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Long-Span Glulam Roofs for Sport Facilities

Construction en bois lamellé collé pour salles de sport

Brettschichtholzbau für Sporthallen

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SUMMARY

The paper presents the state of the art in glulam constructions applied to long-span structures. The various aspects of glulam timber engineering are described including the following topics: material characteristics, production, structural systems, calculation methods, transportation, erection and cost analysis. A selected number of timber structures are presented in order to illustrate the application of this material to sports facilities constructions.

RÉSUMÉ

La communication porte sur l'état actuel de la technique dans la construction de structures porteuses en bois lamellé collé à grande portée. Elle traite des différents aspects relatifs aux charpentes en bois, puis examine les propriétés de ce matériau, sa fabrication, les systèmes porteurs, les méthodes de calculs, les problèmes du transport, du montage et de la rentabilité. A l'aide d'exemples bien choisis, l'auteur illustre les applications de ce matériau dans la construction des centres de sport.

ZUSAMMENFASSUNG

Der Beitrag beschreibt den Stand der Technik bei der Realisierung von Brettschichtkonstruktionen für grosse Spannweiten. Von den unterschiedlichen Aspekten des Ingenieurholzbaus wird auf Werkstoffeigenschaften, Herstellung, Tragsysteme, Berechnungsverfahren, Transport, Montage und Wirtschaftlichkeit eingegangen. Anhand ausgewählter Beispiele wird die Anwendung dieses Materials im Sportstättenbau illustriert.

INTRODUCTION

The need for covered areas in which large numbers of people can assemble has increased greatly in the last decades. To meet this demand structural engineers have to design long-span building structures taking into account economy, attractiveness and safety. Among the construction materials available for this purpose timber plays an important role. Glued laminated timber meets the requirements of a long-span structure material very well. It has a resistance similar to the best concrete, its weight is five times less, its attractiveness is well known, its cost is competitive and it is safe in the event of a fire even without additional protection. Glued laminated timber (GLULAM) is a valid material for the construction of sports centres, conference halls, shopping centres, atria of buildings, churches and all other constructions in which a large span and a beautiful roof are required. Places of assembly in general are a large field where glulam is used, but sport facilities still rapresent the most frequent application of this structural material.

2. TIMBER MATERIAL

2.1 Limitations of solid timber

When a designer wants to use wood in its original form for load bearing structures, he faces some difficulties: the large scattering in the mechanical properties make it necessary to apply high safety values; moisture content, distortion from knots, curved grain and other imperfections reduce the strenght, and dimension of the beams cannot exceed natural wood size.
Lamination solves all these problems.

2.2 Advantges of laminated timber

The technique of gluing together many lamellas reduces the scattering in the properties and improves the allowable strength and solves all dimensional problems. The grain becomes straight along the beam axis and the moisture content is reduced. The result is a material with a high bearing capacity, light, that can be ecologically produced in almost an unlimited range of shapes. For these reasons glulam is the main structural material used for large timber structures.

3. MANUFACTURE

3.1 Laminating stock

Glued-laminated timber (glulam) is obteined by gluing together a number of lumber laminations (lamellas). Usually lamellas are arranged so that the glue line plane is perpendicular to the long side of the cross section of the beam. Prior to gluing, the lumber is selected and dried so as to carry the moisture content under 15%. A large number of conifers are suitable for glulam. In Europe Spruce (Picea abies) is the most widely used species because of its good strenght and its great avilability. Except for special situations laminations have a thickness of 35mm. Spruce lumber is readily available in lenghts up to 4.5 meters, but glulam members always exceed this limit. Consequently, laminations are made of several pieces of laminating stock, end jointed together.

3.2 End Joints
The type of joint used for this purpouse is the "finger joint". Structural finger joints,about 50 mm long, are made by machining each mating surface and gluing the joints together under pressure.
3.3 Gluing
After grading and end jointig, the laminations are ready for assembly into structural members. They are structurally bonded together with one or two types of adhesives, depending on the service conditions. For interior applications a moisture resistant adhesive is used. For exposed exterior locations or continuously humid interior locations such as swimming pools, shower rooms, ice-arenas a waterproof adhesive (usually a resorcinol) is used. Adhesives must conform to the appropiate standards. After application of a controlled quantity of adhesive the laminations are assembled in a clamping jig applying a pressure of 850 kilopascal.The jig is adjusted to the desired shape of the member (if cambered or curvated is desired) before applying pressure.

