Laboratori per a la Innovació
Tecnològica d'Estructures i Materials

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Bending test of an inflatable structure

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1. Introduction

The current report presents the results of an experimental test regarding the flexural behavior of an inflatable structure composed of a synthetic membrane filled with air under pressure, attached to a plywood top by means of textile straps and steel bolts.

The experiment has been conducted in the laboratory of CER LITEM from the Department of RMEE of ETSEIAT Terrassa (UPC).

2. Objectives of the study

- To evaluate the behavior of the inflatable structure under service load conditions.
- To determine the global deflection and the cross-sectional displacements of the prototype.
- To assess the influence of the carried load over the internal pressure of the air contained inside the synthetic membrane.

3. Experimental methodology

The inflatable structure was tested under three-point bending, in service load conditions, until a maximum load value of 2,15 kN was achieved. Because of large vertical deflections it was considered during the experiment that a load increase beyond this value would be undesirable.

Loading was done by a 100 kN MTS hydraulic actuator and the force value was measured by a more precise 50 kN HBM load cell. A steel beam was used in order to better distribute the load across the width of the structure.

The prototype had a total length of 3970 mm, 540 mm in height and 600 mm in width in the middle cross section. The measured span between the supports was 3750 mm. The test setup is described in the following figures.

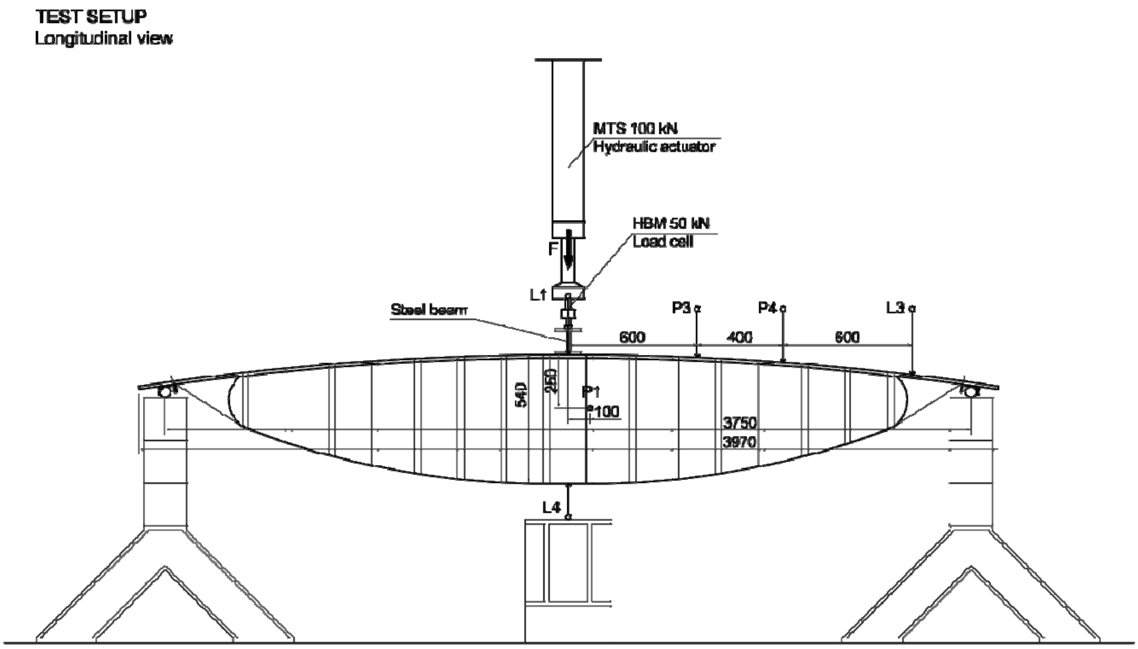

Figure 1. Longitudinal view of the test setup.

