

Effect of flood conditions on the deterioration of porous clay-based brick



AGU FALL MEETING
New Orleans
11-15 Dec. 2017 What will you discover?

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Research premise

Brick masonry represents a significant percentage of historical building material in the urbanised landscape around the world. In particular, historic structures in the UK dating from the onset of the Industrial Revolution (1880s) were predominantly built out of this friable material and can be subjected to deterioration processes due to the friable nature of the bricks (figure 1).

Deterioration of brick masonry is caused by environmental effects, loading, wind, flooding, etc. and can be of particular concern for masonry bridges with load-bearing brick masonry, such as (rail)road over waterways. Increasing storm and flood events with prolonged saturation, in combination with increasing traffic loading, is likely to lead to accelerated deterioration. While flooding can lead to scour and sudden collapse of bridges, saturation can also lead to accelerated medium and long-term deterioration.



Figure 1: Flooding of the River Mole (UK), showing normal river conditions (A) and flood conditions (B)

Use of non-destructive testing in failure detection

A series of small-scale laboratory tests were carried out on brick masonry to identify the effects of saturation on the material properties and changes in the rate of deterioration. Brick masonry prisms have been loaded to failure under quasi-static and long-term cyclic compression (figure 2) and their condition and material parameters monitored using acoustic emission technique, accelerometers, linear variable differential transformers (LVDTs), permeametry and brick surface hardness measurements. Under quasi-static loading saturated specimens show significant reduction in the load capacity and increased fracture development.

Permeametry provides a good indication of progressive failure across the prism, showing cyclical decrease and increase of failure, with acceleration of permeability increase as point of failure approaches (cycles 13-18, figure 3), as indicated by deflection patterns measured in the prism (figure 4)

1. Within the prism, the top and bottom bricks (1 and 5, figures 5 A and E) showed the greatest variability in surface hardness, indicating loss of strength within the surface associated with compression cycles. This compression was less evident in the centre bricks, which exhibited a more gradual deterioration.
2. During the final pre-failure cycles (13-18) the centre brick (3, figure 5 C) deteriorated rapidly, which coincides with the observed failure pattern

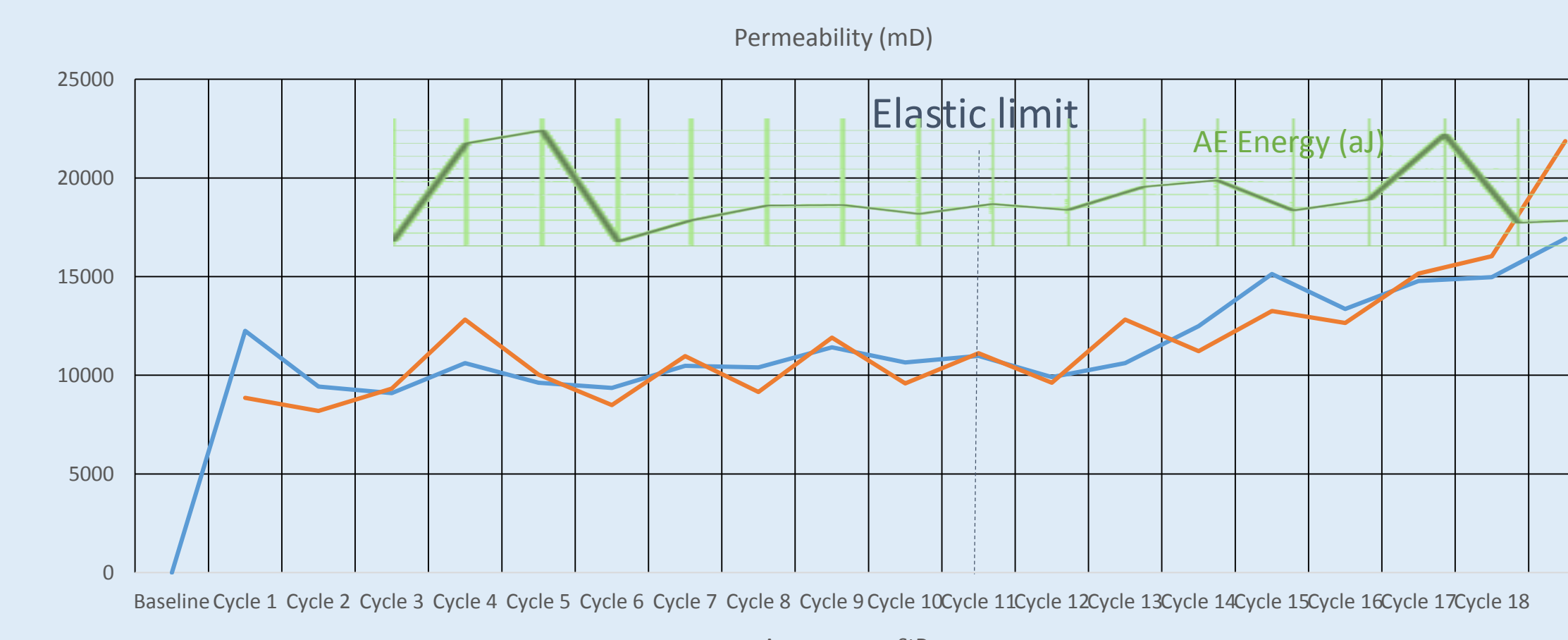


Figure 3: Permeability measurements per cycle, average of all 5 bricks (n=50 per measurement cycle), with acoustic emission (aj)