3.4 Finishing
After the adhesive has set (8-10 hours), the member is removed from the clamping jig and surfaced both sides to remove squeezed-out glue and irregularities. The ends are then trimmed to provide a member of precise lenght. When necessary, the members are also drilled, dapped and grooved to accomodate connecting hardware. Unless otherwise specified an anti-fungus and anti-insects coating is brushed off.It is available in different tonalities according to the customer taste.

4. STRUCTURAL SYSTEMS
Glulam constructions are precast structures, but they are not standardized. Every time a customer orders a structure the manufacturer produces it according to the client's needs. Thus Glulam structures occur in a variety of types and morphologies. In the case of sport facilities roofing structures, the most frequent structural configurations are the following:

4.1 Cambered and tapered beams
It is the simplest structural system. Beams are supported by concrete columns and when possible are placed at a distance of 5-6 m. The span is usually between 25 and 40 m.The camber permits to design the beam with less conservative limits of deflection.

4.2 Three hinges portals
This system is used very frequently because permits to cover large areas with a simple and economic structures. Each half portal can be made of a single curved piece or of several straight pieces jointed together. The consequence of this kind of structures is that it produces big lateral thursts on the foundations. The span is usually between 20 and 70 m.

4.3 Trusses
Trusses are used expecially when the dimensions of the single glulam beam become too large. This may be caused by different reasons: manifacture difficulties when the beam is higher than 2-2.5 m or when its lenght goes beyond 40 m, economic convenience when the distance between the compression and the tension parts of the truss is wide enough. Usually trusses require less material and transport costs but more work for assembly.

4.4 Domes

Domes can be executed in two different ways: when their diameter is under 80 meters they usually are erected assembling together a number of radial arch members connected in the center to a steel compression ring. When their dimensions are bigger they usually are designed as geodesical systems whose general behaviour is the shell structural configuration.

5. CALCULATION METHODS AND STANDARDS

For calculation pourposes, standards are available in the individual countries. For example in Europe we have DIN 1052 in Germany, BS 5268 in the United Kingdom, Regles C.B.71 in France. All these are based on the permissible stress method. A new european code, harmonizing the differences between countries, is now available as an ENV European Provisional Standard, called Eurocode 5, based on the limit state method.

6. TRANSPORTATION

In general the transportation of glulam members does not present loading capacity problems but often the size of the beams create some difficulties. In this case the possibility of transport must be determined at an early design stage. This is important for a correct estimation of costs and for a rational choice of the structural systems. Curved beams with an overall height exceeding 3,6-3,8 m are not trasportable. In these cases structures have to be designed so that the beams can be manifactured in two pieces. Then at the site they can be end jointed with special steel or timber bolted connections.

7.ERECTION

During manifacture all the beams are cut and dapped to their final dimensions. If possible the steel connecting parts are fixed onto the main beams in order to reduce work on the construction site. This preparatory work makes the erection of a glulam structure usually a fast operation. Wire lines can be fixed through special posts on the main girders. When workmen have to walk on the erected beams they must tie their safety belt to the wire lines.
In order to prevent buckling it is particulary important to assemble the bracings as soon as possible.

8. COST ANALYSIS

The cost of a timber structure is important because often economic considerations determine the choice between glulam and other materials. It is often thought that glulam structures are very expensive if compared to conventional materials. This is often not true because a real comparison should take not only the cost of the roofing structure into consideration, but also the finishing grade or the foundation required. In many cases glulam has demonstrated that it is competitive. A rough cost analysis can be carried out as assuming:

8.1 Glulam
The amount of glulam must be established by a pre-calculation of the structural systems. Its cost (1000 DM/m3) has to be increased in the cases of curved beams (5-10%) and if special machining is required (10%).

8.2 Steel hardware
The quantity of steel necessary for the connections depends on the type of structural system. The steel cost can be estimated equal to 10-15% of the glulam's value in the case of simple structures, and to 20-25% in the case of complex structures with important connections.

8.3 Transportation
The transport cost depends on the dimension of the beams and on the distance between manifacturer and the site. When ordinary trucks 12 meter long are used the cost is equal to 3-5% of the glulam value. When special means of transportation are necessary it can increase to 10%.

8.4 Erection
Assembly and erection costs are usually considered for surface unit. A simple and linear roof can be erected with a cost of 20 DM/m2 but in the case of trusses or other complex situations the cost can increase to 30-35 DM/m2 (crane cost is not included).

