BYG·DTU

DANMARKS
TEKNISKE
UNIVERSITET

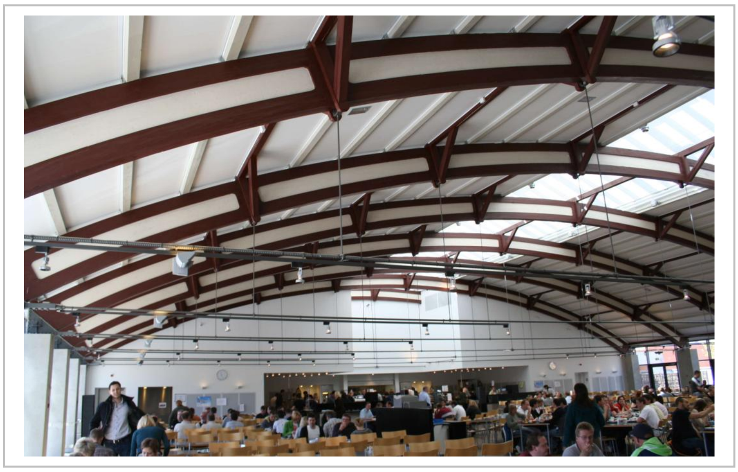
Hilmer Riberholt

Performance of old glulam structures in Europe

Rapport
BYG·DTU
R-177
2007.12.04
ISSN 1601-2917
ISBN 9788778772527

Performance of old glulam structures in Europe

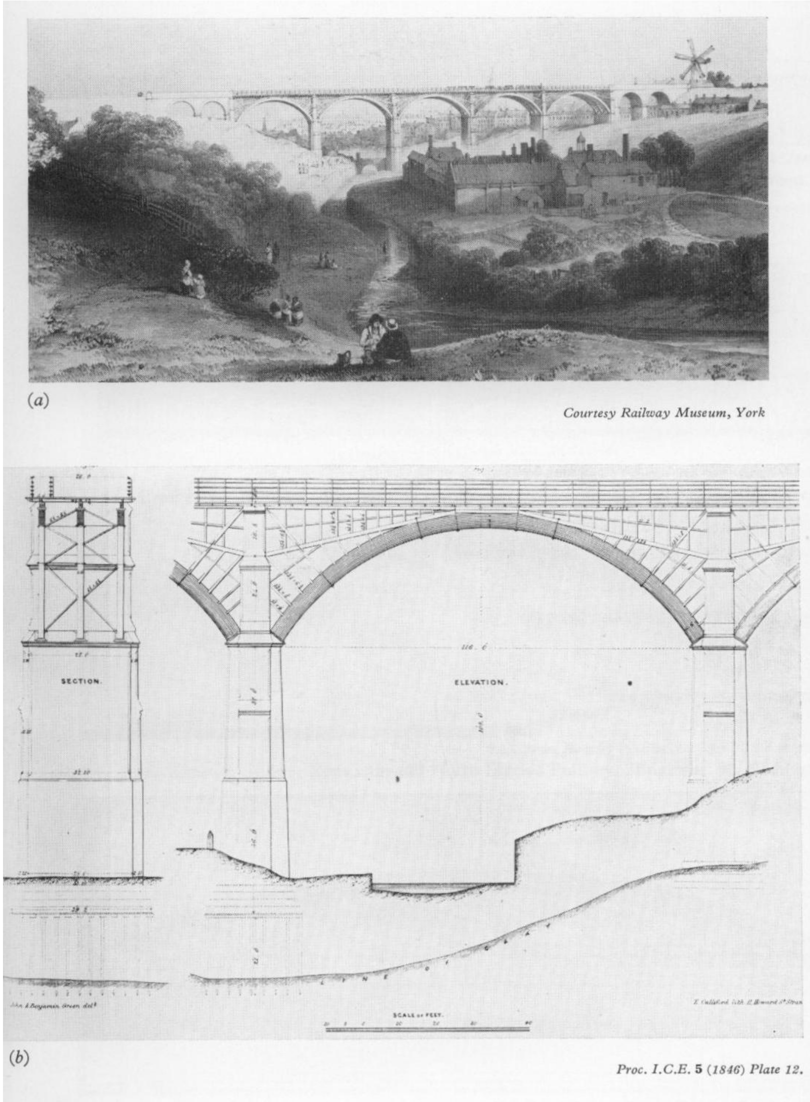
Hilmer Riberholt



Performance of old glulam structures in Europe

History and development

The first railway bridges in England and Scotland were built using glulam arches as the main load-carrying members. According to /Laminated Timber Arch Railway Bridges in England and Scotland/ they were built between 1835 and 1855 and had spans between 18 m and 36 m. The laminations were bolted or doweled together also using natural glues. Tar and other methods were used to prevent decay. With the introduction of heavier trains these bridges were later in the 1800th. century substituted by steel structures.

