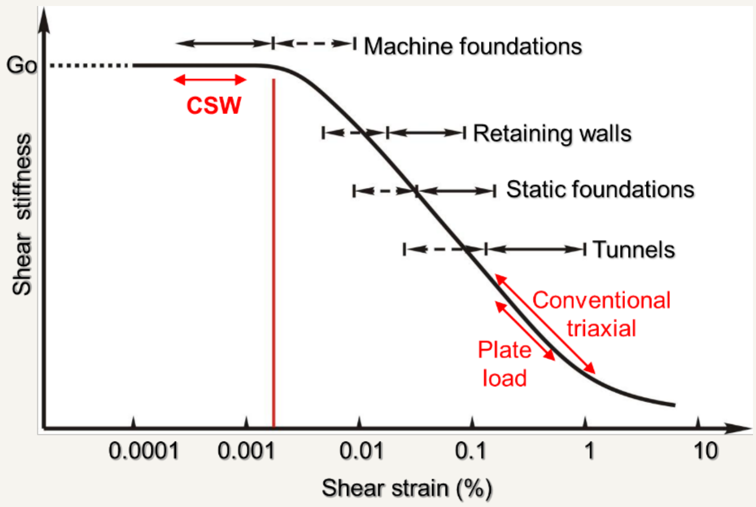
USING ACSW FOR BRIDGE DESIGN

Guidance Note SSGN018

Drivers to economical bridge design

The most economical structural design of bridges is possible when only small differential settlements are assumed between supports. This reduces the maximum design stresses and moments associated with the deformed structure. It also permits the design of structures with fewer expensive to construct movement joints. In addition, minimum clearances must be maintained despite the inevitable immediate settlement of the new bridge structure. This requirement for very small settlement tolerances of foundations can results in large, deep and expensive foundations.



For these reasons obtaining accurate, representative, ground stiffness values is essential for optimising design where foundation movements are critical. This is made particularly difficult because of the non-linear relationship between soil strain and stiffness, the impact of disturbance of soils on measured stiffness values and often unrepresentative nature of small soil samples to bulk stiffness.

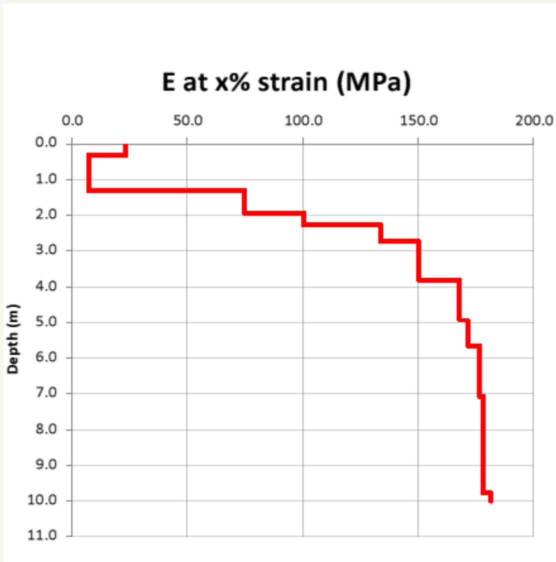
For accurate prediction of ground movements, stiffness measurements should therefore be representative of the bulk in-situ ground stiffness at a known strain, normally requiring very expensive and time-consuming testing.

ACSW stiffness measurement

Traditional methods of determining ground stiffness are either cheap but inaccurate (for example empirical relationships such as with SPT N value) or accurate but expensive (for example large scale load testing or pressuremeter tests). Where the former is used in design, then a conservative approach must be adopted in assessing design values of stiffness which leads to inaccurate calculation of movements.

In contrast, the SoilSafe ACSW testing provides accurate stiffness profiles at reference small-strain levels, non-intrusively, down to typically 6 to 10m depth and often deeper, for about the cost of a plate load test. Since each test takes only around half an hour to complete and costs only about the same as a Plate Load Test, ACSW testing permits not only the economical measurement of accurate ground stiffness profiles but also permits whole site characterisation allowing the variation in stiffness across sites to be assessed.