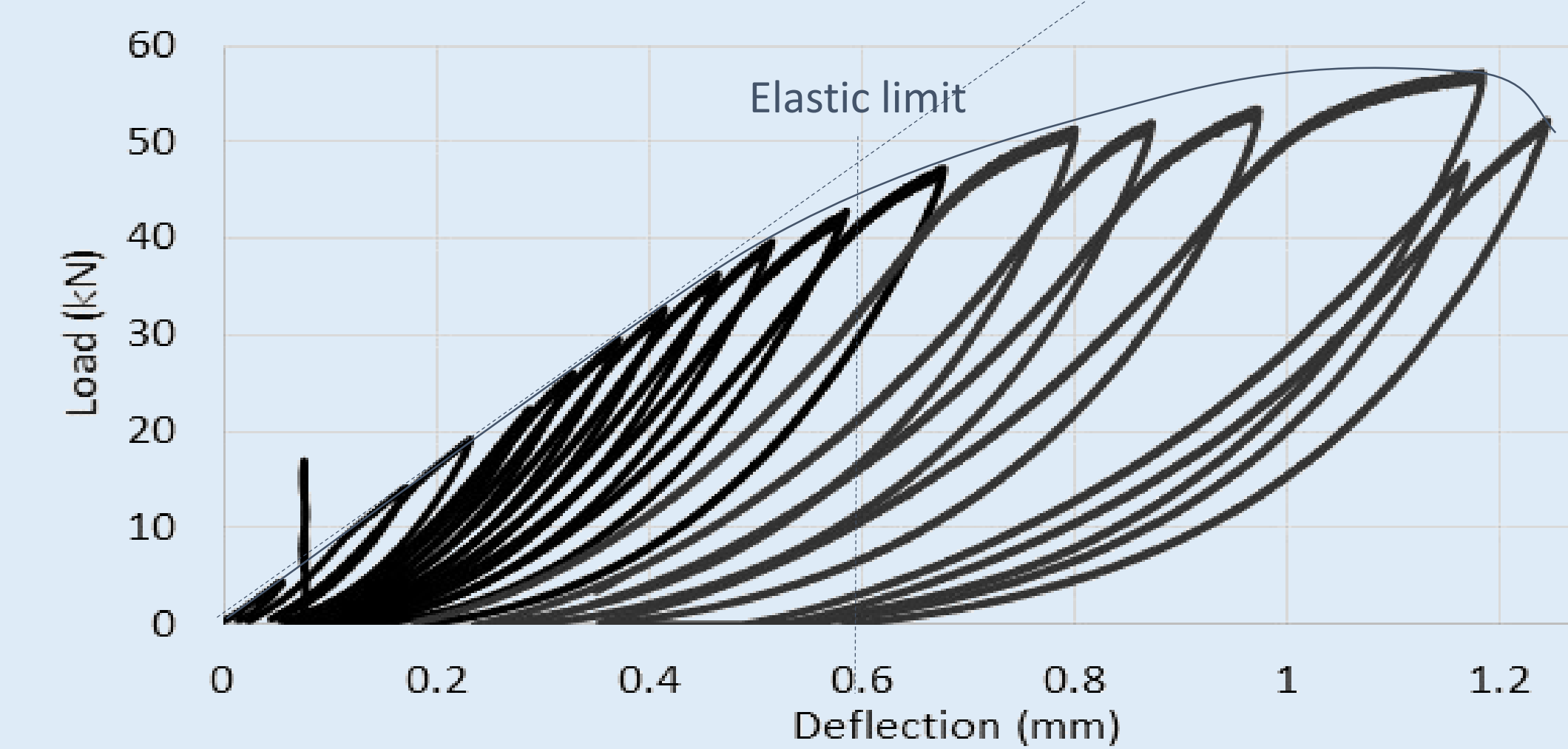


Figure 4: Load and deflection measurements, indicating the elastic limit pre-failure

