STUDY OF PEEL AND SHEAR STRENGTH OF ADHESIVE JOINT BETWEEN PINE WOOD AND CFRP TAPE

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Abstract

Article deals with determination of gluability of CFRP composites to pine wood, with various glue types applied. Pull-off strength according to EN ISO 4624:2003 standard and shear strength (EN 302-1:2006 standard) were tested. Epoxy glues, with cohesive failure of the bond in wood close to 100%, showed greatest shear and pull-off strength between CFRP and wood.

Key words: *CFRP, glue, reinforcement*

INTRODUCTION

Reinforcement of structural wood is known problem of the woodworking and building industry. Wood, being inhomogeneous material, additionally loaded with structural defects of natural origin, such as knots, nonlinearity of grain and other biological ones, is not reliably predictable in physical and mechanical terms. In fact, strength grading at the beginning stages of wood processing is needed for rough determination of applicability of specific piece for the specific task. Such grading is legally required at the stage of structural design, because of material allowances and safety factors for the designed load on the structure.

Additional perturbations with design and project implementation are caused by wood defects, especially knots, having great impact on overall wood strength and load capacity mainly in tensile zone. In this area presence of knots is comparable to presence of a opening. Reinforcing of structural members by various methods and materials are known, usually dealing with application of wooden, metal or other overlays, bars or tension members, glued or screwed to wood. Other tests consisted of evaluation of load capacity of beams made of laminated wood, reinforced by plates or rods [6, 7, 8]. Since nineties, application of composites, applied in various places of the strengthened beam, reinforced with carbon, glass or aramid fiber is considered often. Research dealt, amongst others, with tapes glued underneath the reinforced element [2, 3]. Along, tests with CFRP tape reinforcement placed vertically or horizontally inside the cross-section were made [1, 9].

In objective to limit amount of synthetic material [4, 5] was the local reinforcement of the beams applied, especially these loaded with structural defect, like knot (fig. 1, 2). The local reinforcement of elements was achieved. However, places of destruction appeared in

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the glue joint zone. It is valuable to explain which factor is responsible for these effects. Especially, the role of adhesive joint is important.

The aim of presented study is to explain the influence of adhesive joint types on strength and failure character in reinforced elements.

Fig. 1. Wooden beam reinforced locally with CFRP tape [5]

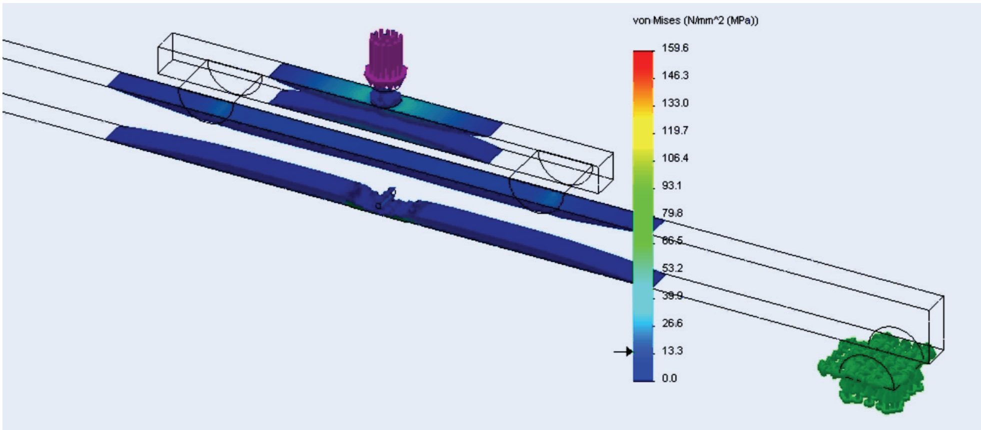


Fig. 2. Stress distribution in wooden beam with CFRP local reinforcement [4]

MATERIAL AND METHODS

Test samples were made of pine wood (*Pinus sylvestris*) of 12± 1% moisture content, as a most popular in building industry.

There is no standard procedure determining glue bond strength in reinforced wooden structural beams. Because of that, strength of joints between CFRP tape and pine wood tested by pull-off (fig. 3) was performed in accordance to EN 1542: 1999, originating from ISO 4624: 2003, dealing with wood coatings. Shear strength of the joints were made in accordance to EN 302-1:2004 standard (fig. 4).

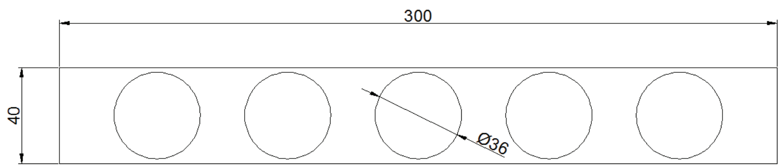
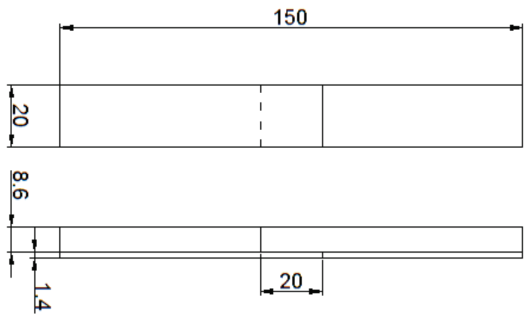