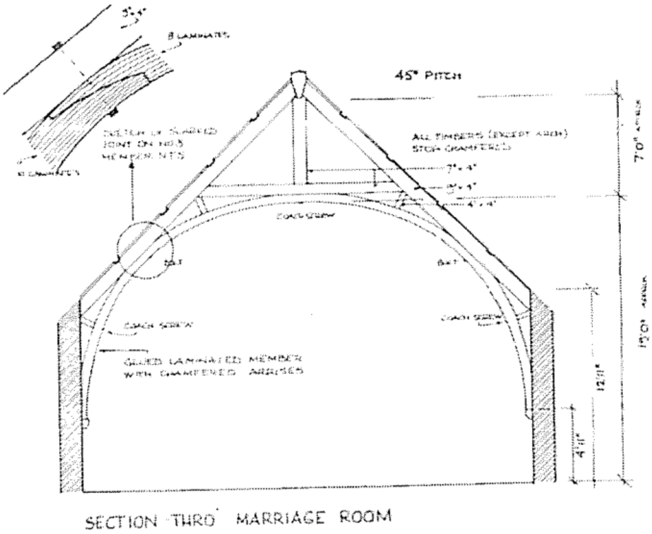


(a) Courtesy Railway Museum, York

(b) Proc. I.C.E. 5 (1846) Plate 12.

Ouseburn Viaduct; Newcastle and North Shields Railway. Engineer: J. Green

In 1860 the glulam arch structure over Southampton Registry Office was erected. But no information about the adhesive has been found. Most likely hot melt water-borne animal glue has been used.



Southampton Registry Office. Erected 1860. Span of the arches 9 m, centre distance c-c 3 m. Cross section of glulam 100 x 200 mm made of 8 laminations 25 x 100 mm. The glulam structure still in use.

In the beginning of the 1900th. century glulam arches and beams were used for roof structures. The arches were bonded using Casein adhesive. No bolts were used in the glulam for the production of the members. Typically the glulam members had an I-shaped cross section with stiffeners at some intervals and the laminations had butt joints. The production of the glulam was patented. Several of these glulam structures exist today.

With the invention of the modern synthetic phenolic- and urea-based adhesives glulam got a renaissance in the beginning of the 1960-s. The glulam structures built since then have all a good and satisfactory performance. No failures of glulam structures designed and erected according to the standards from that time have been registered.

In the beginning of the 1950es the lamination end joints were produced as scarf joints. Some years later this method was substituted by finger joints, which have been prevailing since then.

Since 1960 synthetic adhesives have been used, e.g. Urea and Resorcinol, where Resorcinol has been regarded as the best. Later Urea has been modified with Melamine and recently Melamine adhesives are used solely. During the last 10 years one-component Polyurethan adhesive has been introduced among other things with the argument that it is more environmental friendly since the waist of glue is smaller. This environmental trend has resulted in that the 2-component adhesives now are applied on the laminations as resin and hardener separately, which also reduces the amount of waist glue. The latest development is that separate application of resin and hardener is used for the production of finger joints.

Performance of the adhesive types

One of the most realistic tests of glulam with different adhesive types has been performed at Norsk Treteknisk Institutt – "Norwegian Wood Technological Institute". In an outdoor test rig, partly covered by a roof, partly not covered, glulam beams have been loaded for up to 30 years. The glulam members were produced using Casein, Urea or Resorcinol adhesives. It was found that Resorcinol gave the best durability, Urea was satisfactory especially in covered structures and that

Casein was only satisfactory under cover. These results have been compared with the results of accelerated glue line tests and criteria for adequate strength and durability of such adhesives have been determined.

The findings at Norsk Treteknisk Institutt emphasize the general impression of the performance of the different adhesive types. They have also given confidence in using Urea adhesives and especially Resorcinol adhesives.

