ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 11 N° 4 2015
pp. 411-417

DAMAGE EVALUATION OF GLULAM TWINNED COLUMNS TO BEAM CIRCULAR BOLTED CONNECTION

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Abstract

This paper deals with assessment of glulam twinned columns to beam circular bolted connection. This kind of connection is used for embedded assembly. Because of the moisture content variations, cracks often occur in the direction parallel to the grain. The aim of the study is to understand the mechanism responsible of the cracks happening. In the same time, another aim of this study is to evaluate the residual resistance of a damaged assembly.

The assembly has been designed according to Eurocode 5. Two different initial conditions have been tested. For the first assembly, the columns and the beam have been dried before machining and tested dry. For the second assembly, the beam was wet and the columns were dry before machining, then the assembly was tested dry. The difference of moisture content implies a huge tensile strain in the direction perpendicular to the grain of the columns before loading.

In order to qualify the assembly behavior, strain gauges techniques have been used. This analysis allows a better understanding of the phenomenon of cracks initiation and propagation due to the coupled effect of shrinkage/swelling and loading.

Key words: *glulam assembly; circular bolt connection; dry conditions; strain gauges; eave embedment.*

INTRODUCTION

The glulam twinned columns to beam circular bolted connection is used for eaves embedment in a glulam portal. This kind of assembly is easy and cheap to realize and seems to be a good solution to build a glulam portal (Wilkinson 1991; Pope and Hilson 1995; Smith and Foliente 2002; Thelandersson and Larse 2003; Noguchi et al. 2006; Nakata and Komatsu 2009; Jensen and Quenneville 2011; Kuwamura 2013; Yeh et al. 2015). It is a regular assembly and its design is described in Eurocode 5 (EN 1995). However there is some pathology with this embedment because of moisture content variations, particularly in shrinkage. In fact, the embedment concerns a huge glulam section and the direction of the grain is perpendicular between the beam and the twinned columns. Because there is a difference in the shrinkage coefficients in the direction perpendicular to the grain and parallel to the grain, stress-induced occurs in tension in the direction perpendicular to the grain on both twinned columns and beam (Wilkinson 1991; Pope and Hilson 1995; Garcia et al. 2006; Silvaa et al. 2014). This phenomenon often produces cracks in the direction parallel to the grain.

This study aims to understand the mechanical behavior of a glulam twinned columns to beam circular bolted connection, in normal and dry conditions. Both assemblies were wet machined and one of them was dried before testing to highlight the difference.

MATERIAL, METHOD, EQUIPMENT

The mechanical behavior of twinned columns to beam circular bolted connections was tested in bending test. The sample geometry and profile is given in Fig. 1. It is composed by GL24 Spruce (picea abies L). The columns thickness is biggest because the study focalized on the beam behavior.

