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Technology of Manufacturing Connections on Steel Rods Glued into Wood

Zhumabike Ospanova[1], Liazat Aruova[1], Nabi Dauzhanov[1], Nurgul Alibekova[1], Boris Gordienko[1]

[1] Eurasian National University named after L.N. Gumilev, 010008 Nur-Sultan, Munaitpasov street, 13A, Kazakhstan

ecoeducation@mail.ru

Abstract. In modern construction, glued wood is used mainly by Scandinavian countries, Canada, the USA and Russia. It is rational to use glued wood not only in low-rise housing construction, but also as supporting and protecting structures of large-span public buildings. Large-span glued wooden structures have become popular in modern construction and are widely used for public buildings with spans of 18 meters or more. In the practice of building Western countries with significant reserves of wood, sports facilities, exhibition halls, cinemas and other entertainment buildings are being built from glued wood. According to the condition of transportation, a lengthy beam, frame or truss must be made of two or three elements, and then connected at the construction site into a single structure. The use of mechanical fasteners in the form of bolts is not always possible due to significant compliance, including due to thermal expansion of the metal in a harshly continental climate, for example, in Kazakhstan and under fire safety conditions, when metal parts quickly lose their bearing capacity. Significant deformations occurring in the nodes can cause a redistribution of forces in the elements and as a result lead to the destruction of the structure. To create a durable rigid joint of glued wood constructions, the joints on the reinforcing rods glued under the inclinations to the fibers are used, which, as practice shows, ensure high reliability, durability and low compliance. This article discusses the technology of gluing reinforcing rods into wood to solve large-span structures and their welding. On the basis of experimental scientific studies, the sequence of the necessary technological processes for obtaining a durable, reliable and high-quality glue joint between the rod and wood and the possibility of welding the reinforcing rods glued to the wood with a connecting piece are shown. In this study, various variants of the joints of maple structures, where it is possible to use the welding of its elements, are carried out.

1. Introduction

It is rational to use glued wood not only in house-building, but also as bearing and enclosing structures of public buildings. In the practice of building of Western countries with significant reserves of wood, sports facilities, exhibition halls, cinemas and other entertainment buildings are being built from glued wood. Glued large-span structures have become popular in modern construction and are widely applied for public buildings with spans of 18 meters and more. For example, in 2009, in Russia, was built a ribbed dome of an aqua park of glued wood with a diameter of 90 meters in the Park to them. 300th anniversary of St. Petersburg (figure 1).

Figure 1. The ribbed dome of the water park with a diameter of 90 m

According to the condition of transportation, a lengthy beam, frame or truss must be made of two or three elements, and then connected at the construction site into a single structure. The use of mechanical fasteners in the form of bolts is not always possible due to significant compliance, including due to thermal expansion of the metal in a harshly continental climate, for example, in Kazakhstan and under fire safety conditions, when metal parts quickly lose their bearing capacity. Significant deformations of the node can cause a redistribution of forces in the elements and as a result will lead to the destruction of the structure.

To create a durable rigid joint of glued wood constructions, the joints on the reinforcing rods glued under the inclinations to the fibers are used, which ensure, as practice has shown [1], high reliability, durability and low compliance.

Application of glued rods for the connection of individual elements of large-span structures and their reinforcement are also used in Sweden, in Croatia, for example, for joining two half shells [2] (figure 2).

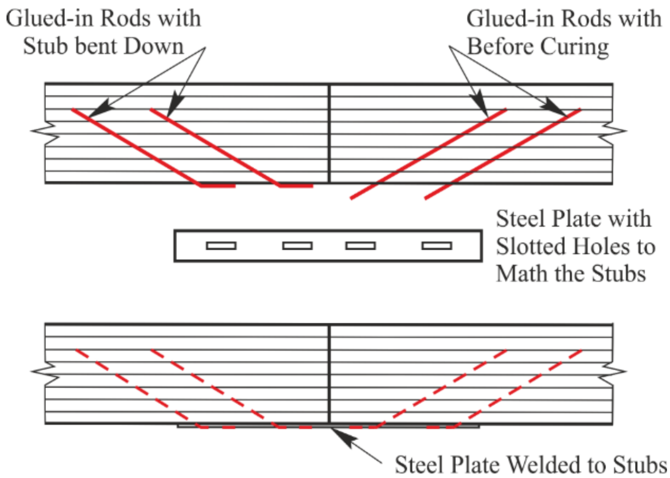

Figure 2. The connection of two half-beams on glued and welded steel rods

The manufacturing techniques of the joining elements include the processes:
- bonding individual rods,
- welding rods with a connecting detail,
- if necessary, welding of connecting details between themselves.