Fig. 3. Test specimens for pull-off test



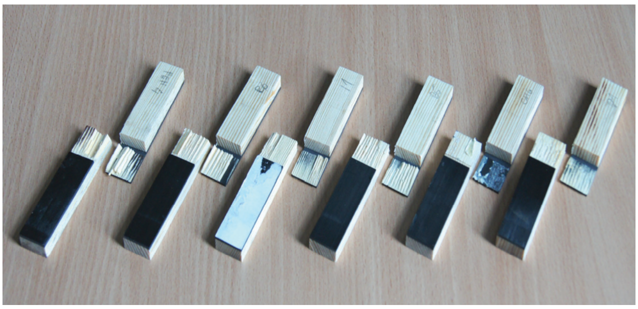


Fig. 4. Test specimens for measuring of shear strength of wood-CFRP tape joint

As a reinforcement CFRP tape was used (full specification in table 1), glued to pine wood with six types of bonds: two types of epoxy resin, isocyanates, chloroprene phenol and polyvinyl acetate ones. After gluing, samples were conditioned for 14 days in normal conditions. Then, the adherence and the bond strength in longitudinal tensile shear strength were measured using FP10 universal testing machine at traverse velocity 10mm/min. Glue line with thickness of 0,1 mm was tested. The joint collapsed after 30 to 90 seconds.

Table 1. CFRP S&P Lamelle CFK 150/2000 tape details

Technical details		
tape width	[mm]	20
tape thickness	[mm]	1.4
Young's modulus	[GPa]	>168
tensile strength	[MPa]	>2800
rupture strain	[%]	> 1.5

After each measurement a visual inspection of surface damage was performed. This evaluation provided an additional criterion of bonding quality. Type of separation as a result of pull-off test was determined on the basis of general principles specified in EN 1542:1999 standard, as follows: A - cohesive failure in wood; A/B - adhesive failure between wood and the first layer; B - cohesive failure in the first layer; -/Y - adhesive separation of CFRP from glue layer; Y - cohesive failure in glue line; Y/Z - adhesive failure between glue line and measuring stamp. Destruction type developed by test of bond strength in longitudinal tensile shear strength was determined in accordance to EN 302-1:2004 standard.

RESULTS

Results of performed tests together with the elementary statistical evaluation are presented in Tables 2 and 3.

Table 2. Adherence of CFRP to pine wood specimen with the use of various adhesives

Type of adhesives	Statistical measures			
	x_{av}	σ	υ	type of failure
	[N/mm^2]		[%]	
epoxy v. a (Dragon)	2.06	0.50	24.5	100% A
epoxy v. b (Bison)	1.97	0.32	16.3	100% A
chloroprene	1.26	0.12	9.8	100% Y
polyvinyl acetate	1.73	0.58	33.5	88% A, 12% A/B
phenolic	1.11	0.26	23.9	95% A, 5% A/B
isocyanate	1.53	0.15	9.9	95% A, 5% A/B

Table 3. Shear strength of various types of glue joints

Type of adhesives	Statistical measures			
	x_{av}	σ	υ	Failure in
	[N/mm^2]		[%]	
epoxy v. a (Dragon)	5.82	1.44	24.8	5% bond / 95% wood
epoxy v. b (Bison)	6.55	0.63	9.6	0% bond / 100% wood
chloroprene	1.59	0.56	35.1	100% bond / 0% wood
polyvinyl acetate	5.61	0.70	12.5	52% bond / 48% wood
phenolic	5.78	0.98	17.0	11% bond / 89% wood
isocyanate	6.01	0.50	8.4	18% bond / 82% wood

DISCUSSION

Basing on the analysis of the results presented in table 2, it was determined that best pine/CFRP adhesion was reached with a variant of the epoxy glue (2.06 N/mm^2). Lowest adhesion was reached with phenolic glue (1.11 N/mm^2). It is worth notice, that various adhesives showed different share of particular failure types at destructive force. It should be emphasized, that in case of epoxy glue lines mostly the cohesive failure of wood took place, while damage in material was the deepest in comparison to other types of glue. This indicates that the cohesive forces of wood material using epoxy glue were the greatest. However, in most cases the failure was in the wood, which proves that the wood base is the weakest point of the composite.

Basing on the results presented in table 3, it was found that highest shear strength of tested joints was reached with variant b of the epoxy glue (6.55 N/mm^2), lowest with chloroprene (1.59 N/mm^2). In case of epoxies, also cohesive failure of wood with considerable depth was noticed. Phenolic adhesive, with lowest pull-off strength, showed shear strength of the bond only insignificantly lower than variant a epoxy one.

CONCLUSION

All bonds tested, except chloroprene, showed shear strength greater than pine wood. Both epoxy resin variants had best shear and pull-off strength with tested CFRP tape, which can be caused by good adhesion properties of the glue and relatively deep penetration into wood (hot pressing, all samples destroyed deeply in the wood).

The pull-off tests showed that chloroprene glue joint has got similar strength to tensile strength of wood perpendicular to the fiber direction.

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