9. EXAMPLES
Here are three exemples of glulam timber long-span structures. They were all erected in Italy in 1993:

9.1 " Sporting Club Milano 3" Tennis Center in Milan
This Sport Center has covered with glulam structures five tennis courts (three of them omologated for international meetings). The structure consists of arched beam with a span of 40 m. The corridor roof is hanging from the arches through gables.

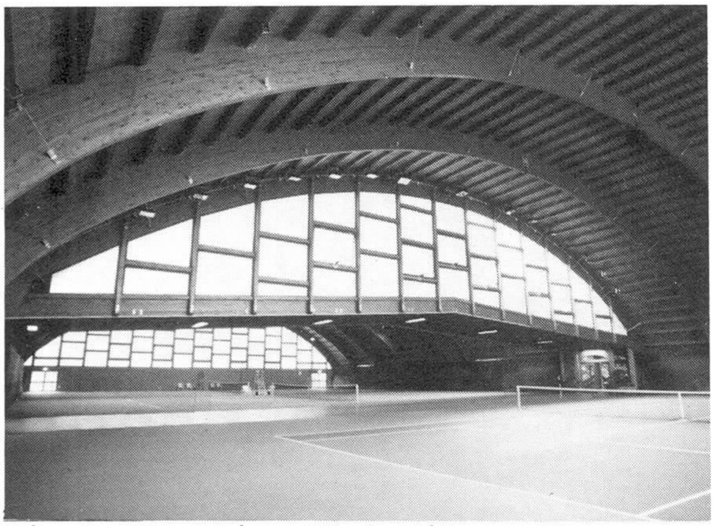

Fig.1 "Sporting Club Milano 3"
Arches cover five tennis courts.

9.2 The Casalecchio Dome near Bologna
This is the largest glulam dome in Europe. The free span between supports is 120x80 m. The geometry of the dome is made from a cylindrical vault and from two half-spherical caps. The triangular grid is made of glulam members having section 14.5x120 cm.

9.3 The "Wave" Ice Rink in Bolzano
This hall is the new ice hockey rink in Bolzano which holds 7000 spectators. The name "wave" comes from the shape of the main purlins which are double-cambered beams.

