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EXPERIMENTAL STUDY REGARDING THE BEHAVIOR OF GLUE LAMINATED BEAMS DOUBLE REINFORCED WITH RECTANGULAR METAL PIPES (RMP)

A.D. BERINDEAN[1] C.A. BERINDEAN[1]

Abstract: *Improvement of the load carrying capacity of glulam beams by the addition of reinforcement is now common practice. The possibility of using RMP as reinforcement for glulam timber elements in place of FRPs is of interest, due to the improved durability of the system, low cost manufacturing and to the easier and faster application guaranteed by the traditional square steel bars. The aim of this paper is to determine the supporting capacity on bending and flexural properties of reinforced (RMP) compared with unreinforced glued laminated beam. The size of each beam is: 115x320x6400mm. The results indicate that the behavior of reinforced beams is totally different from that of unreinforced one..*

Key words: *glue laminated timber, rectangular metal pipes reinforcement.*

1. Introduction

As we know, glulam beams loaded by bending moments fail first at the compression side then tension side at the position of defects, in generally knots. Due to this failure mode glulam beams are mainly reinforced at the compression and tension side to strengthen the weak cross-sections.

The reinforcement for glulam beams should have a high modulus of elasticity (MOE) and a large tensile strain at failure. Materials considered in the past were steel, glass fiber reinforced plastic (GFRP) and since a few years carbon fiber reinforced plastic (CFRP) and aramid fibre reinforced plastic (AFRP). Fiber reinforced plastic (FRP) has the advantage of a high MOE – although generally lower than steel (RMP) – and a high tensile strength. An effective reinforcement leads to a plastic behaviour on the timber compression side. In unreinforced glulam beams this effect hardly occurs and design models therefore do not take into account this effect.

1.1. Possible applications of RMP in timber structures [1]

Possible combinations of FRP and other high strength materials with timber are basically presented in figure 1.

1.2. The main mechanical properties of RMP

Regarding the possibilities to apply and to combine different materials, it's useful to compare their most important

[1] Faculty of Constructions, Technical University of Cluj-Napoca.

characteristics. Figure 2 shows the orders of the tensile strength and the Young's modulus of some materials often used for building tasks [2].

