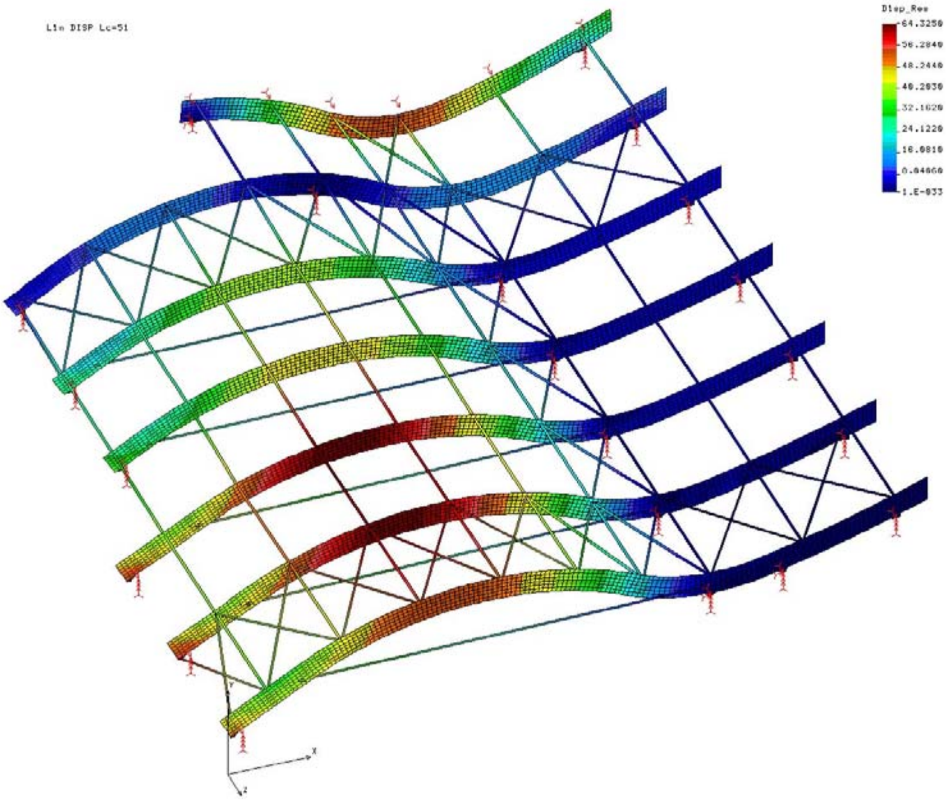

Fig. 4. *Maximum displacement L/360 for load combination LC7 (CONSTANT + SNOW)*

Buckling analysis for maximum load is presented on Fig. 5. It is shown that the buckling safety factor FS =14.5 far exceeds 2.5.

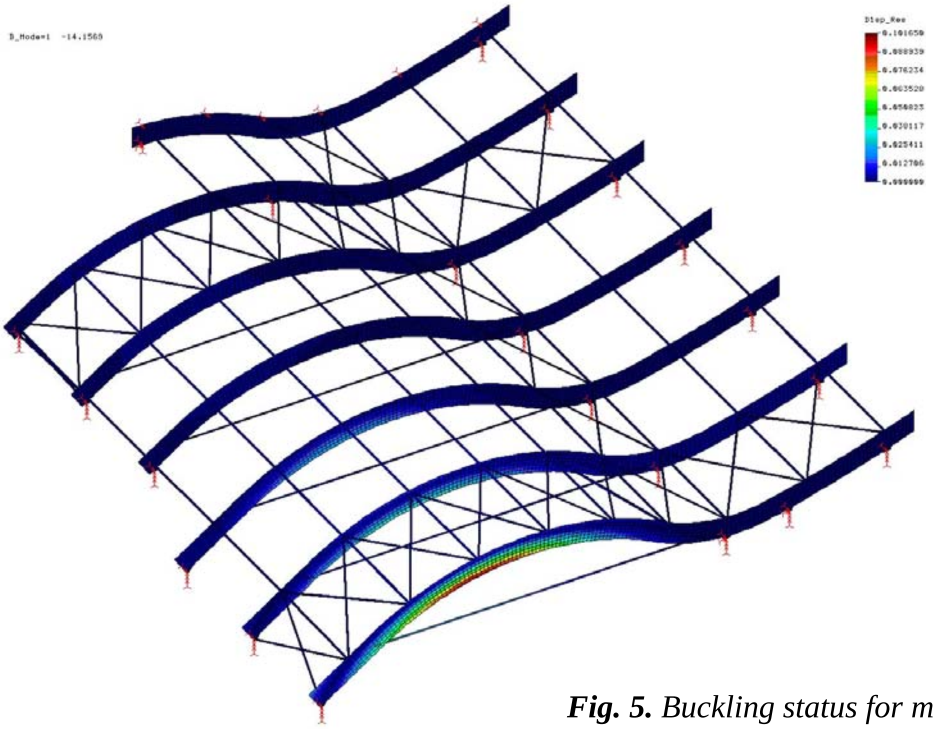

Fig. 5. *Buckling status for maximum gravitation load*

4. Details of the structure

Assembly, erection and roofing of the pool was completed in a short time period of approximately 90 workdays, including all the preparations, erection of steel columns, assembly of the main glulam structure and secondary structure for stabilisation, the roof covering with all the appertaining finishing elements and erection of the glass supporting steel elements.

The timber structure was installed by Haiman-Baljkas Co. Ltd., Zagreb.