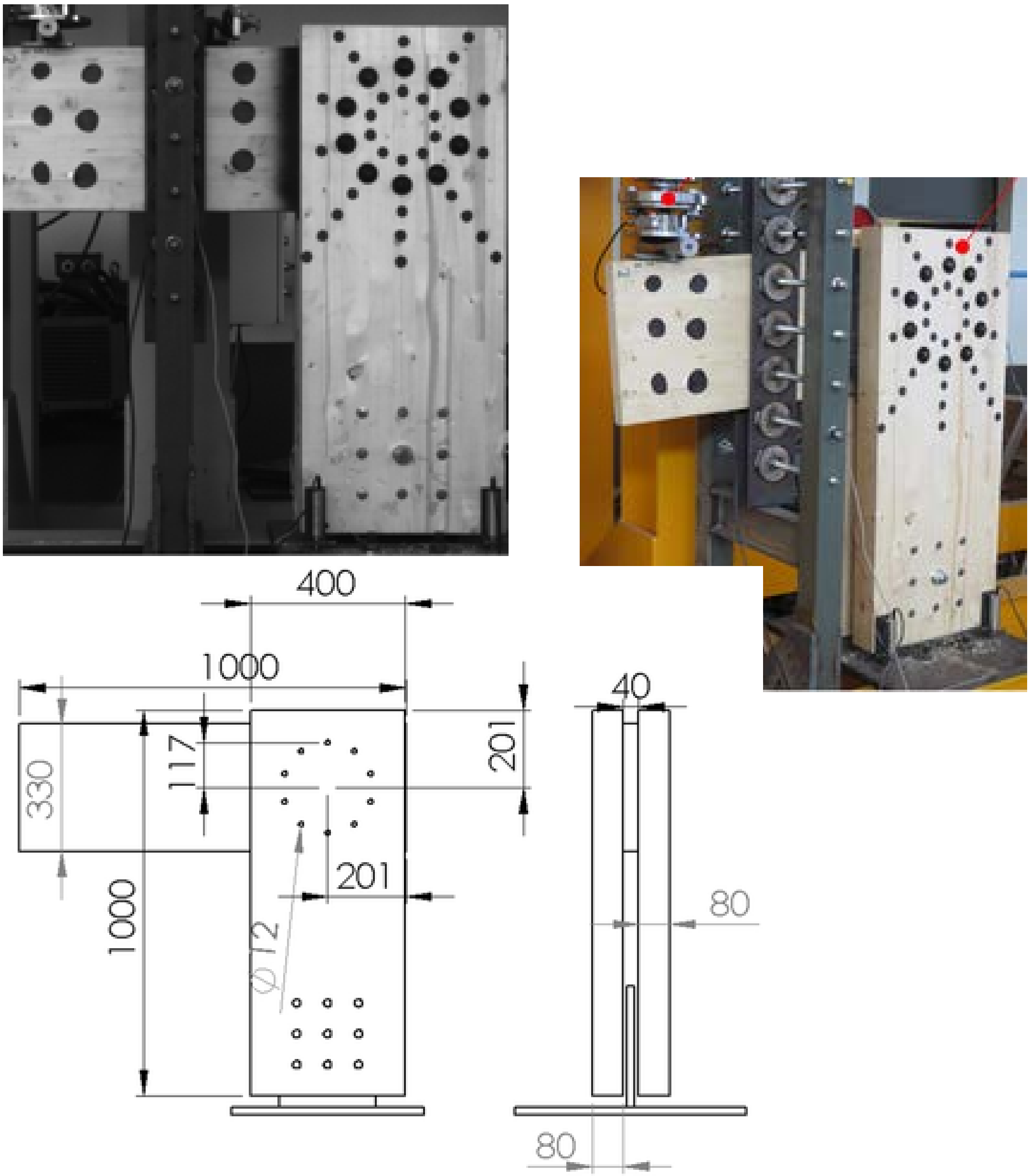

Fig. 1.
Experimental setup and sample geometry

The beam was conditioned at 20°C and 85%RH, about 18%MC and the twinned columns were at 12%MC. After machining, the assembly was conditioned at 20°C and 20%RH but not enough time to obtain equilibrium state. The mean moisture content was about 9%MC. To avoid surface shrinkage cracks, the relative humidity reduction was done step by step as shown in Fig. 3, except from a problem with the conditioning chamber which reach 10%RH for a weekend. During this drying step, the assembly was loaded as shown in Fig. 2. The total load was 1.65kN, which is the maximum load possible in the conditioning chamber.