ACSW test results are presented in an easy-to-use spreadsheet format as both small-strain shear and Young's moduli (G_0, E_0) along with 0.1% strain softened Young's Modulus values ($E_{0.1\%}$) with the ability for the user to adjust the strain softening level. This data format permits direct entry of ACSW data into a wide range of structural and geotechnical analysis software from simple (i.e. input of $E_{0.1\%}$ values into Oasys Pdisp linear elastic layered model) to complex (i.e. direct entry of G_0 values into Plaxis FE model).



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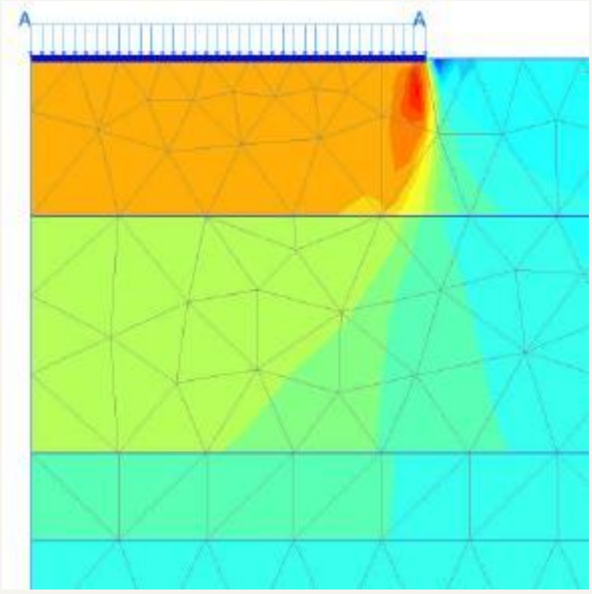
Geotechnical Analysis

Bridge foundation design may be undertaken over a number of stages from conceptual to detailed and may use a range of geotechnical analyses of varying sophistication depending on the complexity of the ground conditions and settlement tolerances. It is noted however that the benefits of using more sophisticated analyses has been shown to be small compared to the use of accurate and representative in-situ soil stiffness values which ACSW provides in conjunction with simple analyses (ref. Heymann *et al*, 2017; see also SSGN005).



Site Characterisation

Whilst ACSW testing is primarily used for the provision of accurate ground stiffness profiles it can also be used for ground profiling where stratigraphy has been demonstrated by intrusive investigation to be associated with significant changes in ground stiffness.

Shear wave velocity (V_s) profiles by ACSW data may also provide preliminary estimates of other design parameters including shear strength and relative density using published relationships. Wherever possible site-specific measurements should be developed, however these relationships can allow an initial assessment of ground conditions to be undertaken without the need for additional intrusive investigation.

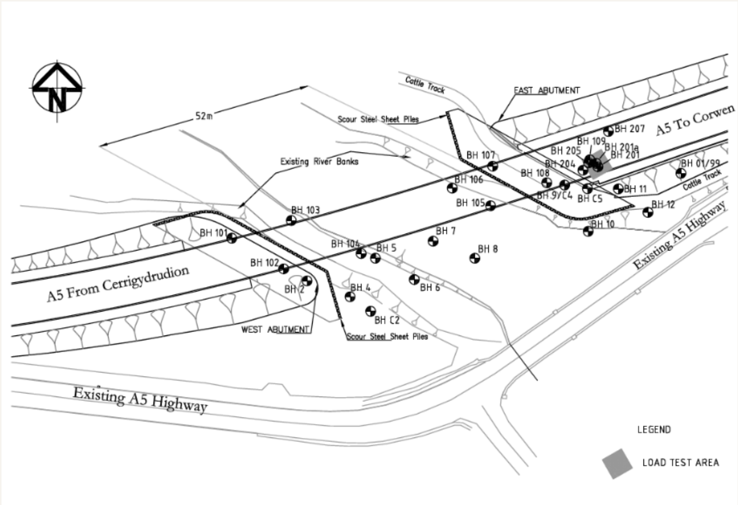
Case Study: A5 Pont Melin Rûg road bridge

The presence of a significant thickness of soft silts beneath the site of a proposed new road bridge provided concerns over the suitability of shallow foundations above unusual sensitive Rûg Silt deposits.

