Strengthening of structures by composite materials based on jute and flax fibers

G Bou Abdallah[1,2], C Diagana[1], J Assih[1], I. Titeux-Peth[1], I Ivanova[2] and D Dontchev[2]

[1] *Civil Engineering Department Sustainable Construction, ITHEMM EA 7548, University of Reims Champagne-Ardenne*

[2] *Department of Applied mechanic, University of Chemical Technology and Metallurgy, Kliment Ohridski Boulevard, 8 Sofia, 1756.*

ABSTRACT Despite the many advantages of synthetic fiber composites, the use of bio-composite as a new material for structural reinforcement will be interesting to aim toward sustainable construction with reduced environmental problems. This study investigated the performance of epoxy polymer composites reinforced with natural flax fabric and jute as reinforcement materials for concrete structures. The jute and flax fabrics were tested in tensile to compare their characteristics with those of carbon. The effect of the type of fabrics as well as the thickness of the composite are evaluated. The thickness of the composites considered were 1, 2, 3, 4 and 5 layers of fabric. The results show that there is an increase of 36% in the ultimate bending load for both fabrics compared to the reference beam. Therefore, the results allowed to consider natural fabric composites as well-suited materials for the strengthening concrete structures.

Keywords Flax fabric composite, jute fabric composite, number of layers, tensile behavior, flexural behavior

I. INTRODUCTION

Reinforced concrete structures have degraded over time due to internal reinforcement corrosion, freeze-thaw action, and poor initial design (Huang et al., 2016). For these reasons, many old buildings cannot longer support excessive loads, so they must either be renewed or rebuilt to keep the safety standard. From an economic and environmental point of view, the external bonding technique is a practical and effective way to strengthen building structures. Carbon fabric reinforced epoxy polymers (CFRP) and glass FRP (GFRP) have been used because of their remarkable physical and mechanical characteristics (Huang et al., 2016). Because of the disadvantages of synthetic fiber composite materials such as their impact on the environment, and the construction sector's emission of 30% of greenhouse gases, it becomes necessary to use environmentally friendly and lightweight building materials with good mechanical properties. Yan et al. noted that flax, hemp, and jute can replace glass fibers considering

cost, mechanical performance, and production efficiency (Yan et al., 2014). Yan (Yan, 2015), showed that flax fiber composites as an external reinforcement material significantly increased the lateral load, deflection, bending strength and fracture energy of the specimen. Indeed, the results show that from two layers of natural fiber fabric, the ultimate load of the structure increases two times more than the reference load of the control structure (Bou Abdallah et al., 2022). The mechanical behavior and load transfer between the fibers and the matrix are influenced by the interface bond (Bou Abdallah et al., 2022). The purpose of this experimental study is to investigate the mechanical properties of natural fibers (flax and jute) as a composite material for the reinforcement of concrete structures. In this paper, the influence of the type of fabrics as well as the thickness (number of layers) of the composite plate, on prismatic concrete specimens will be tested.

II. EXPERIMENTAL PROGRAM

Normal strength concrete materials were rolled gravel dried sand and ordinary Portland cement. The cement: sand: gravel proportions in the concrete mix were 1: 1.82: 2.31 by weight and the water/cement ratio was 0.6. Portland cement type CEM I 42.5 was used and the maximum size of the aggregate was 12.5 mm. Three 160 mm x 320 mm concrete cylinders were also cast and tested, to determine the compressive strength of the concrete at 28 days of age. In fact, 23 prismatic specimens (400×100×100 mm) were tested. Three unreinforced specimens was used as a reference (B0), 10 specimens were reinforced with jute fabrics (Figure 1) and 10 others with linen fabrics (Figure 2) with different thicknesses ranging from 1 to 5 layers. Bidirectional flax and jute fabrics were tested in tensile stress. They were used in bonding with a Sikadur-330, an epoxy resin. Four-point bending test was investigated, where the influence of shear strength is zero between the two loading points. Electrical strain gauges were used local strains and displacement captor LVDT is applied to measure the arrow of beam specimens.

Figure 1. **Jute fabric**

Figure 2. **flax fabric**

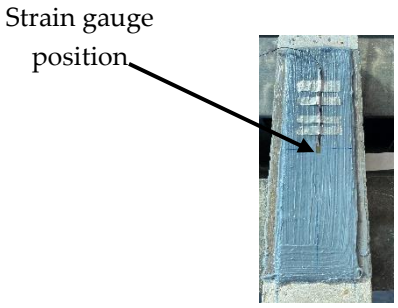

Figure 3. **Strengthened concrete beams**

Figure 4. **Four-point bending test**

III. RESULTS AND DISCUSSION

A. Influence of ultimate load of different fiber fabrics in tensile tests.

Table 1 shows the results of tensile test for both materials (jute and flax fiber fabrics). The results show that the values of ultimate load in tensile for the flax fiber fabrics are higher than those of fiber jute fabrics. Knowing that in strengthening of reinforced concrete beam, only 30% of this maximum load of the carbon fiber fabrics, 950 N, (Bou Abdallah, 2022) is used. This shows that the two fabrics can be used as reinforcement of concrete beams.