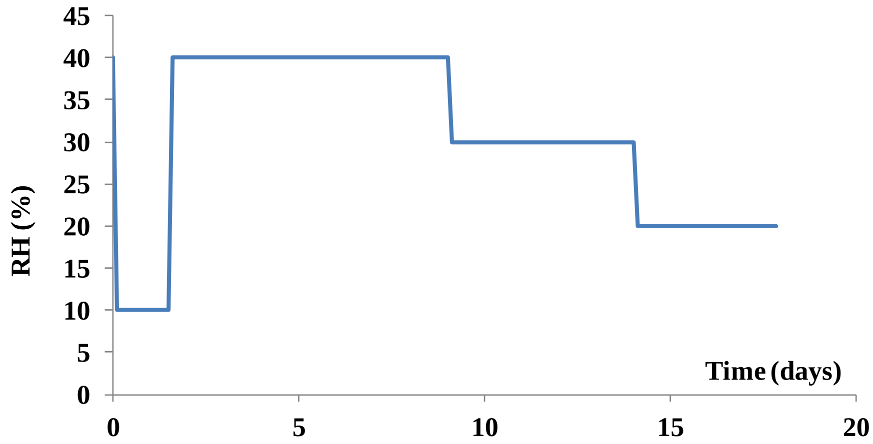

Fig. 2.
Conditioning of sample in the chamber

Both of beams were equipped by strain gauges inside the circular connection of the beam in order to know the tensile strength in the direction perpendicular to the grain. The first assembly had only 3 gauges, because of a knot and the second assembly had 4 gauges. Both of them are shown in Fig. 3.

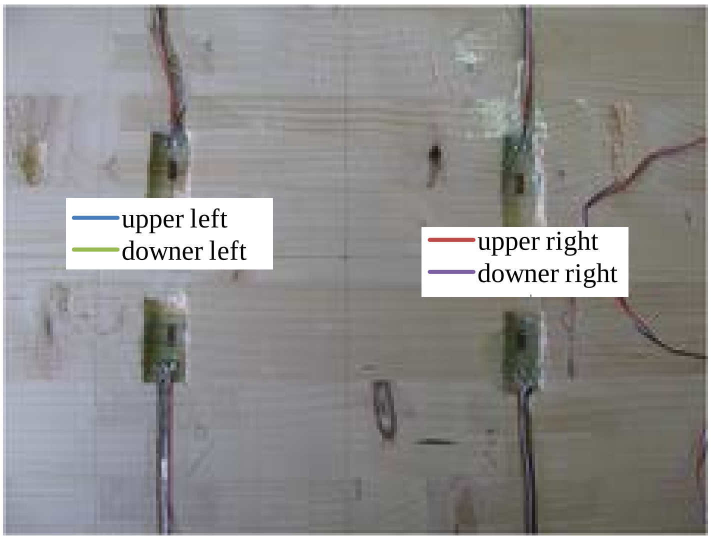

Fig. 3.
Position of strain gauges on the beam

The test was carried out in a prototypal press with a hydraulic jack of 500kN strength capacity and 800mm displacement capacity. The load strength was measured by a 25kN capacity sensor. The speed of the hydraulic jack was 0.5mm/min, under displacement control.

RESULTS AND DISCUSSION

The measurements of the strain gauges inside the circular pattern are shown in Fig. 4. For a change of moisture content from 18% to 9%, the deformation due to shrinkage is about 0.4%. The radial shrinkage coefficient is about 0.1%/% MC, so the total strain has to be about 0.9% (Silvaa et al. 2014). There is only 0.4% strain measured by the strain gauges, so there is stress-induced. It should be noted that no crack occurs inside the circular bolt connection, but there is a crack between the connection and the side of the beam.