Wherein the main efforts in the nodes are perceived by the metal details of the node and transferred to timber. Stress decreases, both in the stretched and compressed zones of the node (see figure 3).

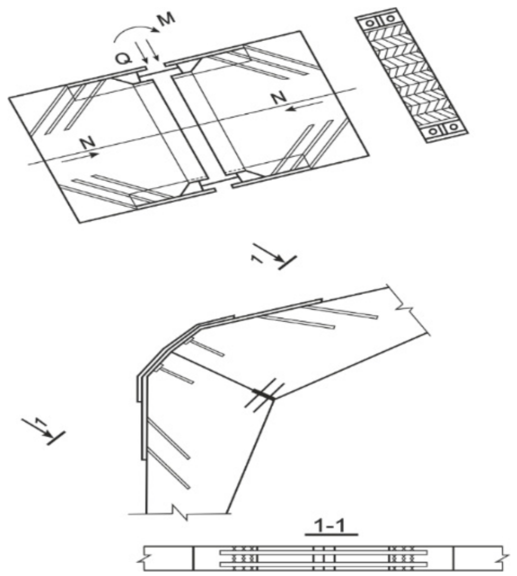

Figure 3. Connections of elements of glued timber constructions on inclined glued rods

The bearing capacity of such knots as a whole is greatly influenced by the quality of the glue seam of the rod and timber. Gluing of the welded comb (plates with rods) into the glued timber bag is qualitatively difficult to accomplish, since it is almost impossible to withstand the ideal angle of inclination of the holes for the rods to the plate provided the template is used. Quality may be affected by welding the rod with a connecting plate. Parallel immersion of several rods welded to a part into holes drilled in a glued package simultaneously is problematic. Accordingly, this will affect the quality of the adhesive joints and the assembly as a whole.

2. Methodology

At the first stage, work has been done on the development of gluing technology of each individual rebar, followed by welding it to the connecting piece. Samples of small sizes (50x50x120mm) and prisms of natural sizes (130x130x280mm) were used for the experiments with holes of 10 and 18mm drilled in accordance with different inclinations of timber fibers to the axis of the rod (see figure 4).

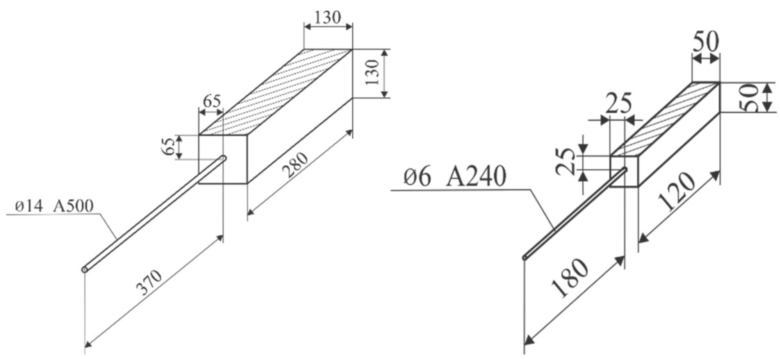

Figure 4. Geometric schemes of prism samples

The small samples were glued reinforcing rods with a diameter of 6 mm class A 240 to a depth of 100 mm, in a prism with a diameter of 14 mm class A500 on the entire depth. To prevent the glue from leaking from the end of the prism, nail the ply timber overlay. The rods were rotated into the pre-drilled hole with glue, which was blown through to remove sawdust. A composite adhesive of the FRF-50T brand based on a phenolic resorcin resin was used with a plasticizer thiokol and a filler in the form of ground sand [3,4]. Glue was applied to the core and poured on a third into the hole. Immersion of the rod to a depth of approximately more than half the length met with strong resistance from the glue and the airlock. The presence of air plugs contributed to the formation of non-glued areas and, accordingly, to a decrease in the adhesion strength. For further immersion of the rod, it was necessary to use any tool for tightening or hammering, which did not guarantee the quality of the connection and did not ensure the immersion of the rod until it stops. Air plugs were formed even with the immersion depth of the rods 5-6 rod diameters. To remove air pockets in the experiments, holes with a diameter of 3-4 mm were drilled from the side surface of the samples perpendicular to the timber element. The side technological holes were drilled in small samples one by one, in prisms and constructions of natural sizes in further tests through 150-200 mm by 2/3 of the length from the beginning of the hole. As the rod was immersed, the glue began to flow from the side technological holes, which were blocked by pre-prepared timber stoppers.