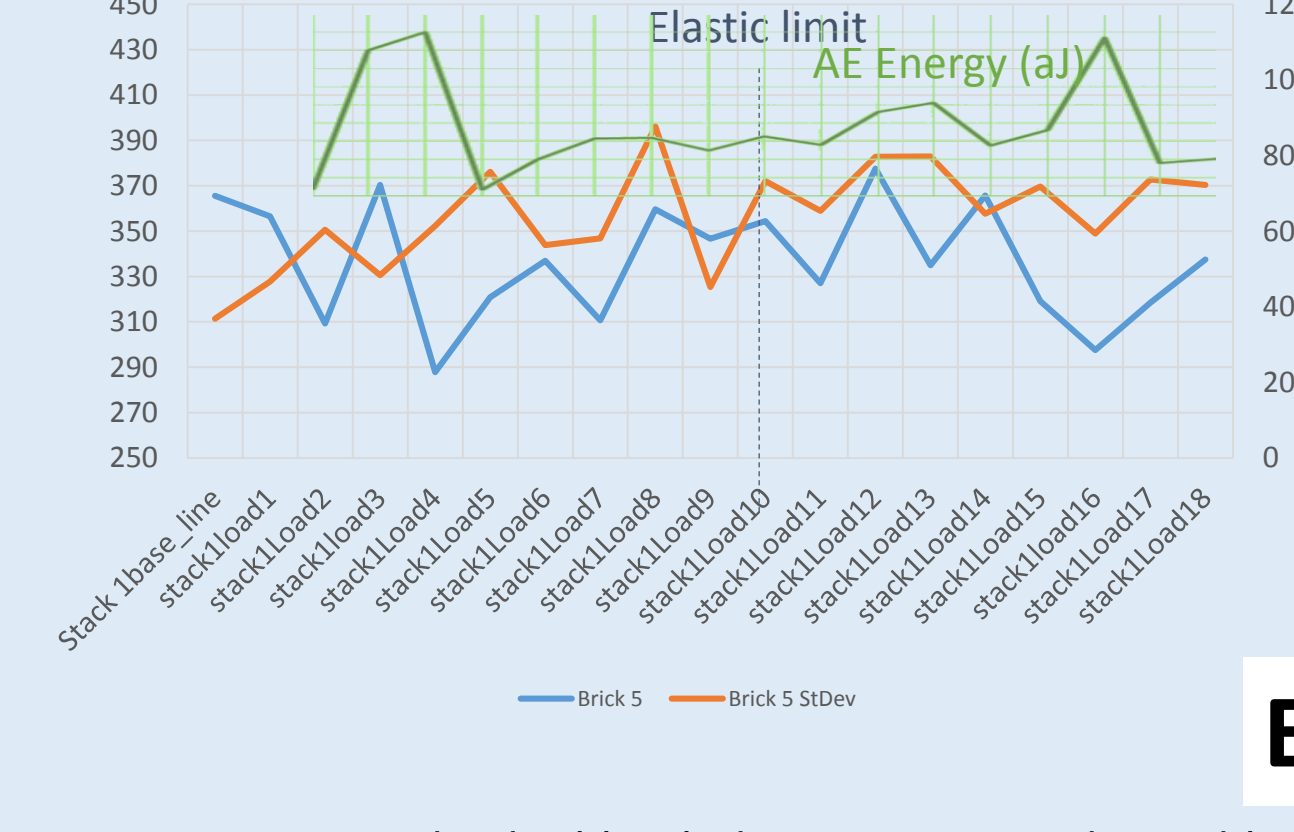
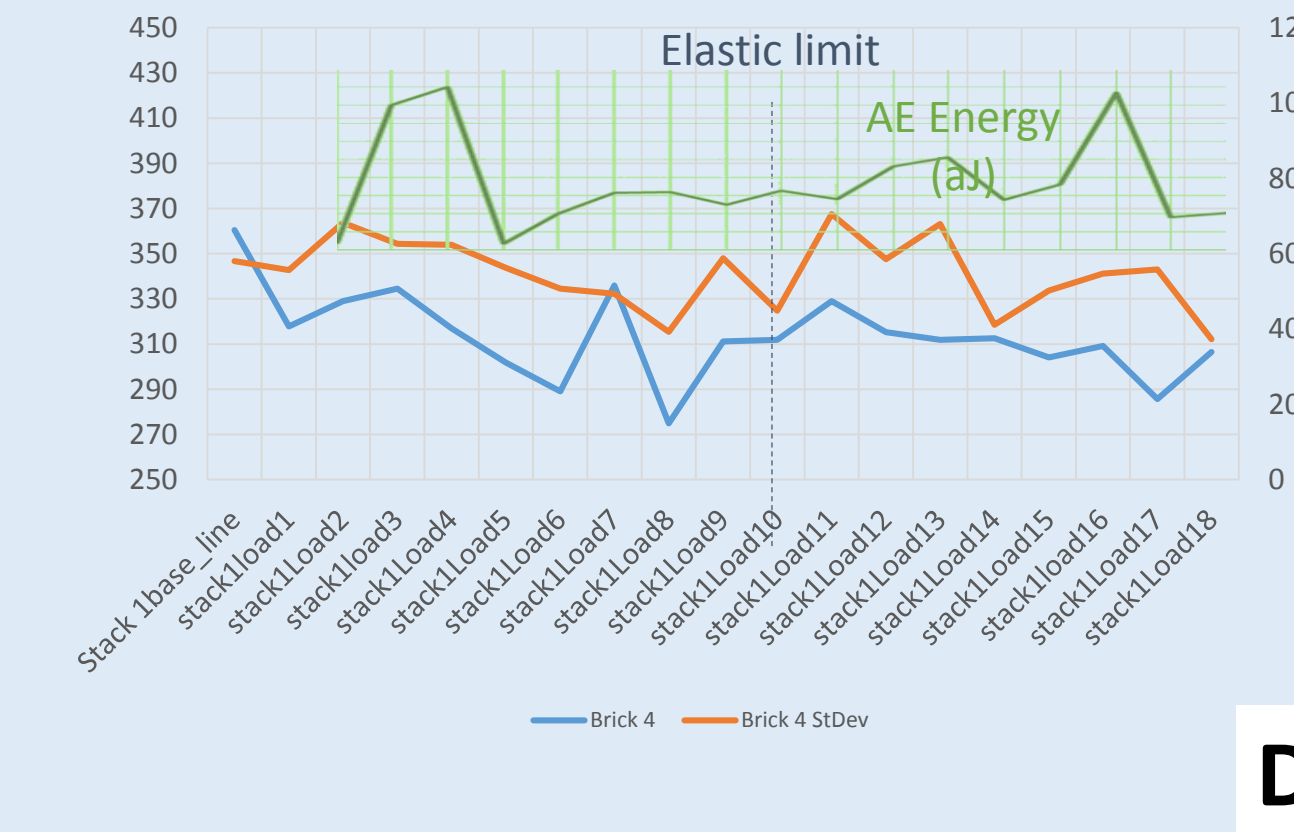
