Bending Analysis of Timber Connection Strengthen with Glass Fiber Reinforced Plastic

Mehmet SARIBIYIK
Department of Construction,
Sakarya University, Adapazari, Turkey,
mehmets@sakarya.edu.tr

Tahir AKGUL,
Department of Construction,
Sakarya University, Adapazari, Turkey,
takgul@sakarya.edu.tr

Ahmet APAY
Department of Construction,
Sakarya University, Adapazari, Turkey,
aapay@sakarya.edu.tr

Ali SARIBIYIK
Technical Higher School,
Duzce University, Duzce, Turkey,
alisaribiyik@hotmail.com

Abstract: In order to obtain both durability and originality of the timber structures it is necessary to strengthen them particularly in the weak joint places. The aims of strengthen in the connecting places are to decrease the stress, to obtain fibre continuity, to reduce disadvantages of nail and bolts. Nowadays, Glass Fibre Reinforced Plastics, (GFRP) produced via pultrusion process that is one of fibre reinforced polymer types, are used for strengthen of the structural elements. In recently, it has been increased strengthen for timber structural elements by using GFRP because of its high strength, light weight, corrosion resistance and also very easily applying to the structures.
The aim of this study is to obtain the fibre continuity of connecting places of timber structural elements of construction systems that under the bending conditions. Mechanical performances of the connecting places of fibre reinforced longitudinal notched lap joints have been investigated. Experimental specimens have been prepared from black pine timber which is very abundant in nature. To determine performances of the specimens, 5 different types of adhesively bonded and strengthen with GFRP bar samples, have been prepared. The specimens have been tested subjected to bending strength and the obtained results have been compared each others. The outcomes demonstrate that the bending strength of the connection points strengthen with GFRP bar has higher than adhesively bonded connection specimen and this ratio is about 300 %.

Key words: Timber Structures, Bending Strength, Longitudinal Notched Lap Joint, Glass Fibre Reinforced Plastic

1. Introduction

In the continuing quest for improved performance of structural materials, scientists and engineers strive to produce either improved traditional or completely new materials. Composite materials are an example of the latter category. Within the past five decades there has been a rapid increase in the development of advanced composites incorporating fine fibres, termed fibre reinforced composites. These materials, depending on the matrix used, may be classified as a polymer, metal or ceramic matrix composites. The high cost of metal and ceramic matrix composite materials prevents their normal use in construction. The majority of composites used in the construction industry are therefore based on polymeric matrix materials. Additional factors in choosing polymeric composite materials for structural engineering applications are: the materials are lightweight, non-corrosive, chemically resistant, possess good fatigue strength, are non-magnetic, and, subject to the materials selected, can provide electrical and flame resistance. Material surfaces are also durable and require little maintenance (Extren, 1998). The construction industry appears to be gradually recognising the additional benefits offered by these materials.

Timber has been extensively used in construction for many decades and has applied in many structural applications in engineering. It is a renewable resource, recyclable, relatively inexpensive, has a high strength to weight ratio and is architecturally attractive. However, wood, also has a number of disadvantages such as biological deterioration over time, dimensionally unstable in alternating environmental conditions and in flexural members it exhibits brittle tensile failures. A number of research studies have examined the option of reinforcing wooden flexural members with pultruded fibre reinforced plastic laminate, sheet and bar forms. Significant strength and stiffness increases in comparison with unreinforced members have been reported by a number of researchers (Fiorelli et al. 2003, Micelli 2005, Akgül et al. 2009). This technique can be easily and efficiently carried out and adds negligible depth and mass to the member that is being reinforced.

Upgrading structures for higher working loads or restoring original design strength has been an engineering task for structures of any material. Before high strength fibre (HSF) were available, steel was mostly used for such purposes. The bonding of steel plates onto concrete was developed in the seventies. In the early eighties the steel plates were substituted by Carbon Fiber Reinforced Plastic (CRP). Today this is a well-established technique. It has been used successfully on approximately 400 structures world-wide as shown in Fig. 1. The main advantages of using CRP-laminates rather than the early steel plates, are their light weight and the corrosion resistance, as well as their flexibility, which allows their convenient and easy transport on rolls to the place of application. It was very tempting to use this material on timber structures as well. A considerable number of timber structures have already been reinforced successfully with CRP.