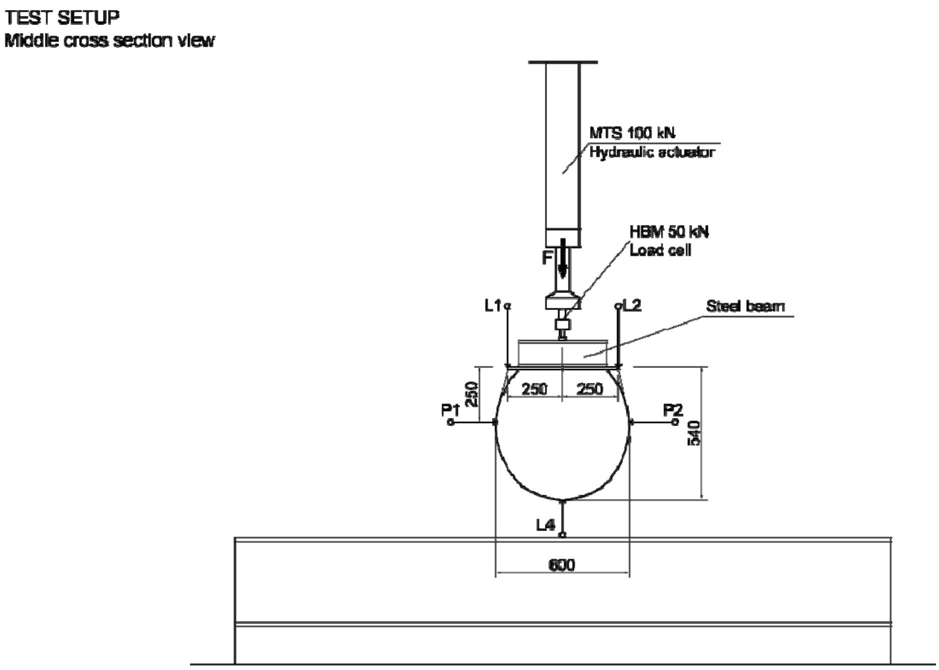

Figure 2. Middle cross section view of the test setup.

The prototype was simply supported on steel cylinders (5 cm in diameter), attached to U-shaped steel profiles in order to avoid local stress concentrations and to allow the free rotation of the specimen.

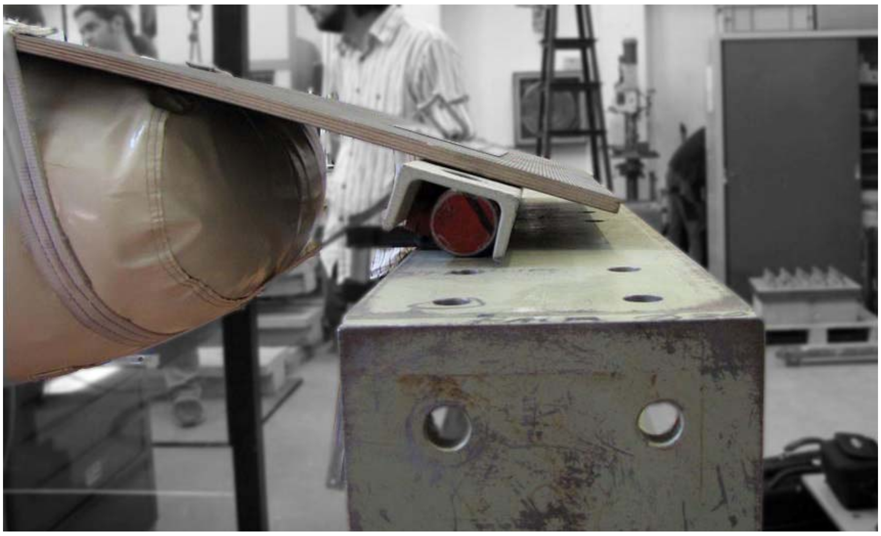

Figure 3. Support design.

Lasers L1 and L2 were positioned so as to measure the top middle displacement, on either side of the specimen. By considering the fact that the membrane itself will deform during the test, another laser, L4, was placed below its middle cross section to evaluate the respective vertical displacement.

The middle lateral deformation of the membrane was measured with two potentiometers, P1 and P2, positioned at 250 mm below the plywood top face, on the first textile strap. In the case of the longitudinal deflection, the vertical displacements were measured in three points by potentiometer P3 (600 mm from the center), potentiometer P4 (1000 mm from the center) and laser L3 (1600 mm from the center, at the end of the inflatable membrane).

The initial pressure, before the experiment commenced, was 220 mbar. The value was double checked with a manual pressure gauge.

Loading of the specimen was done at a constant speed of 5 mm/min and all information from sensors was gathered by an HBM data acquisitioning system (50 Hz sampling).