TABLE 1. Ultimate tensile load of vegetable fabrics

Materials	Jute	Flax
Fu (N)	217.50±65	240±20

B. Influence of thickness on the ultimate load in bending

In this part, the influence of the composite (flax and jute) thickness, on the strengthening concrete beams is investigated. Figure 5 shows the results. In fact, the results show that the ultimate load increased with the number of layers the control specimen is named "B_0" with the letter "B" indicating the beam and zero 0 indicating no reinforcement. The first letter of the identification of the reinforced concrete beam is, as said before, Beam, while the second letter means the type of fabric (J for Jute and F for Flax). The number of layers is then indicated by the number (e.g.: 1, 2, 3). F_0 is the ultimate load of the reference beam.

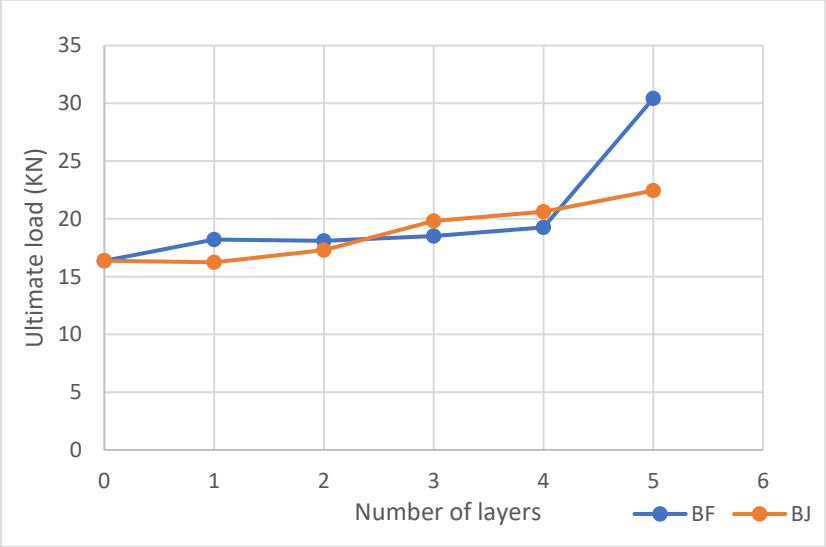

FIGURE 5. Effect of the number of layers on the ultimate load

However, for a number of layers equal to 5, there is a gain of 37.14% and 85.83% in the ultimate load for jute and linen fabrics respectively.

C. Cracking and failure modes

The results show 2 types of failure modes and 2 types of cracking. Under four layers there is a failure of the composite for both fabrics (Figure 6). Otherwise, there is a debonding of the composite and concrete only in the beam reinforced with 5 layers of flax fabric composite (Figure 7). In the other hand the two types of cracking are the flexure (Figure 8) and shear for all the beams. In summary, when the layers of

flax fabric composite increase, the failure mode switched from failure of the composite to debonding.

Figure 6. **Failure of flax composite**

Figure 7. **Debonding of the composite and concrete**

Figure 8. **Flexural cracking**

IV. CONCLUSION

This paper presents an experimental study whose objective is to evaluate the influence of fabric types as well as the number of layers of composites on strengthening concrete beams. The tensile strength of two types of fabric (jute and linen) was tested. Strengthening with jute and flax fabric composites increases the ultimate bending load of concrete beams up to 37% and 86%. Based on these results, the idea of strengthening reinforced concrete beams with these materials will be interesting. Considering the current study, we cannot choose an optimal number of layers. In fact, the results show that 5 layers of flax fabric composites is effective to reinforce beams, but to avoid using multiple number of layers, combining composite fabrics such as carbon with natural fabrics could be a solution.

REFERENCES

L. Huang, B. Yan, L. Yan, Q. Xu, H. Tan & B. Kasal. (2016). Reinforced concrete beams strengthened with externally bonded natural flax FRP plates. Composites Part B 91 (2016) 569-578. www.elsevier.com/locate/compositesb

L. Yan, N.Chouw & K. Jayaraman. (2014). Flax fibre and its composites—a review. Compos B 56:296–317

L.Yan (2015), Plain concrete cylinders and beams externally strengthened with natural flax fabric reinforced epoxy composites. Materials and Structures 49:2083–2095. https://doi/10.1617/s11527-015-0635-1

G Bou Abdallah, I Ivanova, J Assih, C Diagana, & D Dontchev. (2022). Composite materials based on natural fibres applied for structural reinforcement, IOP Conf. Series: Earth and Environmental Science 960 (2022) 012007. https:// doi:10.1088/1755-1315/960/1/012007