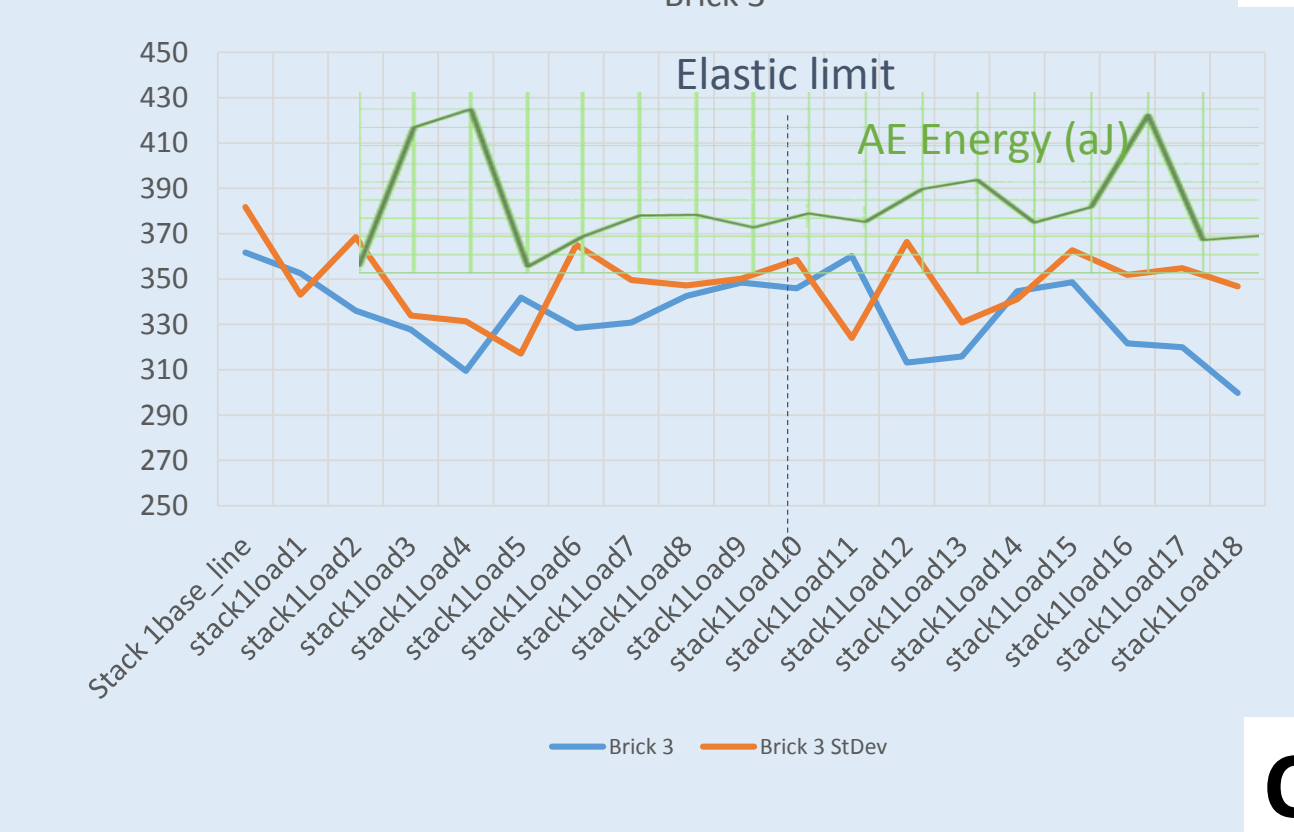
