# Description of the experiment: Damage detection of panel-to-panel moment joints in timber structures by Coaxial Correlation Method

A panel-to-panel moment joint consisting of steel angles joined with timber screws and bolts to plywood panels was selected as the subject of investigation. The experiment involves designing and fabricating a specialised testing stend specifically tailored to simulate the behaviour of multi-storey timber floor structures at various degrees of joint degradation (Figure 1).

The stend consists of two Riga Ply plywood panels of grade IV according to EN 635-2 with dimensions of 1250 mm × 400 mm and a thickness of 18 mm and additional timber supports. Riga Ply, produced by Latvijas Finieris Group, comprises 13 cross-bonded birch veneer layers. The modulus of elasticity of the plywood was experimentally estimated at 6800 MPa. Additional timber supports play a vital role in ensuring the stability of both the vertical plywood panel and the vertical support under the free-end connection of the horizontal plywood panel. The timber supports provide the possibility to represent investigated connection as analogous to the connection between a wall and floor panel in a larger structure. By incorporating the additional timber supports, the stend is fortified against unwanted movements that may arise due to its relatively small size. These supports effectively minimise potential structural instabilities, making the stend more robust and reliable.

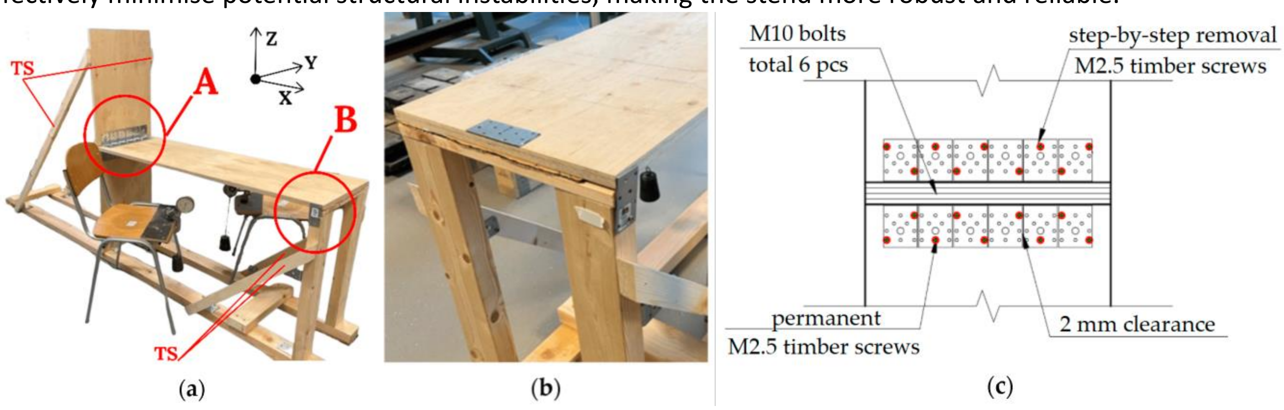
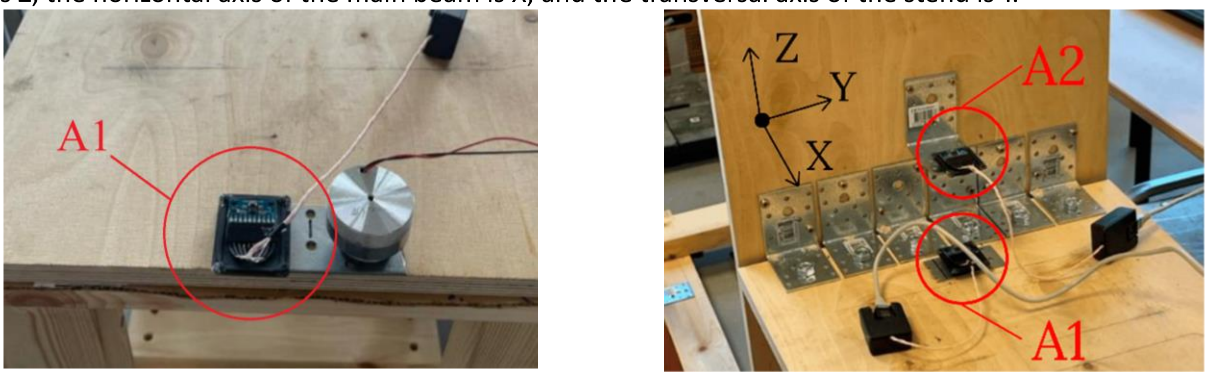