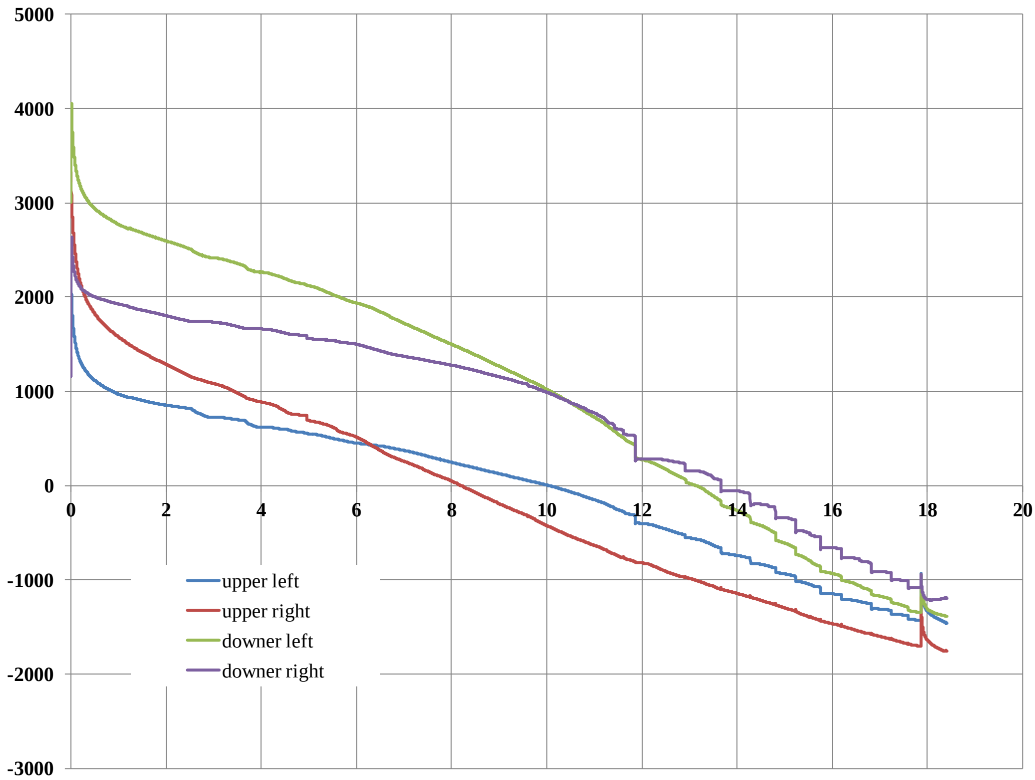

Fig. 4.
Strain gauges vs. shrinkage time

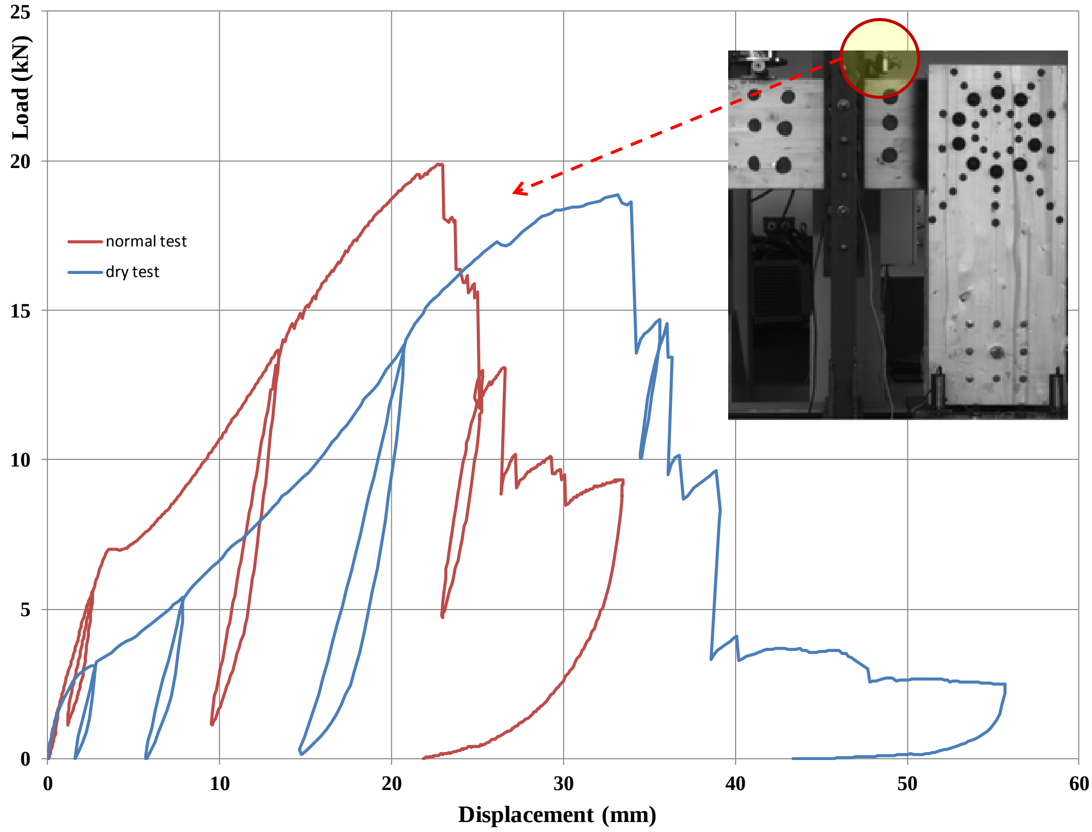

Fig. 5.
Mechanical response of both assemblies

The mechanical response of the assemblies is shown in Fig. 5. The figure reveals that, the shrinkage reduced the tension of the bolts so there is less friction. The first step is friction rigidity. The second step is wood bearing capacity and it's possible to see on the graph that the curves are parallel on this