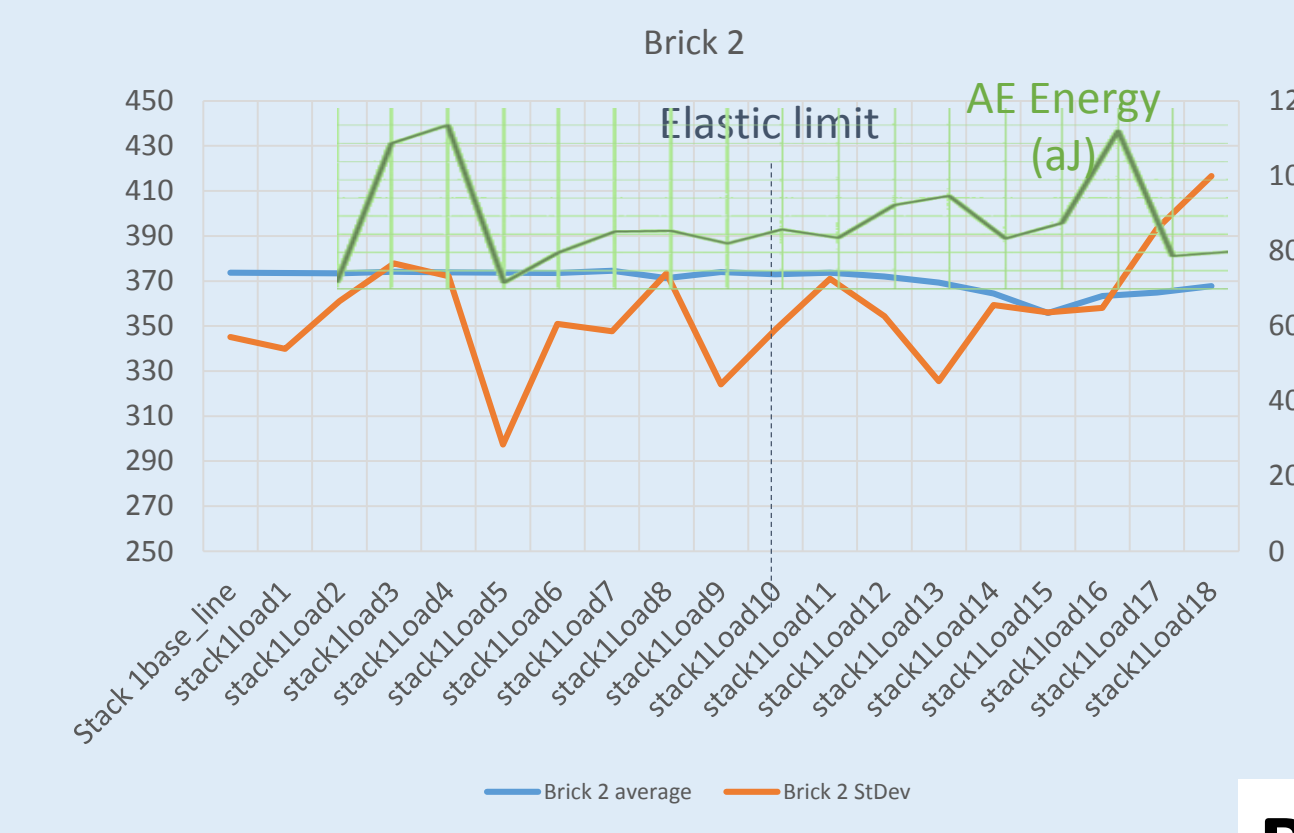
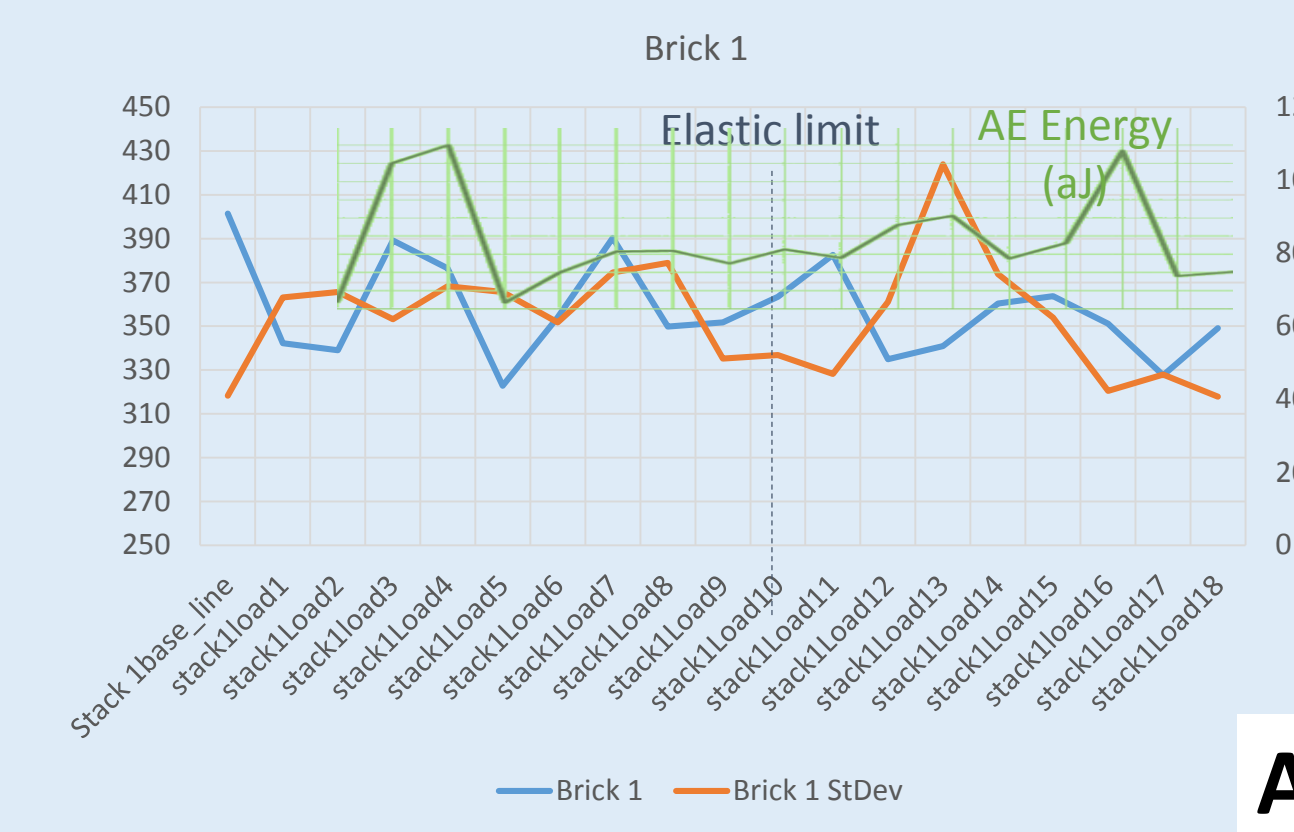