**Figure 1**. Investigated object: (a) stend for modelling semirigid panel-to-panel structural joints of multi-storey buildings, where A is the investigated moment joint of plywood panels, B is a free-end connection of a horizontal plywood panel, and TS are additional timber supports used to ensure stability and reduce unwanted movements of the stend; (b) free-end connection of horizontal plywood panel; (c) investigated moment joint of plywood panels.

The moment joint (Figure 1 (d)) is made of angle brackets with dimensions 70 mm × 55 mm × 2 mm, and Fortis-produced fasteners—timber screws and bolts following the European standard EN 1995-1-1, which outlines the general principles and rules for designing joints in timber structures. Angle brackets produced by Arras CF are one-piece non-welded three-dimensional nailing plates designed for use in timber-to-timber connections. Used angle brackets are made from pre-galvanised steel DX51D + Z275 according to EN 10346:2015, with a steel yield strength of at least 250 MPa and tensile strength of at least 330 MPa. The angle brackets are placed in two rows at the top and bottom of the horizontal panel, with 6 pieces on each side. M2.5 timber screws with a length of 15 mm are used to fasten each row of angle brackets to the vertical plywood panel. We use 8.8-grade M10 hexagon head bolts with thread up to the head, a tensile strength of at least 800 MPa, and a yield strength of at least 640 MPa to connect the angle brackets and the horizontal plywood panel. The total amount of used fasteners is 9 timber screws per one steel angle row (18 timber screws in total for investigated connection) and 6 bolts.

The vibration load on the stand was generated by electrodynamic actuator placed at the end of the free supported horizontal panel in direction Z according to Figure 1 (a).

Two 6D sensors were coaxially placed on the plywood elements as it can be seen on Figure 2, on either side of the investigated joint. There was two cases of the sensor A1 placement – on the free-end of the horizontal plywood panel (type 1), and near the investigated joint (type 2). The signal is initially detected with an accelerometer A1 affixed to the horizontal element (as a reference point) and subsequently with an accelerometer A2 affixed to the vertical element (Figure 2). The placement of the sensor A2 for both cases type 1 and type 2 is the same. 6D sensors are implemented by MPU-9250, which contains a 3-axis gyroscope and a 3-axis accelerometer. The stand axes in accordance with the sensor's axes are shown on Figure 2, where vertical axis is Z, the horizontal axis of the main beam is X, and the transversal axis of the stend is Y.




T1 T2

**Figure 2**. Placement of the accelerometers and the axes of the system: T1 – sensor A1 is located near the free-end of horizontal plywood panel; T2 – sensor A1 is located near the investigated joint on the horizontal plywood panel.

Ten structural joint states were studied. The panel-to-panel moment joint degradation process was modelled by changing the number of screws in the angle brackets row at the top of the horizontal panel from 9 to 0. Nine initial states of the joint correspond to a moment joint (the joint capable to absorb a bending moment). The tenth state of the joint was realised by zero timber screws on the top row of angle brackets and represent the case when the investigated connection cannot carry the bending moment, and the horizontal plywood panel is simply supported. All states of the joint are summarised on Figure 3.