To get a high-quality glue line, it was decided to apply vibration. It was used a micromotor with an eccentric attached directly to the rod for small samples. When the rods were glued into the prisms, a specially designed nozzle was put on the free end of the rod. The vibrator of the brand IV 66 with a flexible hose used for compacting concrete was used as a vibrator (see figure 5).

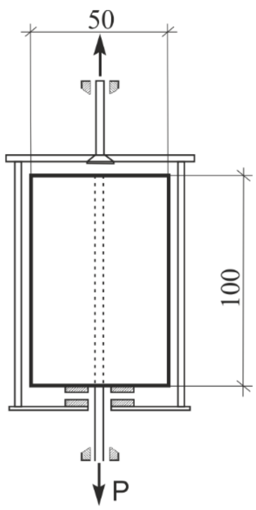

Figure 5. Sample Testing Scheme with end-to-face

A prerequisite for filling with glue is the release of glue to the surface of the prism from the side of the dive. Vibrating was performed within 1-2 minutes. To identify the effect of vibration on the quality of the connection, the rods were immersed in small samples along the fibers with and without vibration, and in natural-sized prisms at an angle of 60 ° to the timber fibers with and without vibration.

3. Results and discussions

Visual inspection and microscopic analysis of the state of the adhesive layers after testing the samples made it possible to conclude that vibration contributes to an improved bonding quality. When gluing without vibration, the number of non-glued areas amounted to 10-20% of the total area, while applying vibration, the percentage of non-glued decreased to 2-5%.

Tests of pulling out specimens with an emphasis on the butt on gluing without applying vibration and using showed that the strength of the joint when performing vibration is about 16% higher.

At the next stage of manufacturing the joint, the work consists in welding separately glued rods with a metal plate - a connecting piece. Flush or overlap welding can be used in this assembly. How the temperature is distributed along the length of the rod, how to prevent timber from igniting during welding, and other issues were solved in this experimental work. In this work, tests were carried out on the welding of elements of the joints flush and overlapped at some distance from the adhesive layer (see figure 6).

The experiment was carried out on half-bars with a length of 4.5 meters of laminated timber, into which reinforcing rods with a diameter of 22 mm of class A-III were glued with FGF-50T glue into holes with a diameter of 25 mm [5,6]. (see figure 7). To measure the temperature along the embedment when welding a rod with a metal plate was perpendicular to the rod, thermocouples of a copper alloy were drilled into holes drilled with a diameter of 3-4 mm.

Table 1. The test results

Sample sizes	Bonding technology	Bearing capacity P, [kN]		Non-glue percentage
		Sample	Average value	
Small samples 50x50x120 Rebar 6mm class A240 Bonding along the fibers	No vibration	11.6	15.5	20
		15.2		20
		15.5		10
		16.1		10
		17.1		10
	With vibration	14.5	17.6	5
		19.0		0
		18.8		2
		17.9		2
		17.9		2
		17.9		2
Prisms size 130x130x280 Rebar 14mm class A500 Bonding At an angle of 60 ° to the fibers	No vibration	69	71.9	10
		70		8
		77		5
		71		7
		72		13
	With vibration	89	83.5	2
		80.5		5
		82.5		3
		81.5		5

Temperature measurements in the rod were carried out during welding, immediately after welding and until the temperature began to decrease. A total of 15 welded joints were investigated. Were tested various methods of cooling during welding, with the aim of reducing the temperature in the glue line and eliminating the possible ignition of timber. Welding was performed at the current of 200 A using electrode with a diameter of 4 mm (see figure 7).