Fig. 1. Restrengthening of bottom chords of the timber bridge (Steiger 1999)

This paper aims to obtain the fibre continuity of connecting places of timber structural elements of construction systems that under the bending conditions. Mechanical performances of the connecting places of GFRP longitudinal notched lap joints have been investigated. Experimental specimens have been prepared from black pine timber which is very abundant in nature. To determine performances of the specimens, massive and 5 different types of adhesively bonded and strengthen with GFRP bar samples, have been prepared. The specimens have been tested subjected to bending strength and the obtained results have been compared.

2. Material and Method

2.1. Timber

Black Pine was the timber specimens used in the test program. The timber was all plain sawn and was harvested from the same stand. Consequently, variability in the wood resulting from contrasting environmental conditions during growth was significantly reduced. An important concern was the high juvenile wood percentage in the material and as a result increased dimensional instability present in the longitudinal direction. The timber was kiln dried in the sawmill to approximately 12±0.5 % moisture content and upon delivery to the laboratory.

2.2. Adhesive

Teknobond 300 adhesive chemicals, capable of curing at room temperature and providing strong adherends, was used for bonding wood to wood as well as wood to FRP materials. This adhesive has very high adherence strength, it penetrates even very thin details due to low viscosity, it does not contain cavities, so it is not water permeable end it is used in places where we want electrical insulation. Teknobond 300 adhesive consists of two parts, a liquid resin A and a powerful hardener B. Mix the proportionally set A and B components with a low cycled drill until it takes homogenous grey colour. Mix materials in appropriate amount according to proportions of mixture by considering the material will be able to use. It should not be applied when the temperature is below than +5°C. The technical advice contained in the adhesive data sheets and that given by the manufacturers was followed closely during preparation of the test specimens.

2.3. Pultruded Glass Fiber Reinforced Plastic

The pultrusion process is a proven manufacturing method for obtaining lengths of high quality fibre reinforced plastic components having consistently repeatable cross-sections. Much improved mechanical properties can be obtained with this procedure due to higher fibre volume fractions than those achieved in labour intensive manual lay-up procedures. In this method, a continuous E-glass fibre reinforcement in the form of alternate layers of randomly oriented mat and layers of unidirectional roving bundles are pulled through a resin impregnator and then on through a heated die to form continuous prismatic members similar in geometry to those produced by the steel industry as seen Fig. 2 (Extren, 1998; Mallick, 1997). The pultrusion process allowed GFRP to become a competitive alternative to traditional structural materials (steel, concrete and wood). At the same time it provided a lower specific weight with respect to strength and good environmental resistance.
Having resolved fundamental manufacturing constraints through the development of the pultrusion process, the mass adaptation of GFRP sections as secondary and primary load bearing elements have been used in a number of civil engineering applications. However; pultruded GFRP sections have not been applied as strengthen the timber structural element in the buildings. Therefore 7 different types of adhesively bonded and strengthen with pultruded GFRP bar samples of the black pine timber have been prepared and tested subjected to bending strength. Pultruded GFRP bars having a circle diameter of 0.45cm is, obtained from ESA Chemistry and Metal Industry, used in strengthening of the timber joint.

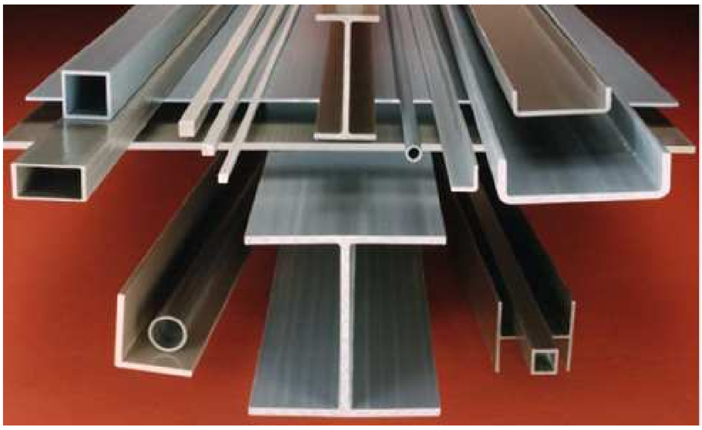

Fig. 2. Examples of Pultruded GFRP profiles (Strongwell)

