Relative Accuracy of High Precision Total Stations and DEMEC Gauges for Masonry Structures

Kallum Booth, Pettiford Cally and Matthew Whomsley (United Kingdom)

Key words: Deformation measurement; Engineering survey; Remote sensing; High Precision Structural Monitoring

SUMMARY

The requirement for precise, sub-millimetric measurements is essential for structural deformation surveys. Whilst total stations offer internal calibration to mitigate the impact of atmospheric factors, residual systematic errors in the instrument persist. Typical total stations such as the Trimble S9 specify absolute accuracies of 1” for horizontal and vertical angles and ±(2mm + 2.0ppm) for reflectorless distance measurements. However, these nominal specifications often fail to represent actual performance under varying angles and distances. High-precision monitoring is essential for ensuring structural integrity, maintaining health and safety, and achieving legislative compliance. Therefore, this research aims to investigate the magnitude and behaviour of systematic error in total station observations as angular deviation increases.

For this study, an array of structural monitoring points were installed to a custom MDF board. A 200mm and 600mm DEMEC gauge, with a nominal resolution of ±0.001mm provided accurate point-to-point distance measurements, producing a baseline dataset. Each point was then observed with a Topcon MS05AX 0.5” accurate total station under controlled laboratory conditions. The instrument was positioned centrally to the target on an elevating tripod to minimise angular deviation, and all surveys were completed in a day.

All total station observations were converted from DMS into arbitrary Cartesian coordinates in Microsoft Excel, where relative distances were compared to the DEMEC baseline dataset. The data was divided into horizontal and vertical sections, where cumulative error was assessed comparing

the 200mm and 600mm gauge measurements to the total station calculated distances. The X and Y plane were analysed separately to investigate the influence of orientation during measurement and potential effects at obtuse angles. Furthermore, both gauge sizes were checked independently to identify any discrepancies in the baseline data.

Results reveal that when comparing observations from the centre to the extent regions of the board, there was a 23% error increase as the horizontal angle increased. This indicates that total station accuracy decreases progressively as angular variation increases from perpendicular line of sight.