Use of GFRP laminates for strengthening or rehabilitation of timber beams

João Negrão[1], Ana Balseiro[2], José Faria[3]

Abstract This paper investigates the strengthening of timber beams with carbon fiber laminates (CFRP). In an attempt to improve the effectiveness of the composite system, a prestressing technique was used. The CFRP laminates were also used to rehabilitate collapsed solid timber beams. For the sake of comparison, one set of beams was sawn at midspan from the tension (bottom) face up to the neutral axis and both sets of beams were rehabilitated and tested. A small-size test specimens campaign was also carried out in order to assess the shear strength of the timber-CFRP connection. The main conclusion is that the system is rather effective under steady dry conditions, though the influence of effects such as creep and cycle loading require further investigation.

Keywords conference, paper, instructions, template

1. INTRODUCTION

The strengthening system studied here consisted of bonding reinforcement strips of carbon fiber (CFRP) laminates on the timber surface. Basic calculations show that the impact of this provision in the strength improvement is much smaller in timber than in reinforced concrete structures, given the ability of the former material to withstand tensile stresses. Besides, the tensile stress in the CFRP part at the ultimate load of the composite element is far below its strength, which questions its suitability for application with timber. Thus, attempting to improve its effectiveness, a prestressing technique was used consisting of gluing the CFRP laminate while cambering the timber beam.

Damaged or fractured timber elements do not allow the use of this technique. For these, however, a passive reinforcement may still be used. That situation was also investigated here. A number of beams were loaded to bending collapse. As the failure surface in bending is highly irregular, an additional set of beams was prepared in which a notch was drilled from the bottom to the neutral axis of the midspan cross section. Given the fundamental role of the shear strength at the interface, a small-size specimen test program was also undertaken prior to assess that parameter under different conditions.

2. SMALL-SIZE SPECIMENS TESTS

Eight series were produced and tested, differing in one parameter only from the basis or reference series. The characteristics of each series were those referred to in Table 1. Each series consisted of 20 test specimens.

[1] João Negrão, CIEC, Department of Civil Engineering, University of Coimbra, Portugal, jhnegrao@dec.uc.pt
[2] Ana Balseiro, anabalseiro@gmail.com
[3] José Faria, Department of Civil Engineering, University of Oporto, Portugal, jmfaria@fe.up.pt

Table 1 - Small-size specimens experimental program

Series	Highlight	Testing conditions
1	Reference	ω_G =12; ω_T =12; L=50; Monotonic loading
2	High moisture content	ω_G =20; ω_T =20; L=50; Monotonic loading
3	Timber shrinkage	ω_G =20; ω_T =12; L=50; Monotonic loading
4	Timber swelling	ω_G =12; ω_T =20; L=50; Monotonic loading
5	Time-load function	ω_G =12; ω_T =12; L=50; Loading to EN26891
6	2x loaded length	ω_G =12; ω_T =12; L=100; Monotonic loading
7	3x loaded length	ω_G =12; ω_T =12; L=150; Monotonic loading
8	Cyclic loading	ω_G =12; ω_T =12; L=50; Cyclic loading
ω_G – Moisture content by gluing time [%];ω_T – Moisture content by testing time [%]; L – Glueline length [mm]		

Figure 1 displays the charts of estimated strength and experimental strength. The main conclusion is that the effect of moisture dramatically reduces the strength of these connections, whether it raises or decreases and happens prior or after the CFRP-timber gluing operation.

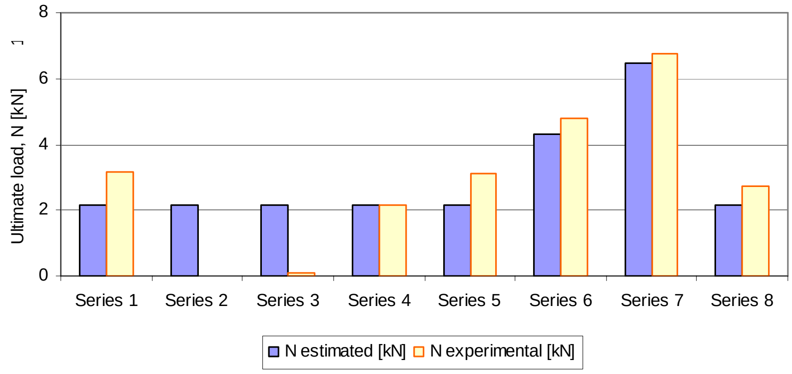

Figure 1 – Expected *versus* experimental ultimate loads for all series

3. STRUCTURAL-SIZE SPECIMENS (BEAMS) TESTS

Table 2 – Final experimental program

Series	Features	Sample size
1	No reinforcement	4
2	Prestressed beams	7
3	Sound beams reinforced with CFRP	2
4	Beams of series 1 after tested and repaired	4
5	Midspan sawn and reinforced beams	3

Five series corresponding to different rehabilitation or strengtthening conditions were produced and tested. Table 2 summarizes the description of the series, while Table 3 shows the results. The main conclusions are that the prestressing technique increases the effectiveness of the reinforcement system in almost 40% with regard to the non-prestressed solution, and that the repair recovers between 50 and 60% of the original strength of the unreinforced beam.

Table 3 – Comparison of results - stresses

	Estimated ultimate load F (kN)	Increase towards reference (%)	Experimental ultimate load F(kN)	Ultimate bending stress (N/mm^2)	Increase towards reference (%)	Increase towards estimated (%)
Series 1	16,55	0,0	29,27	56,4	0,0	76,8
Series 2	22,00	32,9	36,83	55,5	25,9	67,4
Series 3	20,55	24,2	34,75	53,5	18,7	69,1
Series 4	0,00	-100,0	15,64	78,8	-46,6	0,0
Series 5	9,13	-44,8	14,67	73,9	-49,9	60,7