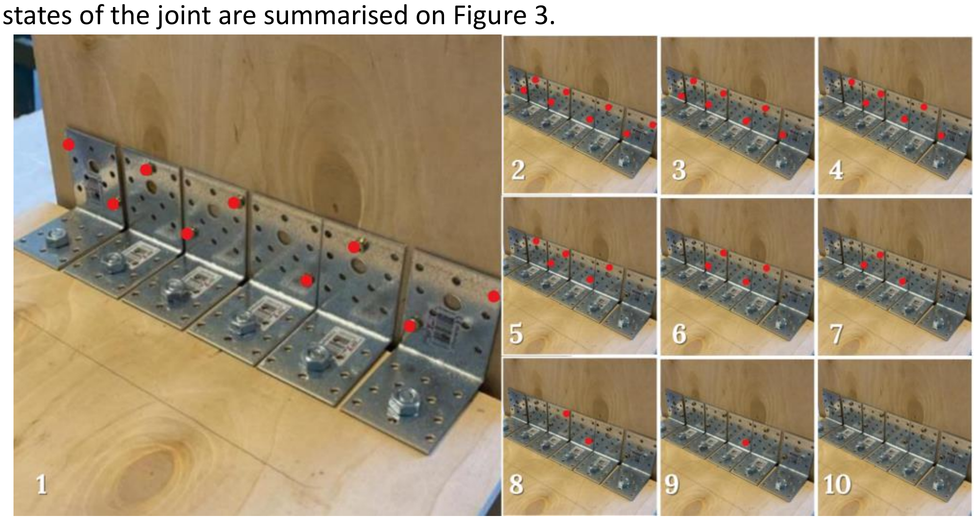



**Figure 3**. Ten initial states of the investigated structural joint, where the placement of the screws is marked by red points (**1** – joint with maximal screws number, 10 – joint with no screws in the angle brackets row at the top of the horizontal panel).

For both cases T1 and T2 (Figure 2) and for each of the ten joint states (Figure 3), measurements were taken for two static load levels equal to 113.9 kg and 151.8 kg. The loading was carried out by adding steel pieces with the weight changing within limits from 17 kg to 21 kg. The placement of the steel pieces during loading is shown in Figure 4.

**Figure 4**. The placement of the steel pieces during loading with 8 pieces (left) corresponding to 151.8 kg, and with 6 pieces (right) corresponding to 6 pieces.

The name of each measurement **.csv** file in the database has format **IMP_L_TX_S.csv**, where:

- **IMP** indicates on the type of impact ("PULSE" – short impulse, or "SWP" – wave impact, sweep type signal with duration 0.5 s in the frequency range of 10 Hz to 2000 Hz);

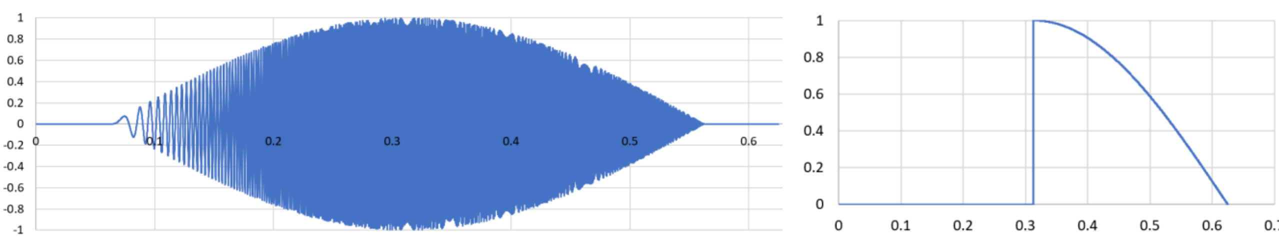



**Figure 5**. Types of impact: wave action (left) and short impulse (right).

- **L** – indicates the load level on the horizontal plywood panel (6 – 113.9 kg, 8 – 151.8 kg);
- **TX** – indicates the placement of the sensors (T1 or T2 according to Figure 2);
- **S** is the number of one of seven joint states (which are described on Figure 3).

For example, the measurement designation PULSE_8_T2_6.csv indicates that the measurement was carried out for the sixth state of the joint (where connection between two panels is realised by 4 screws), under impulse action and the placement of both sensors near the investigated joint, with a total load level on the horizontal plywood panel of 151.8 kg.

Each **.csv** file has the following **structure**:

| **Columns** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** | **O** |
| Time, s | Impact (pulse or sweep) | – | Measurements of the sensor (A1) on axes: | | | | | | Measurements of the sensor (A2) on axes: | | | | | |
| | | | X | Y | Z | GX | GY | GZ | X | Y | Z | GX | GY | GZ |

The structure's response was measured in three directions, namely, X, Y, and Z (see Figure 1), using two 3D accelerometers and around three axes, namely, GX, GY, and GZ, using two 3D gyroscopes, thus providing 6D space measurements.