The European adhesive standards EN 301 and EN 302 specifies some accelerated tests and requirements, which typically gives the same rating to the adhesive types. Therefore, it is believed that when an amino plastic adhesive fulfils the requirements stated in EN 301 the adhesive will also function satisfactory in a glulam member.

For one-component Polyurethan adhesive almost the same test methods and requirements have been written into EN 14080. However, a special long term test has been introduced to check the durability of the Polyurethan subjected to high moisture content and high temperature plus variation hereof.

Requirements to the lifetime of glulam structures

The Construction Products Directive specifies that the structures shall have a reasonable economic lifetime. It does not specify any number of years.

The safety standard EN 1990 specifies that building structures and other common structures shall have an indicative working life of 50 years and monumental building structures, bridges and other civil engineering structures shall have an indicative working life of 100 years. No longer lifetime is specified.

So, the required lifetime of an ordinary glulam structure in a building would normally be 50 years.

Performance of the glulam structures in Europe

From the examples listed in the appendix it appears that glulam members from the beginning of the 1900th. century produced using Casein adhesives are still in service. The examples cover glulam produced using casein adhesive with an age between 50 years and 100 years.

The examples cover also glulam produced with the synthetic adhesives, such as Urea and Resorcinol, and with an age of approximately 50 years, which is the oldest glulam structures produced with these adhesives. Before 1960 Casein glue was used.

Since accelerated adhesive tests document that the modern adhesive types such as Resorcinol and Melamine have a better strength and long term performance than Casein adhesive, these adhesives are regarded better. Therefore, it is evaluated that the modern glulam structures will have a lifetime of at least that of the described glulam structures that is at least 100 years.

Conclusions

The examples show that glulam structures have a lifetime of 50 years and more. This is valid even for covered glulam produced with Casein adhesive. For the modern adhesive types Resorcinol, Melamine and one-component Polyurethan it is evaluated that glulam made from these adhesives will have a lifetime of at least 100 years.

No failures of glulam structures designed and erected since the 1960es according to the standards from that time have been registered.

References

Construction Products Directive. Published in the European Journal, 11th. February 1989.

Laminated Timber Arch Railway Bridges in England and Scotland. L- G. Booth, Excerpt Transactions of the Newcomen Society, Vol. XLIV, 1971-1972.

EN 301. Adhesives, phenolic and amino plastic, for load-bearing structures – Classification and performance requirements.

EN 302. Adhesives for load-bearing structures – Test methods – Part 1 to 7.

EN 1990. Eurocode – Basis of structural design.

EN 14080. Timber structures – Glued laminated timber – Requirements. December 2004.

Annex

New Cross Music Hall, Nottingham, England

Location	New Cross Music Hall, Nottingham, England
Year of construction	1877
Span	14 m
Spacing	5 m
Glulam cross section	See below
Type of adhesive	Casein

Glazed barrel vault form.

Arch Sections 9 laminations of softwood, probably pine. Cross section: b = 145 mm approx., h = 405 mm approx.

Adhesive type: hot melt water-borne animal glue.

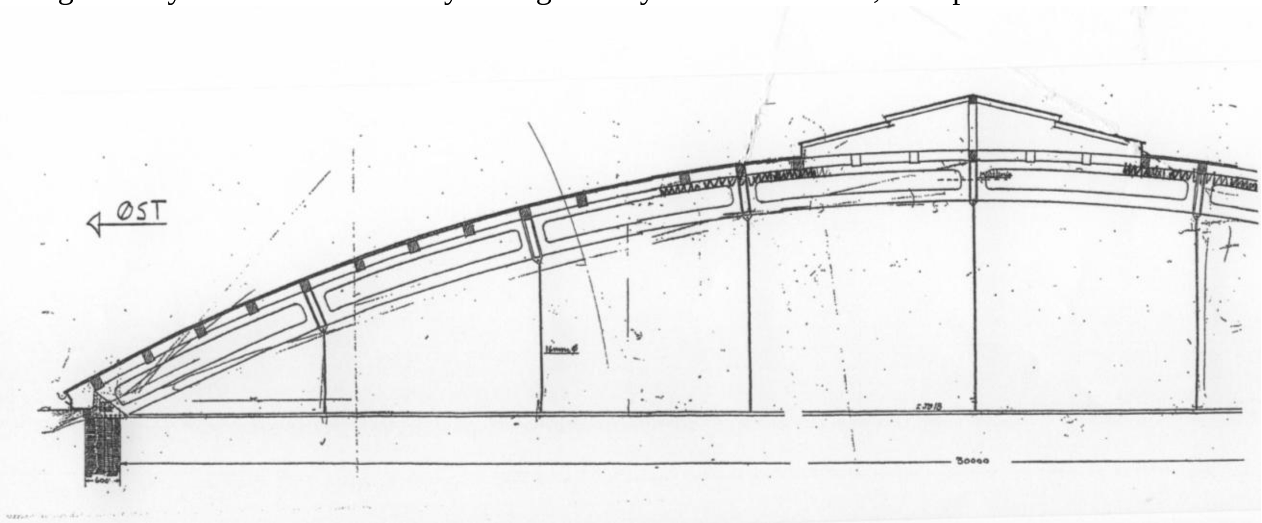
Upper steel ties added to arches as a later measure to prevent spread. Rods in bottom foreground are not structural but for lighting supports.