phase, so the elastic modulus is about the same. It's interesting to notice that the unloading and loading phases are similar.

In the same time the strain gauges measurement evolution during the test is plotted in Fig. 6.

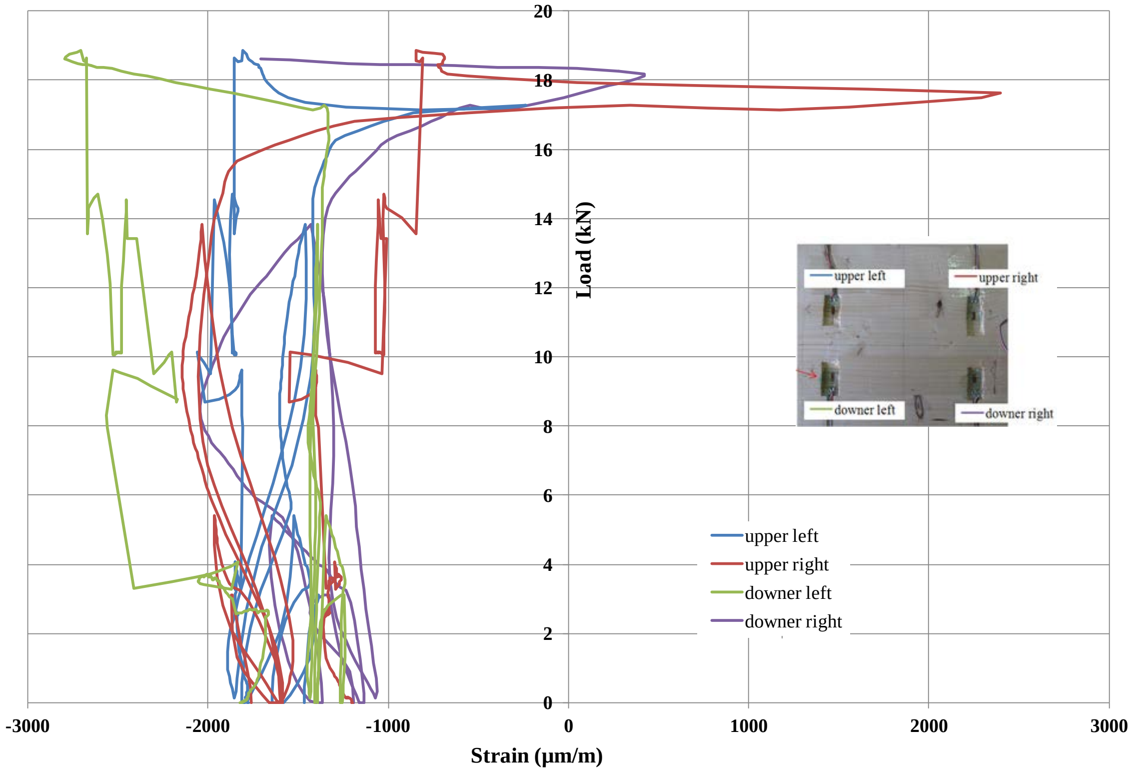

Fig. 6.
Stain gauges evolution during the mechanical test

The analysis of strain evolution reveals that in the centre of the circular bolt pattern under a load strength of 15kN the strain variation is not important.