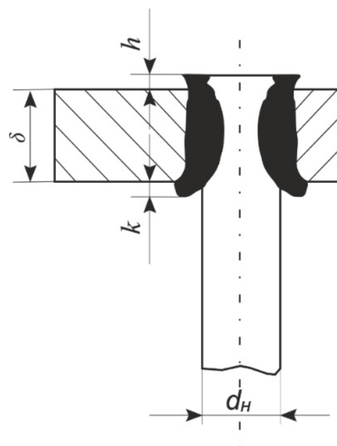

Figure 6. Weld rod and plate flush

With the presence of combustible material timber and glue at high temperatures prone to destruction, the task was set to the possibility of using welding at such sites.

To determine the heating temperature of the glued rod along the length of the seal during welding, studies were carried out on the beams:

- when welding glued rods between themselves overlapped and with lining,
- when welding rods with a connecting plate flush.

In the first case, an embodiment of the connection between the half shafts was considered with subsequent concreting of the joint with polymer concrete.

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The second joint is the most simplified, but more dependent on the results of the experiment. The individual rods glued into the semi-dies were welded to the plate with a milled oval hole, and then to each other with the help of connecting parts (rods or plates). The study of welding reinforcing rods between themselves using linings showed that the heating temperature along the length of the seal depends on the welding time and the distance of the beginning of the weld to the end of the timber element. When welding the rod within 3-4 minutes at a distance of 5d to the end, the temperature at the border with timber reaches 110 ÷ 115ºC, at a depth of embedding 1d it decreases to 70 - 80ºC then falls. Destruction glue does not occur. When welding at a distance greater than 5d to a timber element, the temperature at the embedding depth 1d does not exceed 50 ÷ 60ºC, and in the samples of the second series, welding of the glued rod with a connecting plate is provided (figure 8).