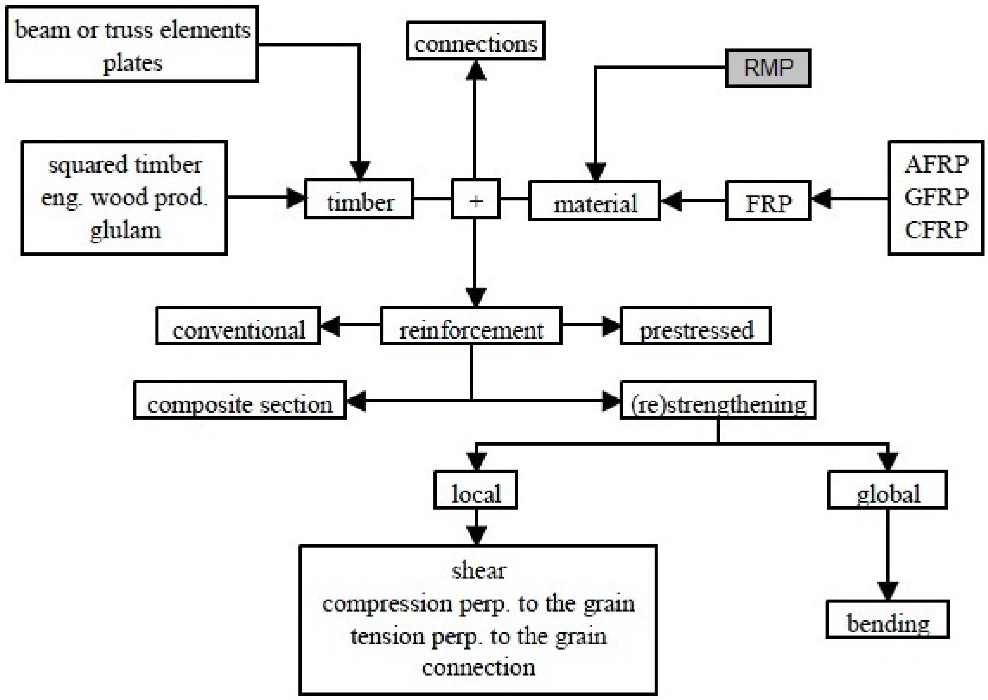


Fig. 1. *Possibilities of using RMP in timber engineering*

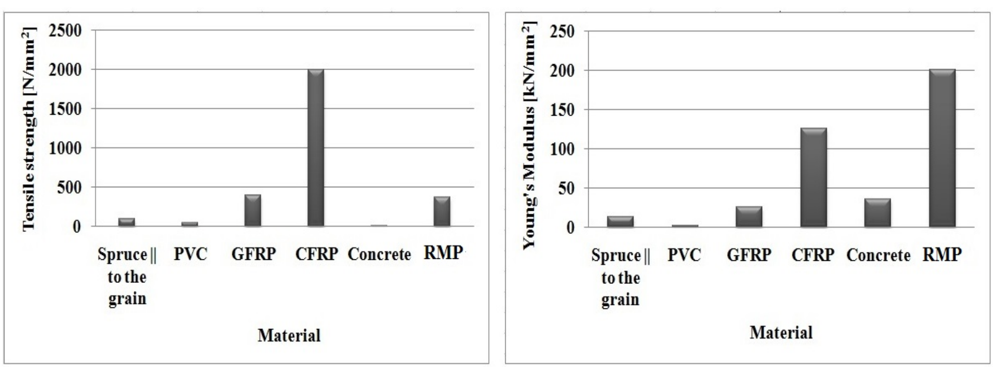


Fig. 2. *Mechanical properties (tensile strength / Young's modulus) for different materials*

2. Structure of reinforced glulam beams

Figure 3 shows the types of reinforced glulam beams cross section. In practice, for reasons of fire safety or for esthetical reasons a facing consisting of a load carrying timber lamination is applied below the reinforcement. RMP reinforcement was applied in the same manner (type 1) [3].

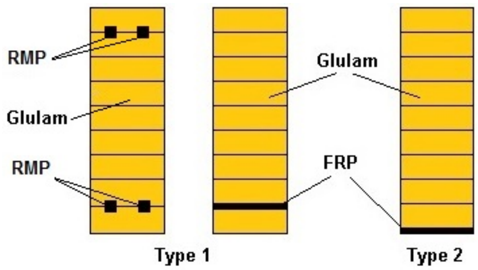


Fig. 3. *Type of reinforced glulam beams cross section*

Using a tensile reinforcement the compressive stress will exceed the timber tensile stress in beams loaded in bending. Therefore plastic deformations are more probable in beams with tensile reinforcement.

Using both, compressive and tensile reinforcement the linear modes will mostly occur due to the reduction of the plastic area in the compressive zone.

3. Experimental study

Non-reinforced glulam beam and double reiforced RMP glulam beam have been tested under static bending for experimental study.

Cross section of 115x320 mm and length of 6400 mm were considered for both type elements. The beams have been manufactured based on SR EN 386 with strength classes of C24 given by SR EN 338 [4] respectively GL24c based on SR EN 14080 [5]. The adhesive used to manufacture the beams (Prefere 4535/5035) was the same type of adhesive applied on RMP used to reinforce the beam specimen [6].

The cross section of reinforced beam is presented in figure 4 included the dimensions of RMP.