Figure 5 A-E: Individual brick deterioration, indicated by rock surface hardness values (Leeb, n=10 per brick per measurement cycle) and standard deviation. A lowering of Leeb value indicates strength deterioration. Overlain is maximum acoustic emission (aj), which appears to be a precursor to cyclical loss of strength

Influence of saturation on brick deterioration

Two brick prisms were submerged in 2,5cm of water for 9 days (figure 6), and were measured before submersion and then at 3-day intervals. Water levels were maintained at 2,5 cm to compensate for loss of water through evaporation and capillary rise.

Permeametry measurements pre-testing indicate high porosity across both prisms (figures 7 A and B). The surface conductivity measurements, using a Proceq Resipod (figure 8 A and B), indicated that capillary rise did not rise above brick 3 (centre brick) over the course of the 9-day experiment. Surface hardness measurements (figures 9 A and B) indicated deterioration of the brick across the prisms, but most rapidly across bricks 4 and 5 (bottom bricks nearest the water).



Figure 6: Submersion experiment set-up

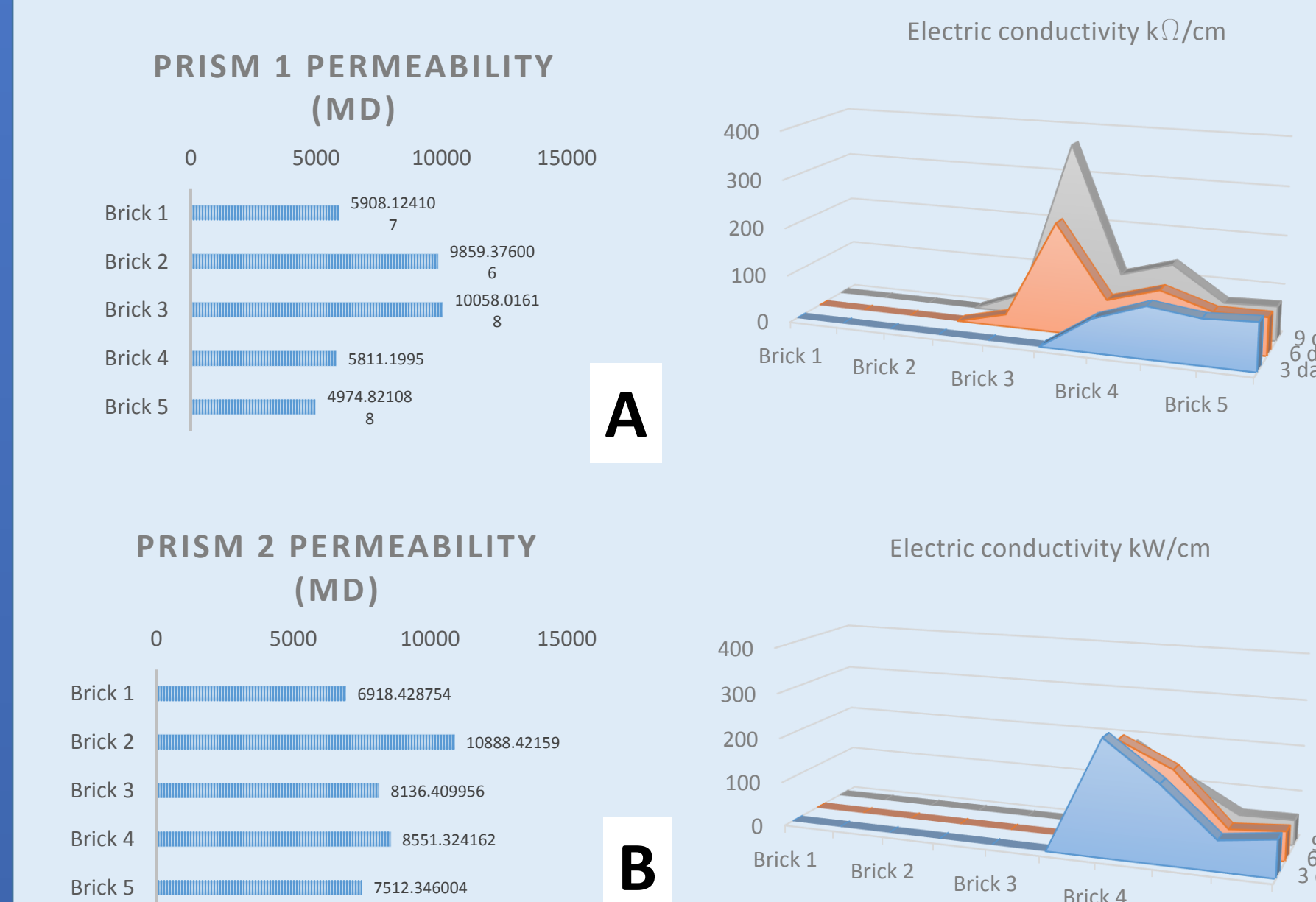


Figure 7: Pre-submersion Permeametry tests (TinyTerm III)