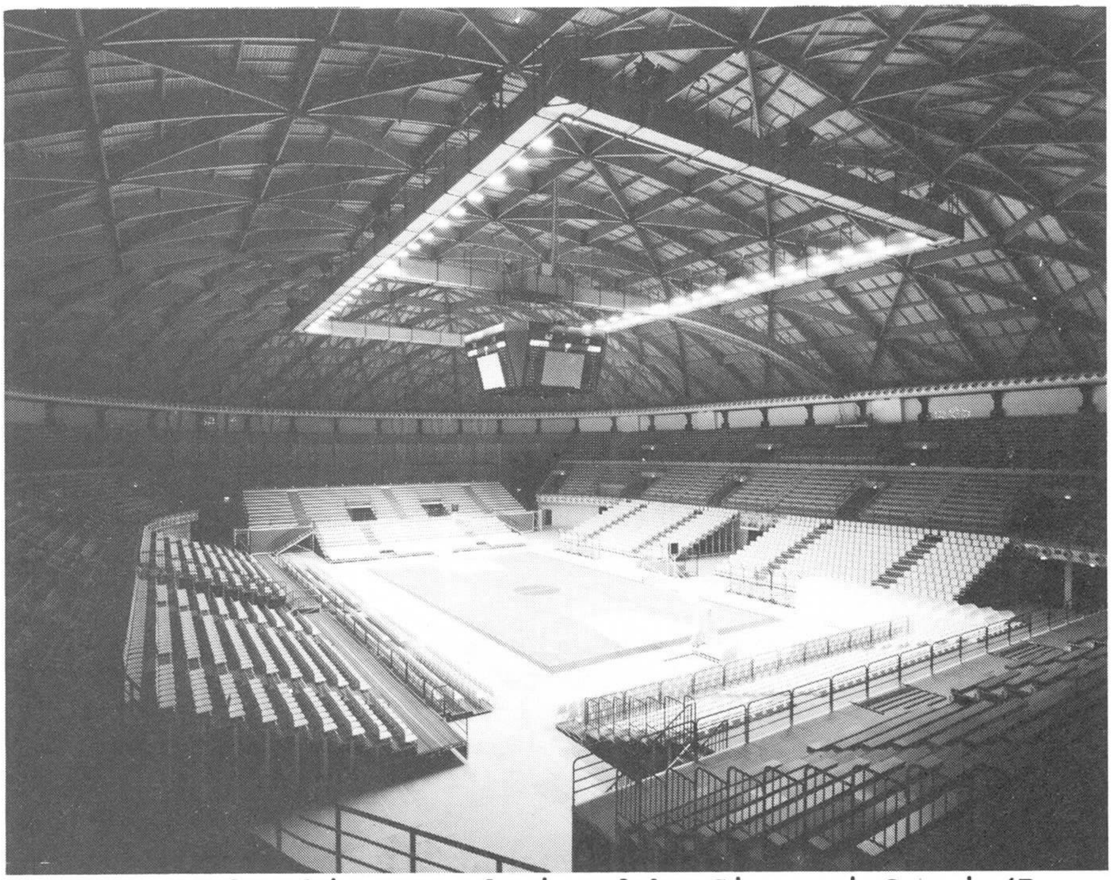

Fig.2 The Casalecchio Dome designed by Giovanni Cenci (Brunate-CO)

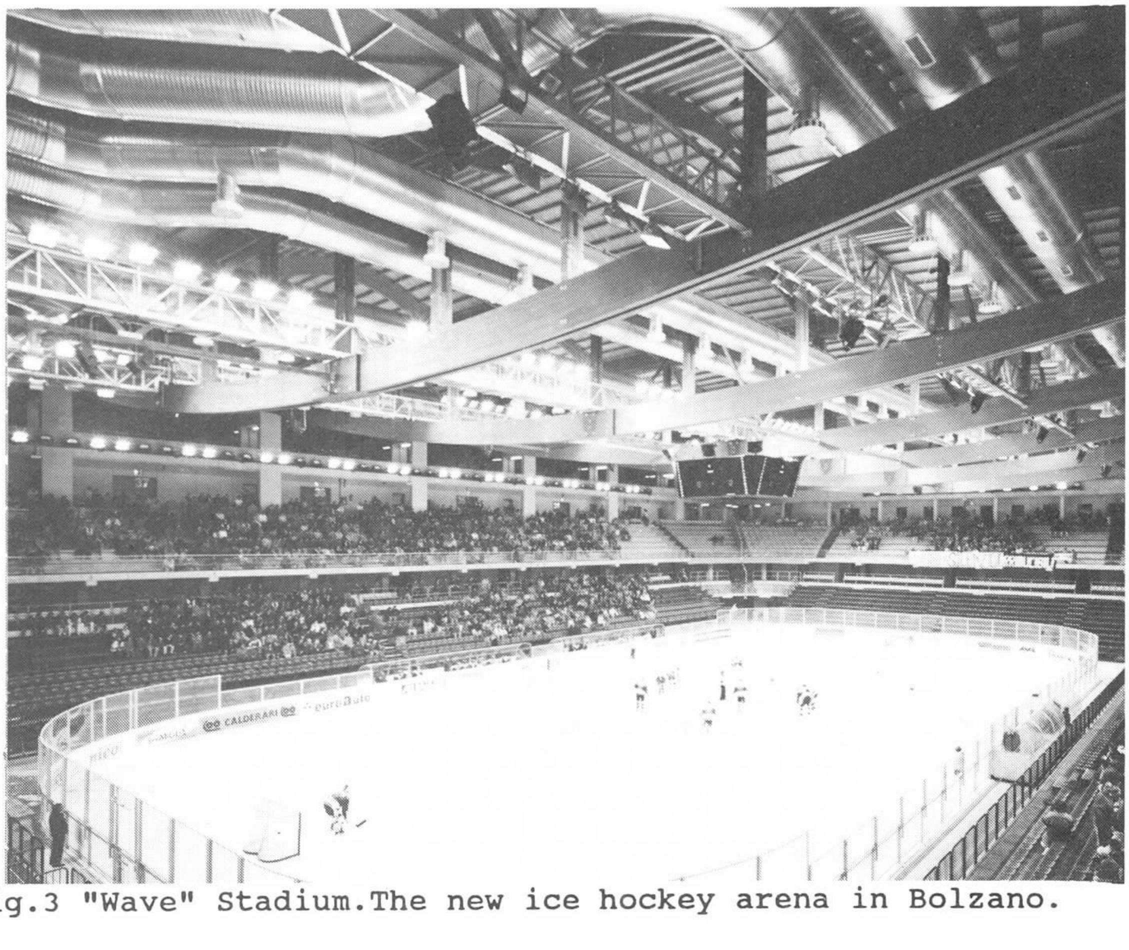

Fig.3 "Wave" Stadium.The new ice hockey arena in Bolzano.