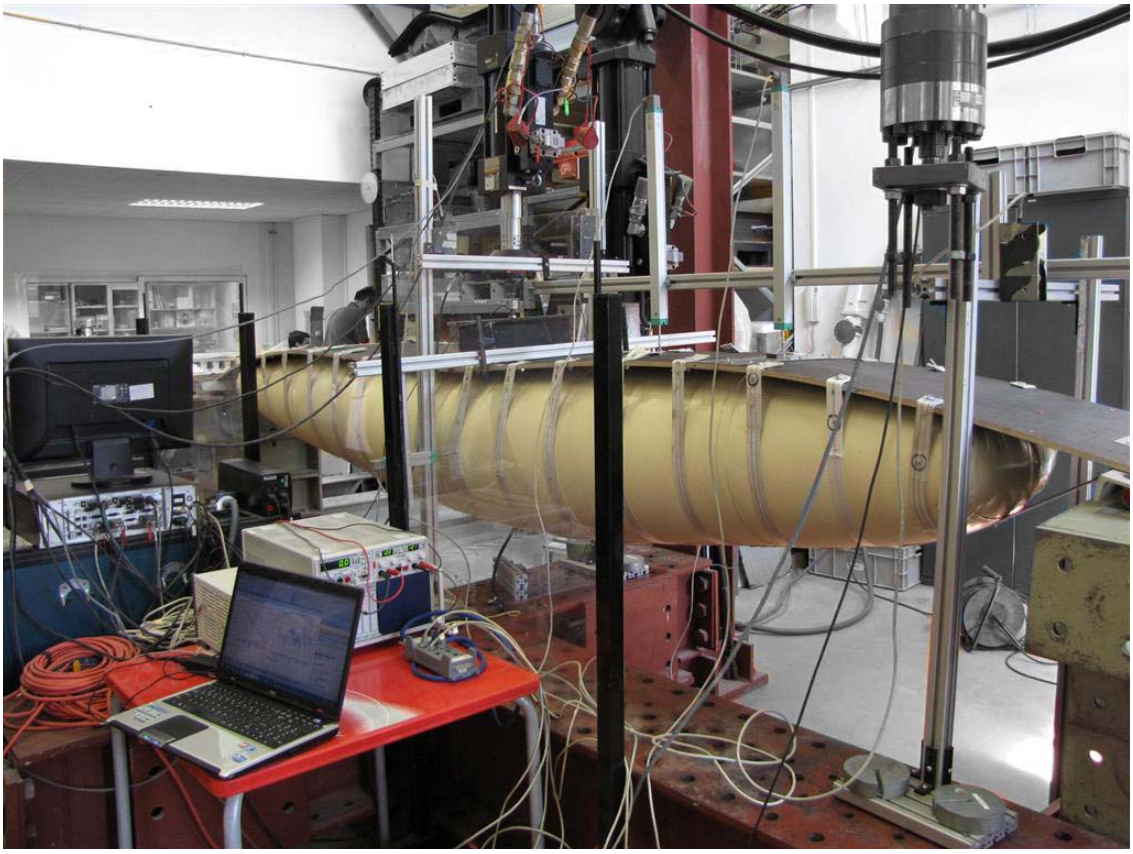

Figure 4. Instrumentation of the inflatable structure.

4. Experimental results and observations

As we can notice from the force vs. time diagram, the force varied linearly until the maximum value, with a small exception at the beginning of the test, when the system was still settling.

The inflatable prototype was subjected to service load conditions until a maximum value of 2,15 kN. Due to large vertical deflections it was decided not to increase the load further and instead keep the specimen for approximately 20 minutes under constant displacement, since the test had been carried away under displacement control method. We can observe in the graphic that during this stage the force dropped 0,15 kN until an almost constant value of 2 kN. It can be argued that this case happened because of the capability of the system to better redistribute the load – possibly owning the fact to the deformation of the textile straps that tied the inflatable membrane to the plywood board and the movement of membrane itself.