2.4. Preparation of Specimens

The black pine timber specimens for the bending tests were 500 mm long and 30x40 mm dimensions. At the beginning, the prepared plain samples (without connection) have been tested to evaluate timber bending strength. In the second level, samples formed of two pieces having the same sizes with plain timber but combined with half-lap size in the middle are prepared (see Fig. 3). Subsequently, sawdust was completely removed, either GFRP bars were introduced in their place and, finally, GFRP materials were glued on the wood and the two pieces of wood were glued each other by using Teknobont 300 epoxy resins. After gluing, the specimens were kept under a press for a week at a temperature of about 20°C. After that the samples were cleaned and tested.

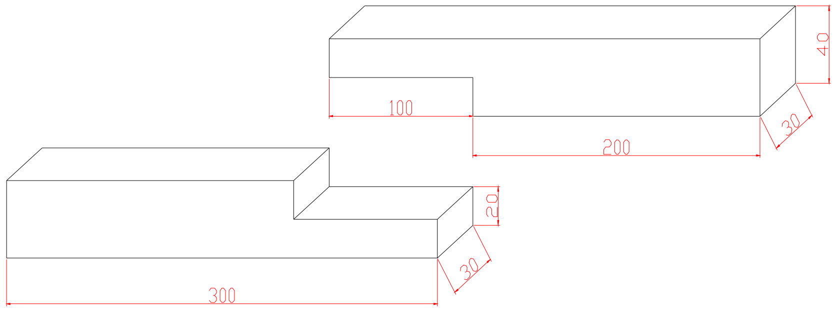

Fig 3. Longitudinal notched lap joint configurations

3. Testing of Specimens

Three point bending test have been applied as shown in Figs. 4 and 5. To determine performances of the specimens, have been prepared and tested according to the Turkish Standards (TS 647, TS 4499). The specimens have been tested subjected to bending strength and the obtained results have been compared each others. The adhesively bonded and strengthen with GFRP bar sample types are named as;

1. Massive Timber sample
2. Connected timbers without reinforcement
3. Connection with single GFRP bar under the samples
4. Connection with double GFRP bars under the samples
5. Connection with single GFRP bars under and top of the samples
6. Connection with double GFRP bars under and single GFRP bars on the top of the samples
7. Connection with double GFRP bars under and top of the samples