Arch in Copenhagen

A glulam arch with a span of 30 m was designed and erected in 1916 in Valby. The arch covered a workshop with some processes generating water vapour. It is now being used as a canteen.

The arch has a cross section with an I-shape. A steel rod is used as a tension member. Lamination thickness 33 mm. The total depth is 700 mm, the width of the flange 166 mm and the width of the web 95 mm.
The glulam was bonded with casein adhesive.

The glulam system was invented by an engineer by the name Hetzer, who patented it.



Cross section in the roof structure showing the glulam arch, the web stiffeners and the tension rod. The arch is supported by concrete columns.

Canteen with glulam arch


Canteen, overview and skylight


Detail at support

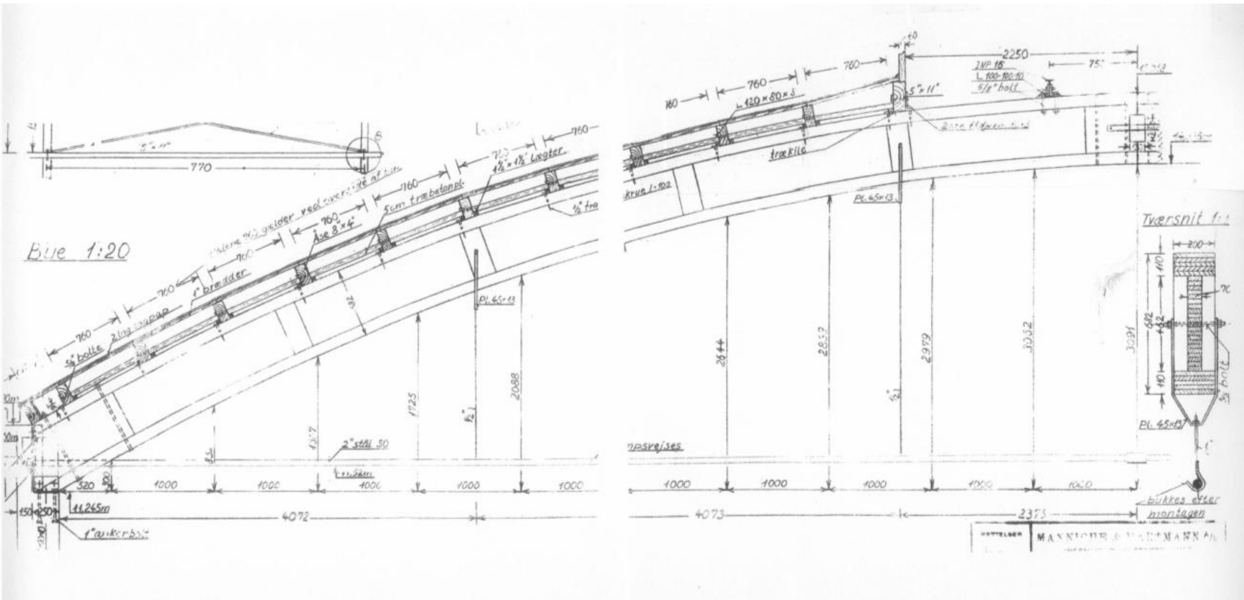
Detail at web stiffener

Canteen from the outside.