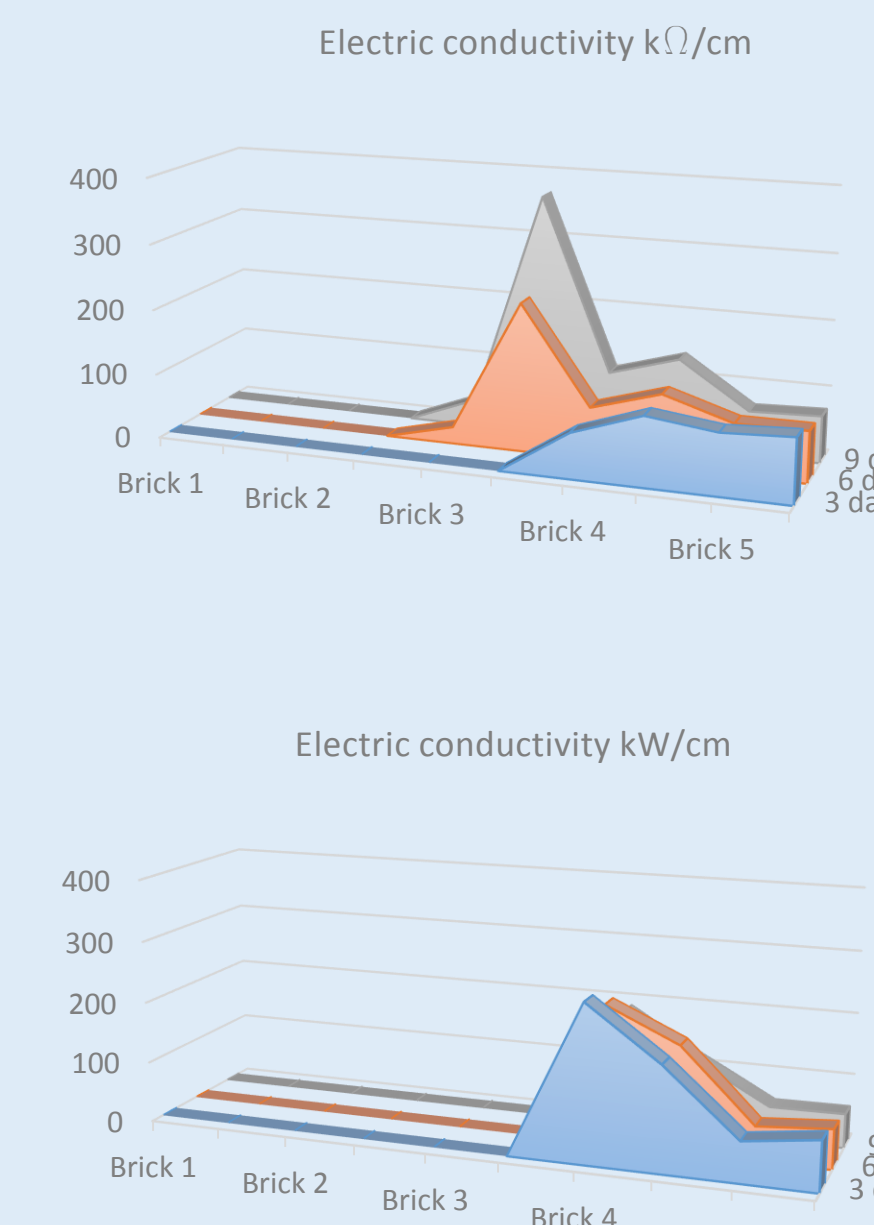


Figure 8: Proceq Resipod surface conductivity measurements

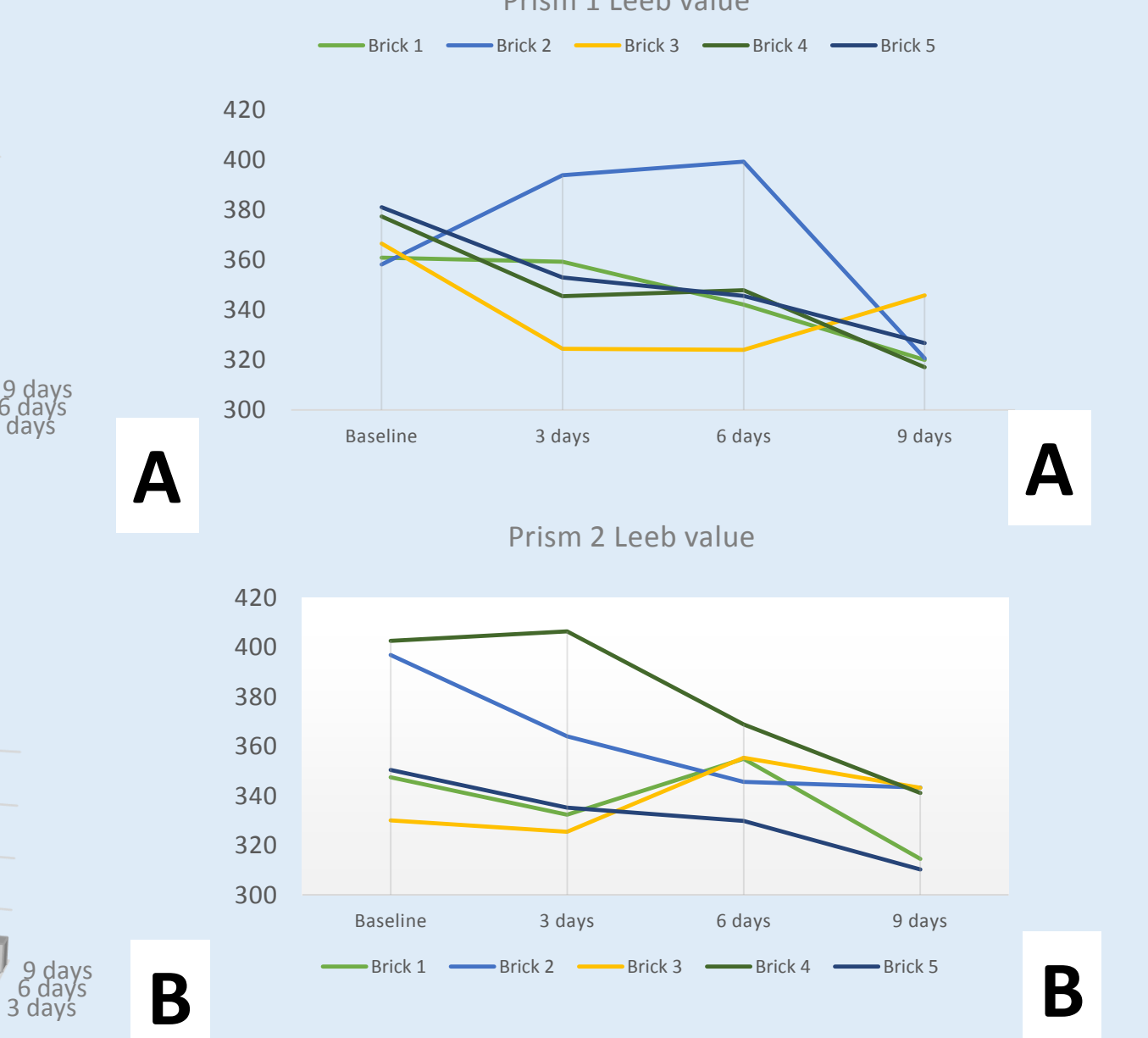


Figure 9: Surface Hardness measurements (Proceq Equotip 3)