Despite extensive conventional ground investigation, concerns remained over the reliability of stiffness data in this poorly understood material and so a large

scale, fully instrumented load test was undertaken to better determine ground stiffness at significant cost.

The load test data obtained was used in conjunction with sophisticated numerical analysis to demonstrate that the settlement of shallow foundations would be acceptable avoiding the need for extensive and deep piled foundations.



Following completion of the bridge construction, ACSW testing was undertaken and a range of simple non-linear elastic settlement analyses conducted to model the behaviour of the load test. ACSW testing measures stiffness values a consistent known small strain level and provides a layered stiffness profile which identifies the presence of soft or stiff layers that may be important to subsequent settlement assessment.

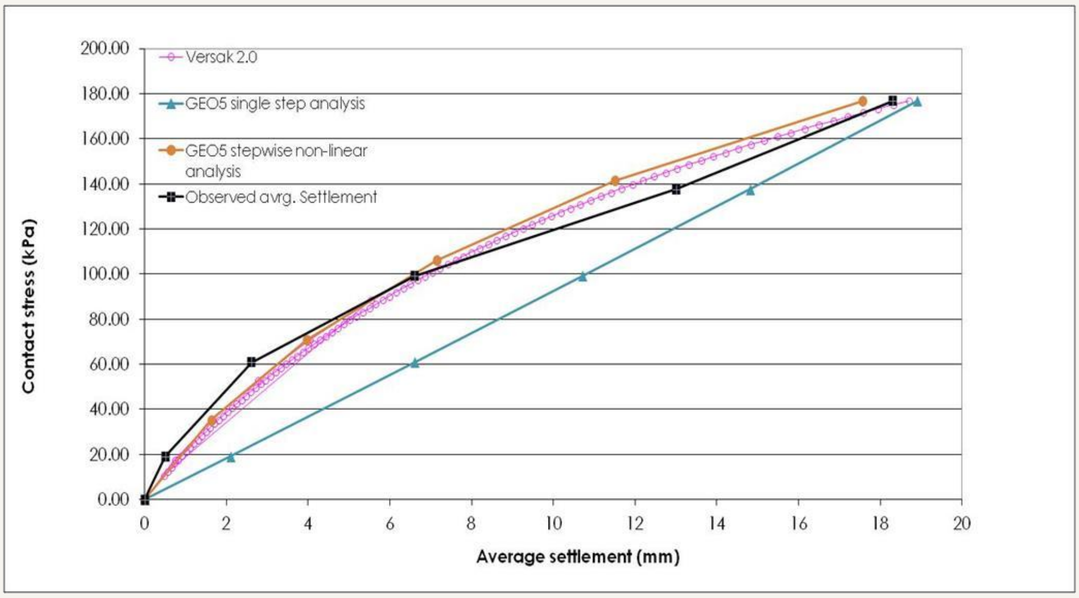


Figure 1: Comparison of ACSW data settlement analyses against measured settlements during Pont Melin Rûg large scale load test.

References

- Guidance Note SSGN001 - Specifying ACSW testing
- Guidance Note SSGN002 - Application of ACSW testing
- Guidance Note SSGN003 - Analysis with ACSW test data
- Guidance Note SSGN005 - Using ACSW for settlement analysis
- Guidance Note SSGN011 - Description & limitations of the ACSW technique
- Heymann, G. (2007) Ground stiffness measurement by the continuous surface wave test. *Journal of the South African Institution of Civil Engineering.* Vol.49, No.1, p25-31.
- Heymann, G, Rigby-Jones J and Milne C. A. (2017) The application of Continuous Surface Wave testing for settlement analysis with reference to a full-scale load test for a bridge at Pont Melin Rûg, Wales *Journal of the South African Institution of Civil Engineering*
- Rollins, K M, Evans, M D, Diehl, N B and Daily, W D III (1998) Shear modulus and damping relationships for gravels. ASCE, *Journal of Geotechnical and Geoenvironmental Engineering*, 124(5):396–405.