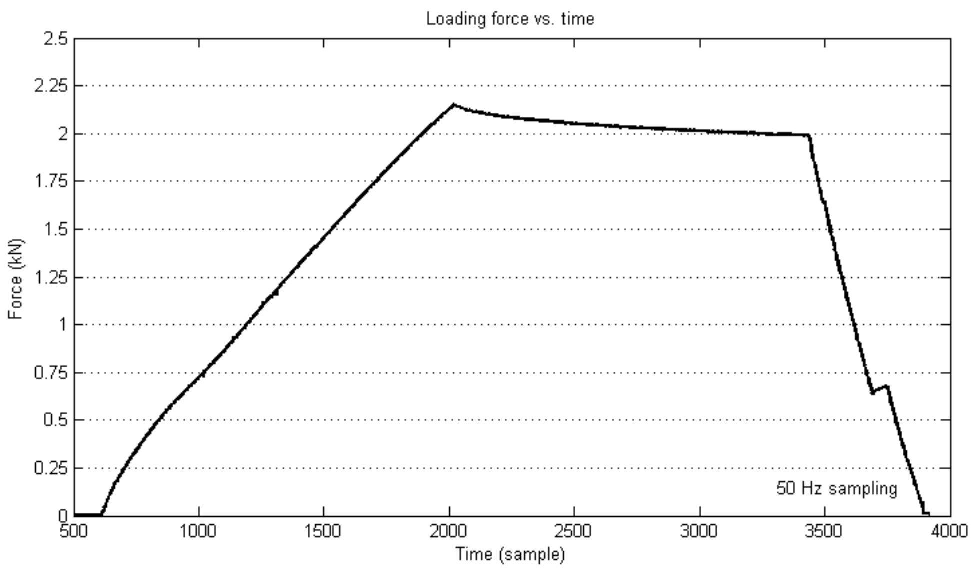

Figure 5. Loading force vs. time.

The final test stage consisted in monitoring the unloading of the specimen at a constant rate of 5 mm/min. At a force value of approx. 0,6 kN the speed was increased to 10 mm/min until it was fully unloaded.

The following figure plots the force parameter versus the top middle displacement of the structure. It is noticeable that the system evidenced as designed a linear behavior, with no evidence of failure. The maximum displacement measured was 115,9 mm.

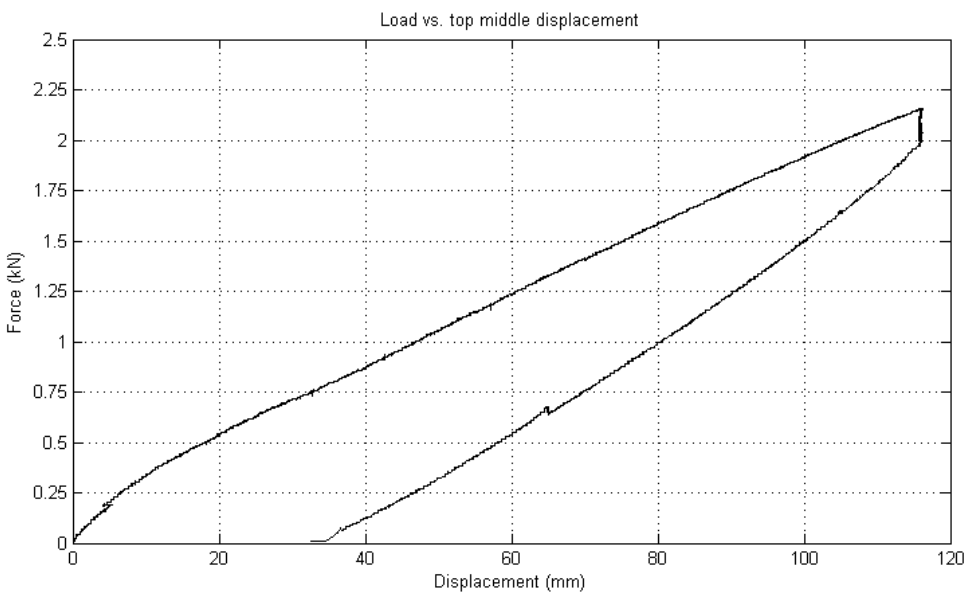

Figure 6. Load vs. top middle displacement.

After the maximum load the displacement was kept constant but the load decreased to 2 kN, as mentioned before. The unloading of the system was fairly linear until the end.

In a more complete plot a comparison is made between the displacements registered at the middle cros section of the structure. Plotted with blue line, the bottom displacement grew slower than the top one, presenting the same linear trait. Due to the fact that the system had important vertical deflections and that laser was positioned close to the membrane, the measurement stopped at approx. 73 mm and continued only in the unloading stage. Presented with blue dotted line is the possible unrecorded variation of the bottom deflection, where a maximum value of 85 mm might had been achieved.