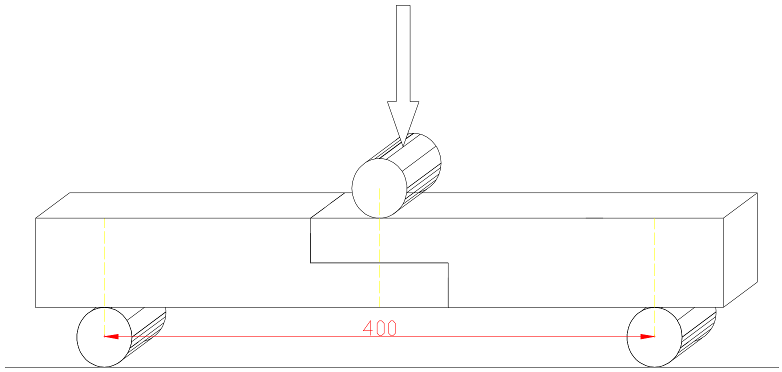

Fig. 4. Three point bending test configurations

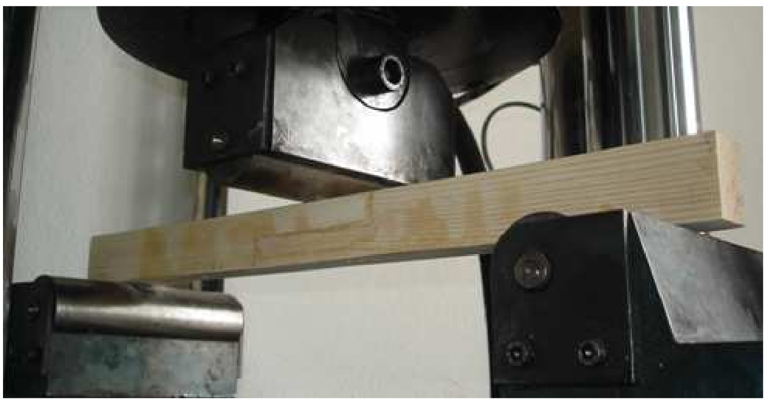

Fig. 5. Bending test configuration of longitudinal notched lap joints

4. Test Results

The fibre continuity of connecting places of timber structural elements of construction systems and mechanical performances of the connecting places of fibre reinforced longitudinal notched lap joints have been investigated. To determine the performances of the connection specimens, 5 different types of adhesively bonded and strengthen with GFRP bar samples, have been tested and compared with massive timber and connection without reinforcement.

The bending strength of the massive timber is found as 83.4 N/mm^2. The connection sample without any strengthening is found as 16 N/mm^2 as shown in Fig.6. This results demonstrated that the connection place needs an extra strengthen material to improve the bending strength of timber joints. The average outcomes of the timber connections bending strengths are given in Tab. 1.

Tab.1. Mean value of connection bending analysis.

Samples Name	**Bending Strength (N/mm^2)**
Massive Timber sample	83.4
Connected timbers without reinforcement	16.0
Connection with single GFRP bar under the samples	40.9
Connection with double GFRP bars under the samples	60.3
Connection with single GFRP bars under and top of the samples	40.9
Connection with double GFRP bars under and single GFRP bars on the top of the samples	62.0
Connection with double GFRP bars under and top of the samples	61.6

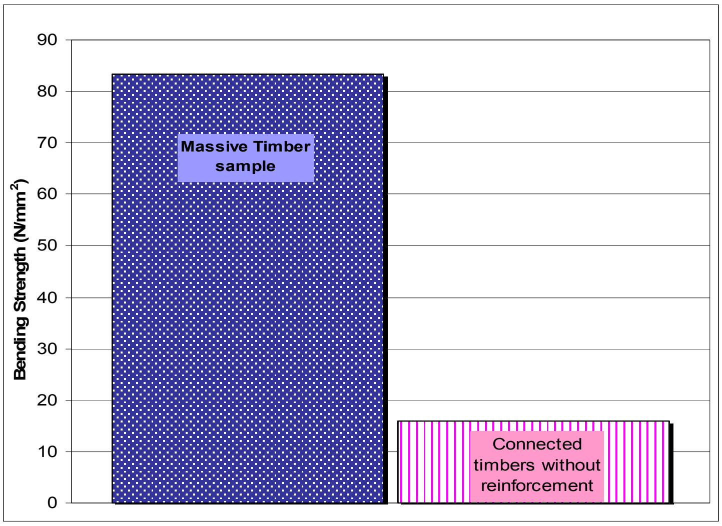

Fig. 6. Comparison of massive timber and connected samples without reinforcement

To increase the performances of the connection specimens, 5 different types of adhesively bonded and strengthen with GFRP bar samples (see Fig. 7), have been tested and are compared with massive timber and connection without reinforcement. The average bending strength of the timbers strengthen with single GFRP bar under the specimen and connection with single GFRP bars under and top of the samples are found as 40.9 N/mm^2. The outcomes showed that the strengthen of the connected timber is increased about 155% when compared with the adhesively bonded connection as shown in Fig. 8. The results showed that the GFRP bar on top of the specimens have no effect to the bending strength of the connection.