The failure mode of assembly is illustred in Fig. 7. The picture reveals two cracks from bolt 1 and 6 to the right of the beam. The initial crack is located between bolt 3 and 4 and didn't have any propagation. It's possible to see some crack propagation inside the circular bolt pattern on the dry test beam, it shows less ductility of dry wood.

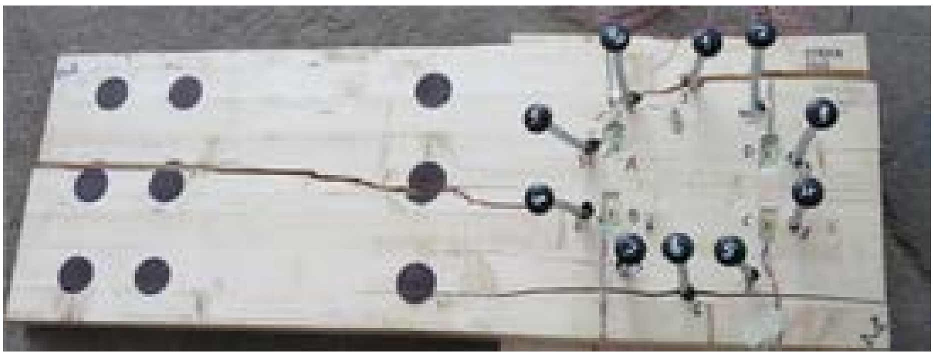

Fig. 7.
Failure mode

In addition with the measurement devices of testing machine, the sample deformation was performed from the measurements by Mark Tracking method. These measurements allow determining displacement and strain fields. The Mark Tracking method configuration used consisted of a monochrome CCD camera and a light source. Deftac software, developed by PEM team of Pprim Institut of Poitiers, was used to perform the optical analysis (Bretagne et al. 2005). According to the principle of the mark tracking method illustrated in Fig. 8, several black marks are positioned manually on the sample surface. Once the black marks were positioned on the specimen surface, their movement was recorded using the CCD camera during the test.

The displacement evolution measured by means of Mark Tracking method is plotted in Fig.8. These displacements correspond to four loading steps given on the loading graph. The analysis of displacement fields on the jointed zone reveals the evolution of the kinematic state during the loading. The displacement analysis allows the evaluation of the rigid body motion and the bolted joint deformation.

