BLOCK GLUED GLULAM - BRIDGES, BEAMS AND ARCHES

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ABSTRACT: The paper reports on the assets of block glued glulam for heavy duty load bearing components to be used in bridges, long-span arches and members as a substitute for steel and reinforced concrete. The term "block glued glulam" defines beam-like timber elements with a cross-sectional build-up consisting of at least two glulam beams glued together. By gluing of several glulam cross-sections, large cross-sections with a rectangular, box or rib-plate shape up to about 3 m in width and 1.5 m in depth can be formed. The length of the elements may be up to about 60 m. Such elements provide strength and stiffness features enabling the substitution of heavy duty reinforced concrete or steel beams. The block glued elements, covered by a differing extent by European and German standards are increasingly employed for any type of wide-span beams, arches and combined bridge-beam decks. By now considerable proven excellent performance heritage exists. The paper reports on build-up principles, important manufacturing issues such as gap-filling adhesives and cramping pressure, design and shows examples of executed block glued structures, highlighting the advanced potential of this timber product type.

KEYWORDS: block glued glulam, heavy duty timber beams, gap-filling adhesives, cramping pressure distribution

1 INTRODUCTION

The idea of adhesively joining large glulam beams to form even more massive monolithic or resolved cross-sections has been first realized in the year 1989 in conjunction with the pedestrian and cycling timber bridge “Otto-Munz-Steg” at Reichenbach in the state of Baden-Wuerttemberg, Germany (Figs. 1 and 2). The manufacturing requirements and design advice were provided to the building authorities for this previously never-built timber construction type by MPA University Stuttgart (Otto-Graf-Institute). Since the first realization of the block glued construction principle, numerous follow-ups – beams, arches, bridge decks - were enabled and certified by University Stuttgart. In this context it is important to point out that glue lines in block glued timber elements may easily reach thicknesses of 1 to 2 mm, being beyond the performance limits of most adhesives certified for conventional structural timber gluing’s, e.g. glulam. In order to enable the new technology three adhesive brands were tested and assessed by MPA Univ. Stuttgart for this gluing purpose, based on new adhesive performance tests.

As a consequence of the increasing number of block glued constructions, the block gluing principle has first been standardized in the German timber design code DIN 1052:2004. The new European product standard on glulam EN 14080:2013 now for the first time includes block glued glulam, however exclusively with rectangular cross-sections. Deliberate cross-sectional shapes, such as I-, T- or multiple box-type block glued cross-sections are covered by the new German standard DIN 1052-10. The manufacture of block glued glulam features several challenges, especially related to adhesives and cramping technology.

\textbf{Figure 1: Cross-section of first block glued glulam construction for “Otto-Munz-bridge” in Reichenbach, Germany, erected in 1989}
2 BUILD-UP

Block glued glulam consists minimally of two (prefabricated) glulam beams of rectangular cross-section glued together in a secondary production step along the wide and/or narrow cross-sectional sides (for examples, see Figs. 1 and 3). The glue lines between the individual glulam beams are called block glue lines and are subject to specific technical considerations and requirements (see below). In an extension of the depicted principle build-up deliberately shaped trapezoidal-, phi- or multiple box-type cross-sections are possible. The sizes of the block glulam cross-sections are in principle unlimited and ultimately restricted by the cramping equipment and the bonding technology. The largest cross-sections built so far have had depths and widths of about 3 m by 1.2 m. The lengths of block glulam elements are essentially governed by the manufacturing equipment (premises, presses) and the transport restrictions. The largest block glulams realized had a length of about 60 m. In side and top elevation the block glulam elements may be straight or curved. It is obvious that the manufacture of block glulam beams is only in rare cases possible in conventional glulam presses.

3 MANUFACTURE OF BLOCK GLULAM

3.1 GAP FILLING ADHESIVES

It is evident from the sheer dimensions and herewith related stiffnesses and tolerances of the components of the block glulam that the permissible thicknesses in use for bond lines as used in conventional glulam no longer apply. According to the European standard for structural polycondensation wood adhesives, EN 301, the maximum glue line thickness in use of a PRF or MUF adhesive applied undermixed, e.g. in glulam, is 0.6 mm (for the case of separate resin and hardener application the thickness in use is restricted to 0.3 mm). For block glulam production the relevant standards (EN 14080 and DIN 1052-10) require a gap-filling adhesive which allows for a permissible thickness in use of 1.5 mm (qualification testing with 2.0 mm). At the time three adhesive brands (PRF and MUF) have been certified for the block glulam related performance level (e.g. [1]).

3.2 CRAMPING

The dimensions of the glued components further lead to the situation that the nominal glue line cramping pressure which for classical glulam products is in the range of about 0.7 to 0.9 MPa is in most cases no longer applicable due to the resulting high forces and the related cost impact of the equipment. Therefore, the gap-filling adhesives have to be verified for their aptness at rather low cramping pressures of minimally 0.2 MPa. Apart from the issue of the nominal glue line pressure, the resulting dimensions of block glued elements necessitate specific consideration of the pressure distribution along both width and length of the block glulam element. Due to the large areas to be cramped, ideally evenly, the bending of the steel bars used for cramping and the related cambering issues are greatly important for production of strong and durable bond lines. Closed form solutions for the cross-sectional dimensions, the cambering and the advisable spacings of the cramping bars were derived in [2] on the basis of the differential equation for a beam on elastic foundation and verified by finite element analysis. The results of these cramping device optimizations have already been successfully implemented in industrial productions.

REFERENCES

[1] Z-9.1-823 (2013): German technical building approval issued by DIBt for “Melamine-urea adhesive Kauramin resin 683 with Kauramin hardener 686 for the manufacture of glued bonds with thick glue lines” (in German); issued first on 21.01.2013; approval holder: BASF SE, Ludwigshafen, Germany.