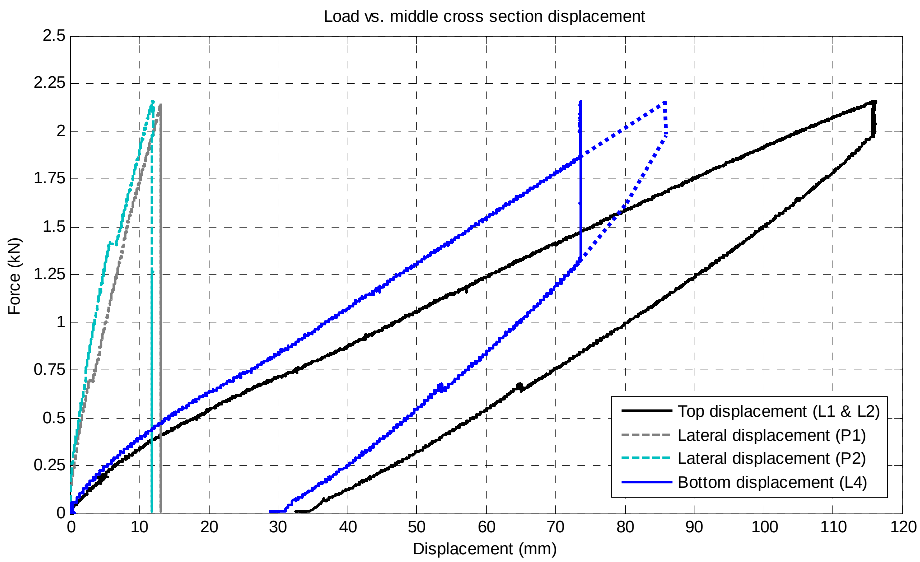

Figure 7. Load vs. middle cross section displacements.

In the case of the lateral displacements both potentiometers measured similar values – the maximum displacement was around 13 mm for P1 and 12 mm for P2. After starting the unloading phase the instruments detached from the textile straps and hence the constant measurements until the end of the experiment.

By plotting discrete values of the vertical deflections evaluated in the longitudinal direction and by considering the symmetry of the test setup it is possible to analyze the global deformation of the inflatable structure. The values are displayed for forces at an interval of 0,5 kN.

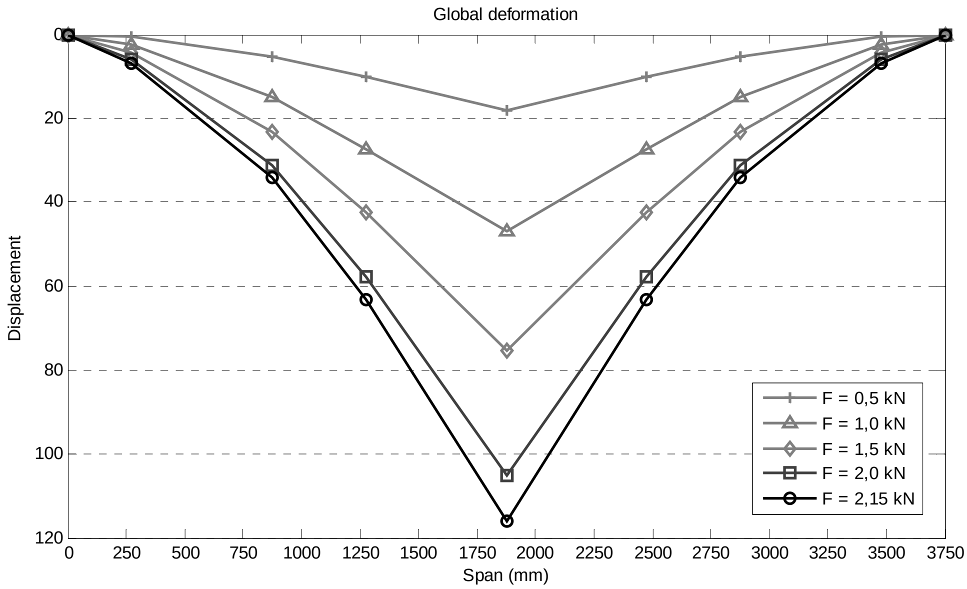

Figure 8. Global deformation of the inflatable structure.

Opposed to typical simply supported structures the inflatable structure did not illustrate a parabolic distribution of the deflections and instead a more triangular one with the maximum deflection encountered, as expected, in the middle of the system. This fact can be noticed also in the picture below.