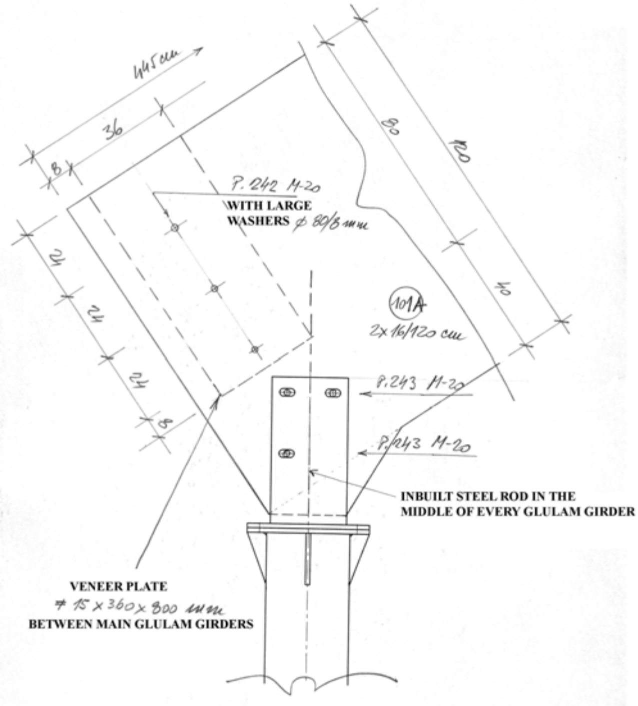

Fig. 6. *Steel column - beam connection drawing*

Fig. 6a. *Complete detail*

The steel columns are supported by the reinforced concrete individual foundations connected by continuous concrete beams. On the top of steel columns between bearing sheets, the elements of the main glulam girders are supported in the joint by 30 mm thick neoprene rubbers. The connection between steel and timber elements is made by bolts (Fig. 6. and 6a.)

Erection of the timber structure started on March 3rd last year with setting the first two elements of the main continuous elements of Gerber girders as shown on Fig. 7. The capacity of crane was 35-tons. Gerber hinge element was prefabricated and during erection it supports the other part of the wave-formed main girder. The connection is made with bolts.

***Fig. 7.** Start of installation of main girders of the glulam structure*

The timber structure is protected by insecticide and fungicide eco coating LESOL. Over that first layer, double protection by colourless UV protection scumble is placed, as usual for pool structures. Besides, the photograph of the structure (Fig. 11) shows that inside the pool area there is protection of de-aeration and humid air replacement by blowing in dry air. The safety system is made by means of perforated PVC pipes in white colour.

The columns are made of the structural S235 steel with standard corrosion protection for specific swimming pool conditions. All steel connectors between timber elements, bolts and lateral bracing elements are made of stainless steel of class 1.4301.

Progress of the construction of the main and secondary elements of structure is shown in Fig. 8. This is the situation at the beginning of April. The installation of the timber structure took 36 workdays.

***Fig. 8.** Installation of timber structure in early April 2005.*

Fig. 9 and 10 show some other details of the glulam structure.

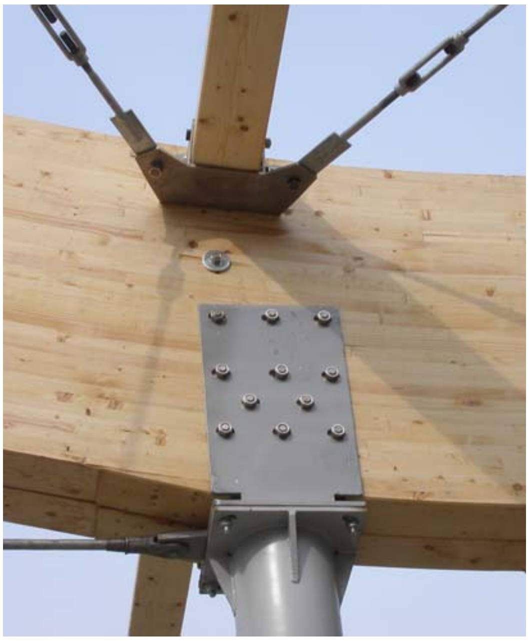

Fig. 9. *Detail of support on central column*

Fig. 10. *Detail of connection of tie road to main girder*

Fig. 9 shows a detail of supporting of the main glulam girder on the central column. The analysis has yielded the maximum force of approx. 20 tons, which could not be assumed by direct contact of bearing neoprene rubber with timber, and the difference of indirect force transfer is assumed with 11 M-24 bolts.

The detail shows the connection of those verticals of the bracing as well as stretchers for the entry of the initial force into the diagonals of the bracing.
On the top of the column, the elements of bracing are connected with Besista joints.
Connection of Besista joints on the other side to the glulam girder is presented in detail on Fig. 10.

Fig. 11. *Completed glulam structure with completely finished facility.*

The analysis of this structure encompasses the possibility of a completely continuous wave-formed beam with possible continuous extensions as the transport conditions did not allow single-part girders. Therefore we selected this solution where a Gerber hinge was used in the continuation of main glulam girders.

5. Conclusion

The quantity of timber for this glulam structure was less than 0.1 m^3/m^2 of the ground plan. It should be noted that cost-effective timber structures are those with the use of timber quantities ranging from 0.05 to 0.12 m^3/m^2.

The use of timber structures, particularly glulam ones, has expanded in the recent twelve years in Croatia. Their application, in addition to pools, is very frequent in the roofing structures of churches, sport halls, public facilities, marketplaces, and alike.

Fig. 12. *Night view of the structure of roofed and open pools in St. Martin, Croatia*

6. References

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