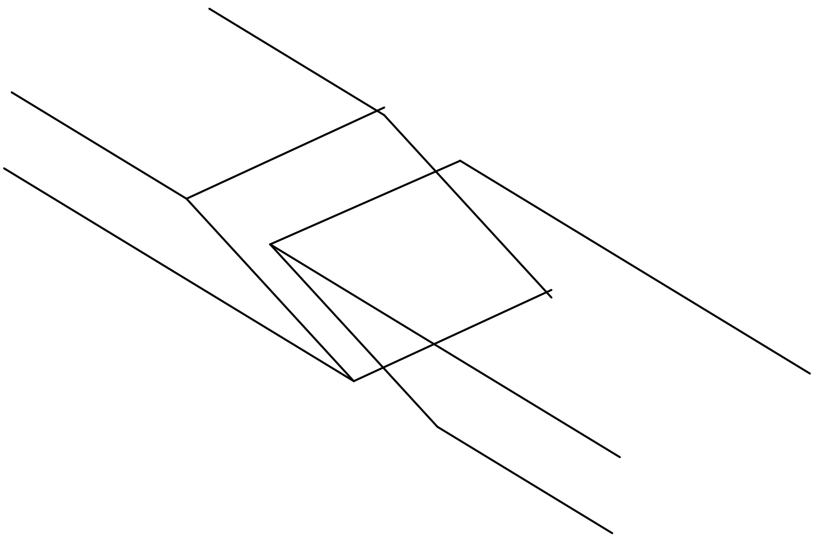
Arch in the harbour of Copenhagen

A glulam arch with a span of 22 m was designed and erected in 1951 in the harbour of Copenhagen. The arch covered a workshop for the shipyard B&W.

The arch has a cross section with an I-shape. A steel rod is used as a tension member. Laminations with a thickness 33 mm and with scarf end joints. The total depth is 682 mm, the width of the flange 200 mm and the width of the web 70 mm.
The glulam was bonded with casein adhesive.
The glulam was in a fine condition when the building was taken down because a new has been erected.



Cross section in the roof structure showing the glulam arch, the web stiffeners and the tension rod. The arch was supported by concrete columns.


A scarf joint in the lamination.

Cross section of hal.

Cross section in glulam arch

Scarf joint. The surface coating has been cut away to show that the scarf joint is OK. No delamination.

German sports hall

Examples for long-lasting Glulam constructions in Germany

<u>Sports hall in Celle, Germany</u>

Location:	Nordwall, 29225 Celle, Germany
Year of construction:	1910
Length:	25,00 m
Width:	15,00 m

The sports hall was constructed using the building type "Hetzer" ("Hetzerbauweise").

The construction is based on frames with three joins ("Dreigelenkrahmen") using a raster of 5,00 m. The girders have a span of 15,00 m.

The type of glue is "Casein" ("Caseinleim").

The sports hall was renovated some years ago. It is still used by the local sports club on a daily basis.

View from the outside:

View from the inside:

German storage hall

Examples for long-lasting Glulam constructions in Germany

Storage hall in Dortmund

Location:	44147 Dortmund, Germany
Year of construction:	1964
Length:	ca. 60 m
Width:	ca. 20 m
Eaves height:	6.50 m

Type of construction:	Frame of double links („Zweigelenkrahmen")
Maximum cross-section of truss:	160 x 1.100 mm
Distance between trusses:	6.00 m
Type of glue:	„Resorcin" ("Resorcinharzleim")
Type of roof construction:	Cladding ("Koppelpfetten mit vollflächiger Verschalung")
Special elements:	Frame corners ("keilgezinkte Rahmenecken") and glued ridge ("verleimter Firststoß")

The storage hall is in very good technical condition. It is used for storage of wood material.

Stockholm central railway station

Location	Centrum of Stockholm, Sweden
Year of construction	1925
Span	23 m
Glulam cross section	See below
Type of adhesive	Casein

The waiting room of Stockholm main railway station erected in 1925 is designed with a glulam arch with a span of 23 m. The length of the building is 120 m.

The arch is constructed with an I-shape. Lamination thickness 28 mm. The total depth is 800 mm, the width of the flange 170 mm and the width of the web 100 mm.

The arch is supported by concrete columns.

The glulam is bonded with casein adhesive.

Architect. Mr Folke Settervall

Constructor: Mr David Tenning

Supplier glulam: Aktiebolaget Fribärande Takkonstruktioner (today Moelven Töreboda AB)

References
Printed: The historic development of Stockholm Central – railway station – reconstruction 1925-1927.


gooh!

Oxford Road Station, Manchester, England

Location	Centrum of Stockholm, Sweden
Year of construction	1960
Conoid roof shell