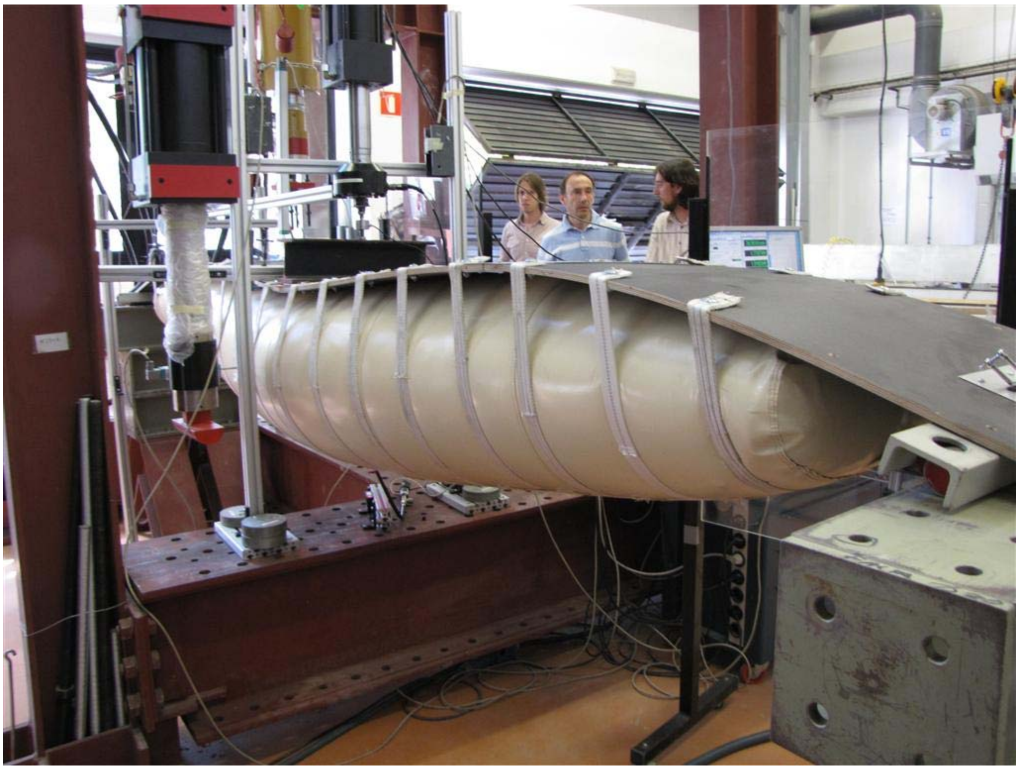

Figure 9. The deflection of the specimen under constant displacement.

This type of behavior can be attributed to the way the plywood top was designed – with a metallic plate connection at the middle – and to the fact that the load was concentrated on it.

The internal air pressure in the synthetic membrane was measured by a manual pressure gauge and determined to be 220 mbar at the start of the test. When the test finished the pressure was measured again and a value of 210 mbar was displayed as shown in Figure 10, very close to the initial one. A little lost of pressure might be justified by a leak of gas because of hand manipulation of the measurement system.

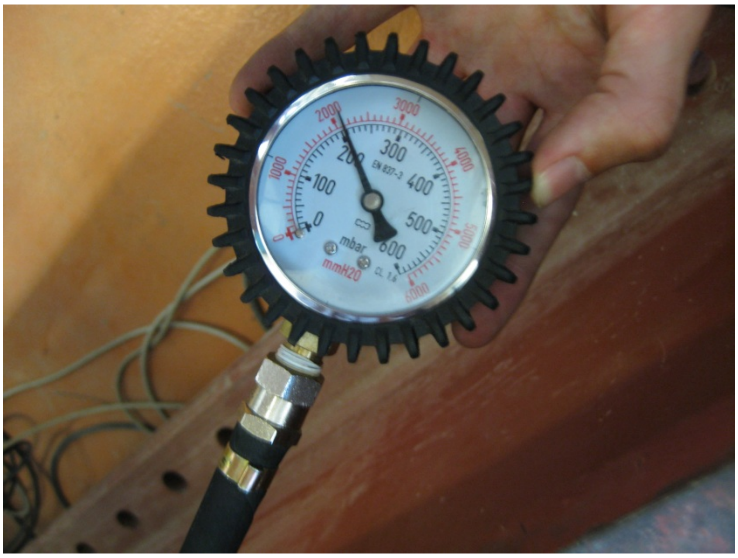

Figure 10. Manual measurement of the internal air pressure.