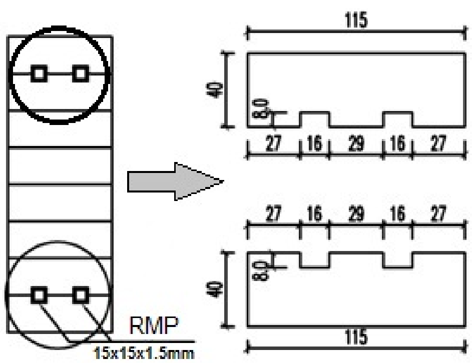


Fig. 4. *Cross section of double reinforced beam with RMP*

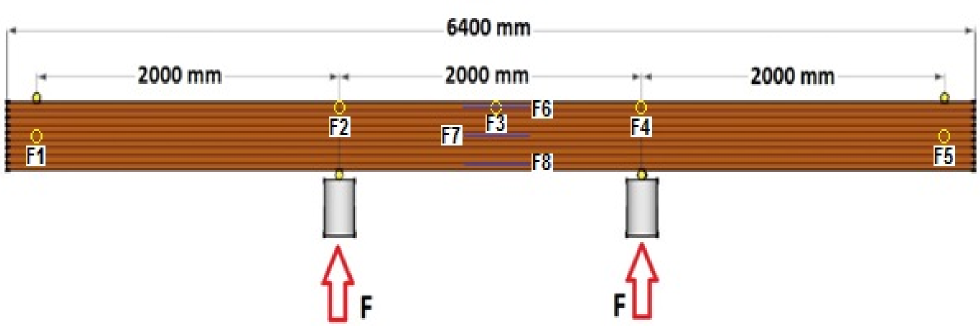


Fig. 5. *Cross section of double reinforced beam with RMP*

Adhesive thickness around reinforcement was 0.5mm, the same between lamellas. Both elements have been bent to failure applying loads as per SR EN 408 (the span was 6000 mm and the loads were applied 2000 mm away from each support).

An increment of 1.0KN has been used when applying the loads and the deflection in three different locations was recorded as follows: F2 and F4 at location of loads and F3 at mid span.

Also deformations of beam in 5 different locations have been recorded as follows: F1 and F5 at supports, F6, F7and F8 at mid span over a length of 500mm for tensioned fiber, median fiber respectively compressed fiber (figure 5).

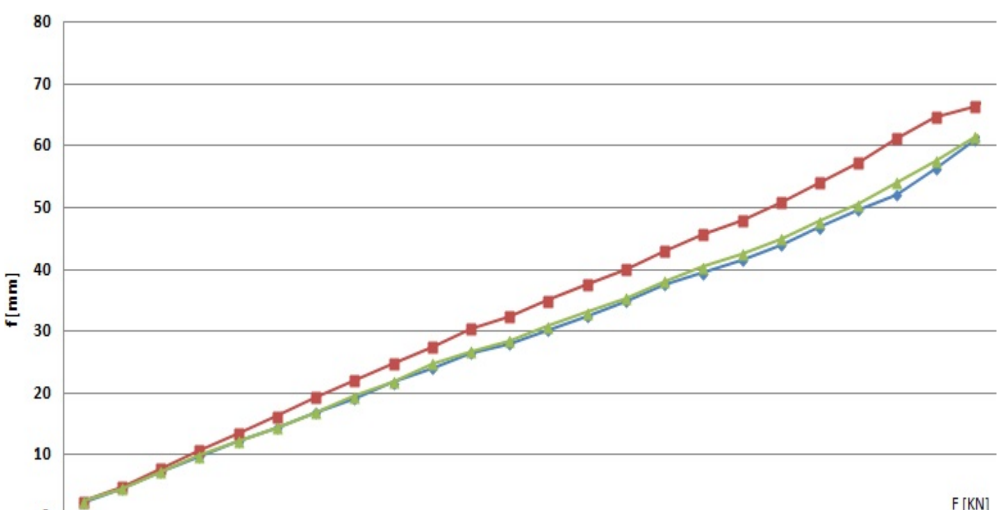
The test results are shown in table 1. The differences, quite large, between deflections can be observed for the same of load (F_{max} = 48 kN).

Curves load-deflection are shown in figure 6 and figure 7 for the three locations (F1, F2 and F3).

Figure 8 shows RMP double reinforced glulam mode of failure.