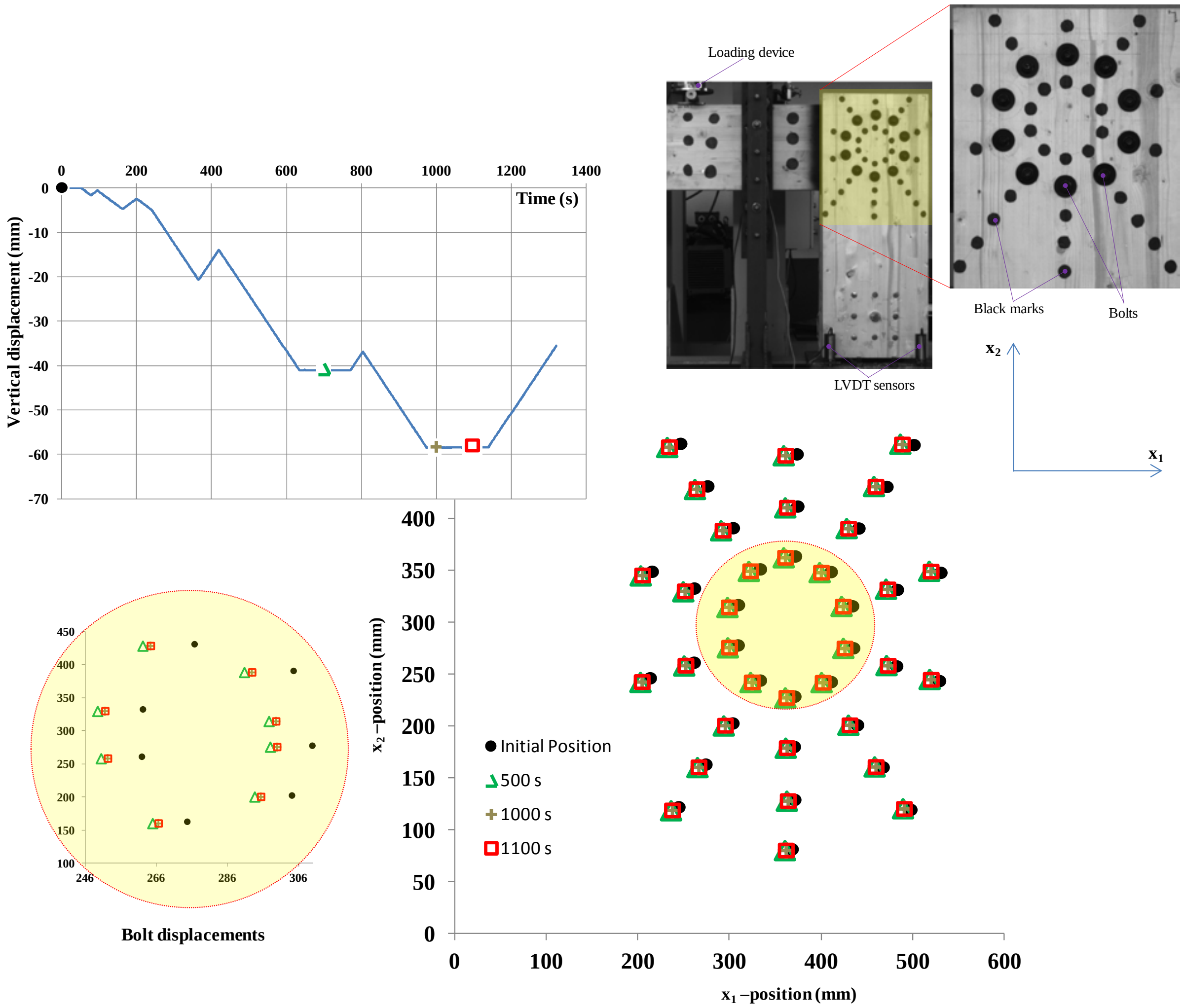

Fig. 8.
Displacement field evolution measured by means of Mark Tracking method

As in the case of strain gauge measurements, the analysis of displacement by means of Mark tracking method reveals that the strain inside the circular pattern is not important.

CONCLUSIONS

In the present study the mechanical behavior of glulam twinned columns to beam circular bolted connection is analyzed from the displacement and strain fields measured by strain gauges. The mechanical behavior of the assembly is evaluated from bending test. The results obtained from the experimental investigation allow observing the global and the local behavior of assembly. Moreover the evolution of strains shows that the shrinkage reduced the tension of the bolts so there is less friction. In parallel with the strain gauges, the Mark Tracking method is employed in order to measure the displacements fields. This method allows a multi-scale analysis of the mechanical behavior of assembly. Mark Tracking method allows also to extend the analysis by coupling the experimental data with the numerical approach.

This study highlights also the failure mode of assembly, it's possible to see some crack propagation inside the circular bolt pattern on the dry test beam, it shows less ductility of dry wood. There is no important difference of behavior between the two loading conditions, only a little difference of the level of the maximum load strength.

In future studies, several tests will be realized using the different temperature and relative humidity conditions. This could allow the identification of mechanical behavior of assemblies and damage level, in order to monitor the failure process.

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