Conclusions

Test results indicate that increasing flood events can accelerate moisture-related deterioration in porous brick masonry. During quasi-static loading of brick prisms crack development commonly initiates from the middle bricks. Deterioration measured through surface conductivity and hardness measurements also show greater deterioration of the middle bricks.

The wetting tests indicate that porous brick, as used in many historic bridge structures around Europe, is heavily affected by submersion in water and subsequent capillary rise. Using non-destructive testing wide applied for stone weathering approaches in combination with classic bridge testing approaches such as acoustic emissions and deflection can therefore give valuable insight into the deterioration of brick masonry and increased risks associated with flood conditions.

Acknowledgements

Infrastructure for these experiments was set up with funding from the UWE Vice Chancellor's Early Career Research Award 2016-2017

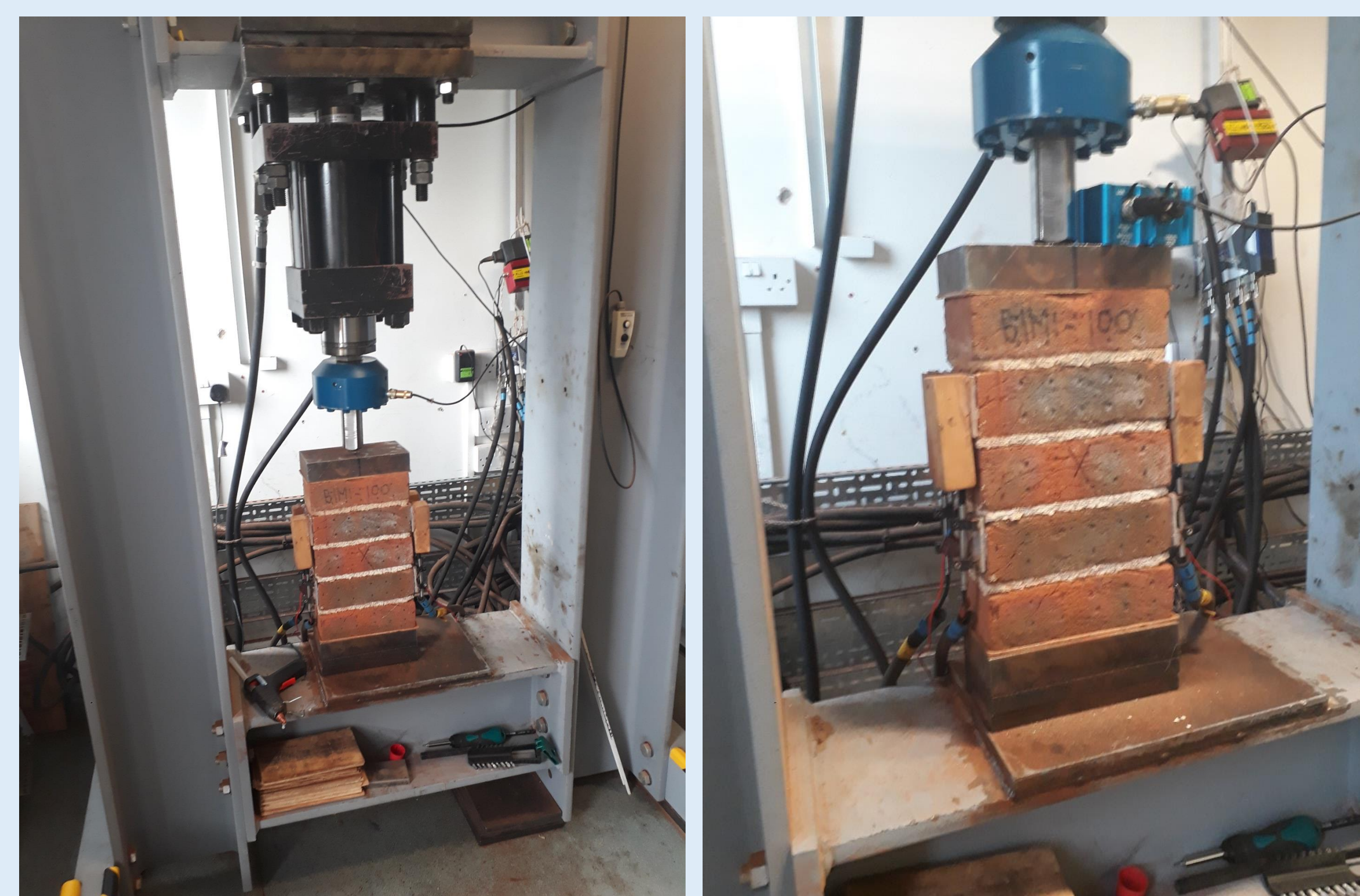


Figure 2: Loading rig set-up in the Masonry Bridges