Robust, Non-Invasive, Instrumentation of Geosynthetics Using Novel Electrical Sensing

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The true mechanical response of installed geosynthetics is still poorly understood due to their deployment primarily being in sub-soil applications where direct measurement is challenging. Use of typical sensor packages such as foil strain gauges or fibre optics has been limited in effectiveness as they are vulnerable to damage and protecting them significantly alters the geosynthetic-soil interaction characteristics, especially for the case of geogrid reinforcements, and face further issues in bonding effectively to the geosynthetic. Such sensors also exhibit poor utility in live engineering projects due to their low resilience to environmental conditions such as moisture, pressure, and abrasion (Zamara et al. 2022).

Use of transmission lines as strain sensing elements on geosynthetics has been shown to be effective through isolated testing. To further develop this technology for use in commercial geotechnical applications, it is necessary to validate the efficacy of the sensing system in adverse environmental conditions, including high confining and shearing forces, as well as presence of moisture in the vicinity of the sensor. This study focuses on the testing of sensor-enabled geogrids in adverse environmental conditions as a proof of concept.

Testing was performed in order to evaluate the employment of transmission lines as strain sensors for use in unfavourable environmental conditions. The geogrid samples were instrumented by applying a conductive substance to form transmission line traces on the geogrid ribs. Coaxial connectors were used to interface between the conductive traces and electronic equipment. A vector network analyser was used for interrogation of the transmission line parameters and a modified large-scale shear box was used to apply strain directly to the geogrid under a confining pressure of 100kPa in sharp sand.

Fig. 1. A transmission line sensor-enabled geogrid placed in soil within the testing shear box prior to loading.

$$\Delta\phi = -\beta \Delta l \qquad (1)$$

Equation 1 is the primary defining equation for the transmission line-based strain system. This equation relates the change in the measurable electrical parameter of signal phase angle ($\Delta\phi$) against the line length change (Δl). This enables strain determination using phase angle measurements. The phase constant β is dependent on electrical characteristics of the transmission line. Phase angle was measured at each 1mm of shear box displacement at various frequency points across the 1MHz – 6GHz frequency sweep.

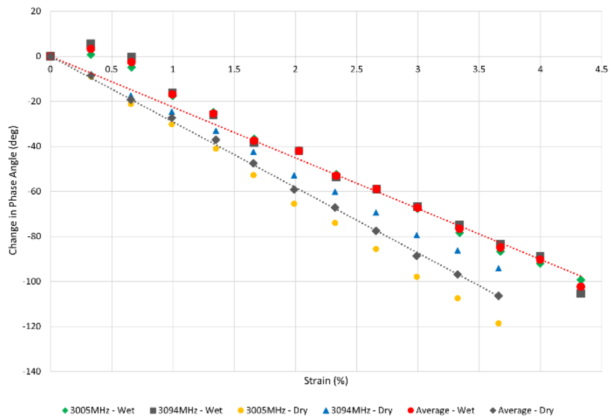

Fig. 2. Phase angle against mechanical strain for samples tested under 100kPa of confining pressure in both dry and wet soil conditions.

Figure 2 shows the raw results from this study which demonstrate a clear linear response of phase angle shift as a result of direct strain application to the samples. The R^2 values for average phase shift in the dry and wet tests are 0.999 and 0.991 respectively. This indicates that the system is suitable for the detection and measurement of strain. In proving the viability of transmission lines as strain sensors, these findings are highly encouraging as it has been shown that the sensors are capable of surviving testing at confining pressures up to 100kPa and in high soil moisture contents. Further to this, the sensors are capable of continued sensing despite significant damage, indicating that the system is highly redundant and resilient to environmental stresses.

REFERENCES

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