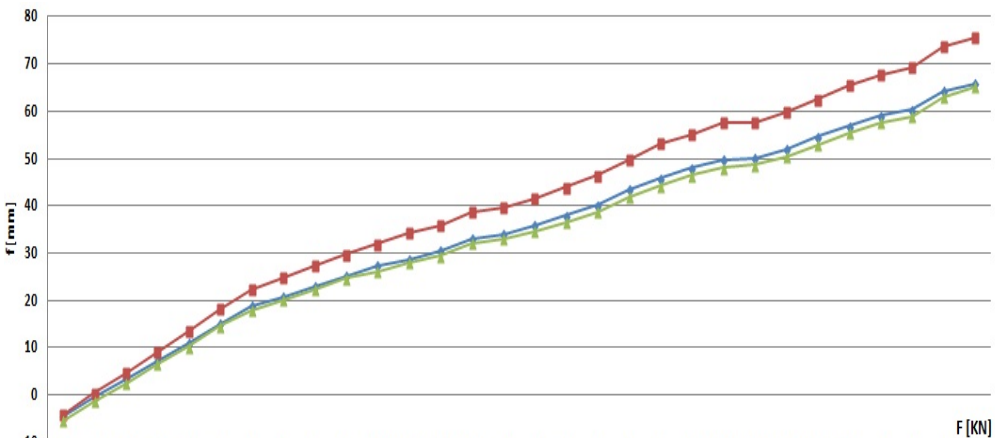
Test results Table 1

		Non-reinforced glulam	RMP double reinforced glulam	
Maximum load „F_{max}" [kN]		48	(48)	76
Bending moment „M" [kNm]		47.41	(47.41)	75.41
Deflection „u" [mm]	**F2**	61.00	(37.90)	65.80
	F3	66.30	(43.90)	75.60
	F4	61.50	(36.60)	65.20
Bending strength „f_m" [N/mm^2]		24.15	38.42	



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Tr.1	Tr.2	Tr.3	Tr.4	Tr.5	Tr.6	Tr.7	Tr.8	Tr.9	Tr.10	Tr.11	Tr.12	Tr.13	Tr.14	Tr.15	Tr.16	Tr.17	Tr.18	Tr.19	Tr.20	Tr.21	Tr.22	Tr.23	Tr.24
F2	2.3	4.7	7.4	9.7	12.2	14.5	17	19.2	21.7	24.1	26.5	28	30.2	32.5	34.8	37.5	39.4	41.5	44	46.8	49.7	52	56.3	61
F3	2.5	4.8	7.8	10.8	13.5	16.3	19.3	22	24.7	27.5	30.4	32.5	35	37.5	40.1	43	45.6	48	50.9	54	57.2	61.2	64.7	66.3
F4	2.5	4.6	7.4	9.9	12.2	14.5	17	19.5	21.9	24.7	26.8	28.5	30.8	33	35.4	38.1	40.4	42.5	44.9	47.8	50.5	54.1	57.5	61.5

Fig. 6. *Load-deflection curve of non-reinforced beam*



	2	4	6	8	10	12	14	15	16	17	18	19	20	21.5	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	Tr.1	Tr.2	Tr.3	Tr.4	Tr.5	Tr.6	Tr.7	Tr.8	Tr.9	Tr.10	Tr.11	Tr.12	Tr.13	Tr.14	Tr.15	Tr.16	Tr.17	Tr.18	Tr.19	Tr.20	Tr.21	Tr.22	Tr.23	Tr.24	Tr.25	Tr.26	Tr.27	Tr.28	Tr.29	Tr.30
F2	-4.4	-0.3	3.3	7.3	11	15	18.8	20.8	23	25.1	27.3	28.5	30.6	33	34.1	35.8	37.9	40.1	43.4	45.8	48	49.8	50	51.9	54.6	56.8	59	60.3	64.3	65.8
F3	-4.1	0.4	4.7	9.2	13.5	18.2	22.2	24.9	27.4	29.7	31.9	34.4	35.9	38.7	39.6	41.5	43.9	46.4	49.7	53.1	55.2	57.5	57.6	59.7	62.5	65.5	67.8	69.2	73.7	75.6
F4	-5.3	-1.2	2.4	6.5	10.2	14.6	17.9	20.2	22.4	24.7	26.2	28.1	29.4	32.2	33	34.6	36.6	38.6	41.8	44.2	46.4	48	48.6	50.4	52.8	55.3	57.5	58.9	62.9	65.2

Fig. 7. *Load-deflection curve of RMP double reinforced glulam*

a.

b.

c.

d.

Fig. 8. *Type of failure*

Conclusions

Timber facing failure at tension side occured first (fig. 8a) because of knots. Second to fail was the adhesive around RMP (fig. 8b,c) followed by total collapse of beam (fig. 8d).

RMP double reinforced glulam gained approximate 59% in strength and the values of deflection have been recorded lower with 33.8% then non-reinforced beam, for the same value of load.

References

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