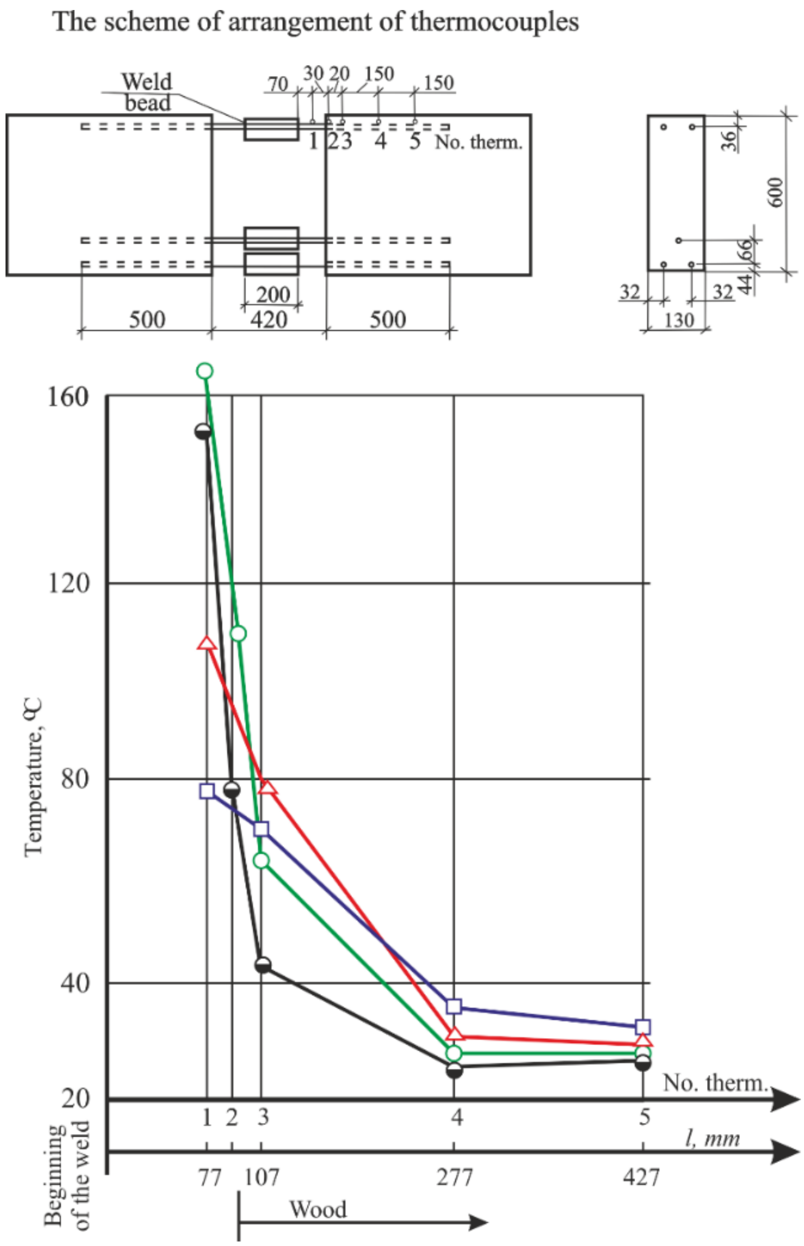

Figure 7. Temperature distribution in the rod during welding using linings. Time: 1 - 10; 2 - 15; 3 - 20; 4 - 30 minutes after welding

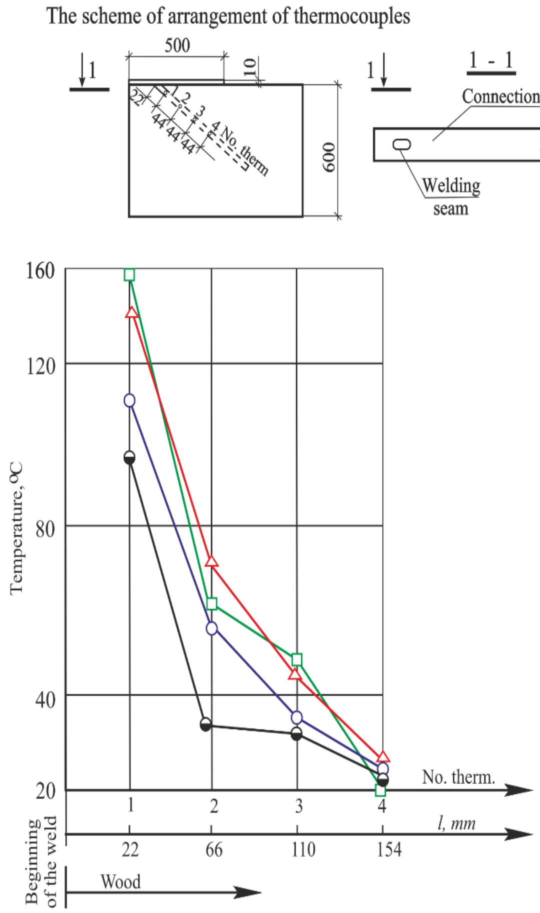

Figure 8. Temperature distribution in the rod during welding with a connecting metal plate and forced cooling: 1 - immediately after welding; 2 - 1.5; 3 - 5 and 4 - 10 minutes after welding

In this embodiment, the most stringent conditions for the adhesive layer occur, since welding is performed at the very end of the timber element. Heat traps were provided in the weld zone by cooling with water in the form of wet cloth swabs around the weld on the plate. Welding was performed in one step for 1.5 minutes and two steps of one minute each with a break of 3 minutes. Studies have shown that at a depth of 1d, the temperature in the process of welding gradually increased and reached a maximum value of 135 ÷ 140ºC after 1 minute 20 seconds after the end of welding in one step. At the depth of the 3d installation, the temperature decreases sharply and does not exceed 70°C, the overall decrease in temperature along the length of the installation is observed 10 minutes after the end of welding. When welding in two steps maximum temperature 110ºC. The destruction of the adhesive layer was observed at a seeding depth of 10-15 mm, which is 0.5d.

4. Conclusions

Based on the performed experiment, the following conclusions were made: - To obtain a high-quality assembly of large-span structures, it is necessary to glue reinforcement bars separately each;

- The technology of sticking a rod requires obligatory observance of the following operations: drill the main and technological holes, Ablow holes, apply glue to the core and pour into the hole, apply vibration when the rebar is dipped.
- Welding of connecting elements on steel rods glued into timber by connecting elements of glued large-span timber structures can be performed subject to the arrangement of heat traps and compliance with fire safety rules.

- When performing welding work, the temperature in the reinforcing rods glued into timber decreases significantly at the embedding depth of 1*d*, as a result, the destruction of the adhesive layer does not threaten.

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