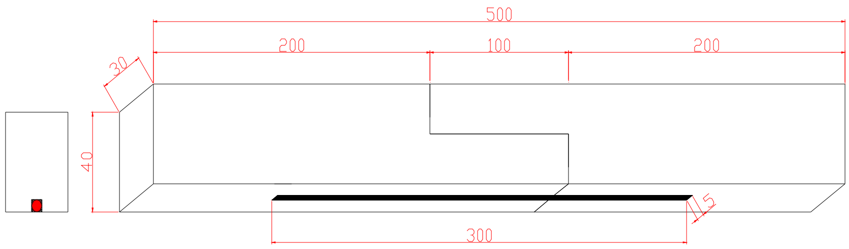

Fig. 7. Configuration of timber connection strengthen with GFRP bar.

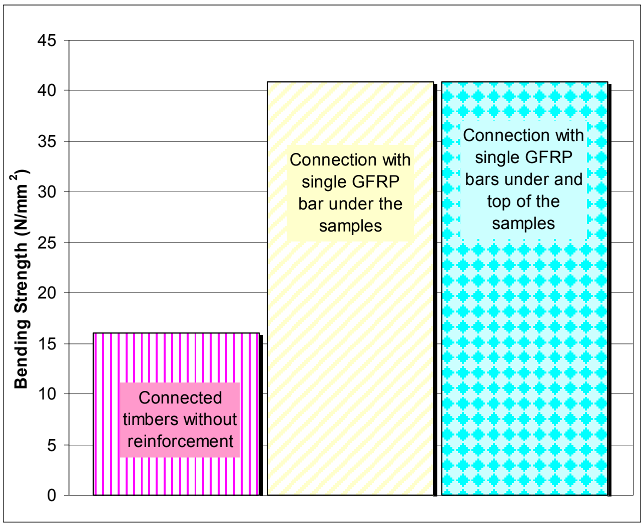

Fig. 8. Comparison of connected timbers without reinforcement with connection with single GFRP bar under and top of the connection

To increase the performances of the connection strengthen with double GFRP bar under the specimen and connection with double GFRP bars under and top of the samples have been prepared and tested. The results demonstrate that the bending strength of the connected timber is increased about 287% when compared with the adhesively bonded connection as shown in Fig. 9. The results showed that the GFRP bar on top of the specimens have very little effect to the bending strength of the connection.

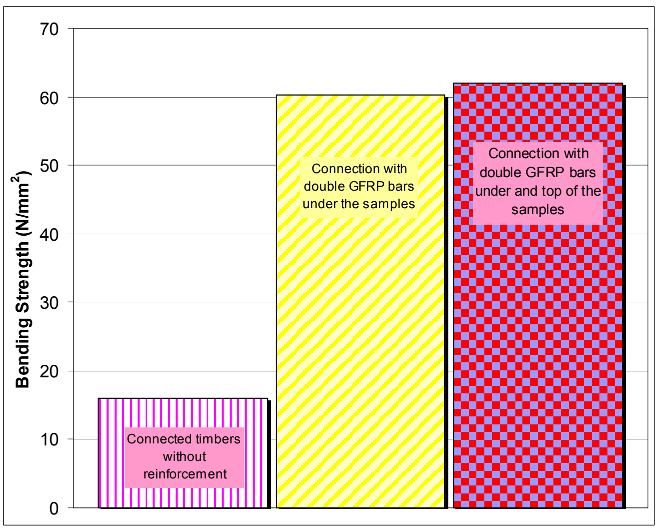

Fig 9. Comparison of connected timbers without reinforcement with Connection with double GFRP bars under and single GFRP bars on the top of the samples

5. Conclusions and Recommendations

Mechanical performances of the black pine timber connecting places of fiber reinforced longitudinal notched lap joints have been investigated. The specimens have been tested subjected to bending strength and the obtained results have been compared with massive timber specimens and each others.

The experimental results showed as the use of GFRP bars seems to be effective strengthen materials when the timber beam subjected to bending. The outcomes demonstrate that the bending strength of the connection points strengthen with GFRP bar has higher than adhesively bonded connection about 300 %. The strengthen techniques of GFRP bars proved to be easy and fast to execute, even when on in-situ applications.

Acknowledgements

This work was carried out in the scope of the Sakarya University BAPK Project 2007-05-08-002 “Reinforcement of Timber Construction Elements Weak Region using Fiber Reinforced Plastic”. The financial support of the Sakarya University is gratefully acknowledged.

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