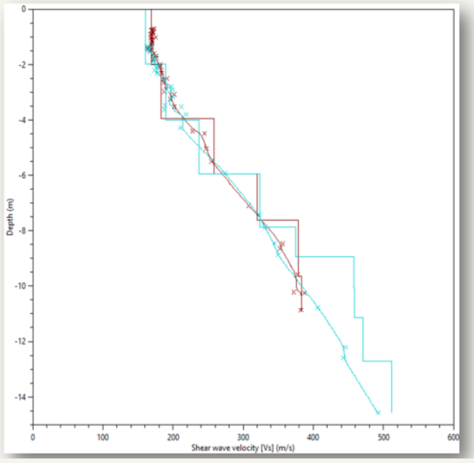
INTRODUCTION

Advanced Continuous Surface Wave (ACSW) testing provides a rapid and non-intrusive means of obtaining representative in-situ ground stiffness profiles for pavement and geotechnical assessment. The technique measures Rayleigh wave propagation velocities (V_r) using a controlled vibratory source and geophone array, allowing determination of shear wave velocity (V_s), small-strain shear modulus (G_0) and Young's modulus (E) with depth.

Whilst traditional pavement assessment in the UK has relied heavily upon California Bearing Ratio (CBR), modern pavement design guidance such as CD225 increasingly adopts stiffness-based assessment approaches using foundation surface stiffness modulus. ACSW testing is particularly well suited to this transition since it directly measures representative in-situ stiffness rather than empirical penetration resistance.

ACSW STIFFNESS MEASUREMENT

ACSW testing measures surface Rayleigh wave velocity (V_r) over a range of frequencies. The resulting dispersion curve is inverted to determine a representative shear wave velocity profile with depth.



The small-strain shear modulus is determined from:

$$G_0 = \rho V_s^2$$

Young's modulus may then be obtained using:

$$E = 2G(1+\nu)$$

The resulting stiffness values represent bulk in-situ ground behaviour over a significantly larger soil volume than conventional intrusive testing methods and are unaffected by sample disturbance.

RELATIONSHIP BETWEEN STIFFNESS AND CBR

The relationship between Young's modulus and CBR adopted within TRRL Laboratory Report 1132 (Powell et al., 1984) is:

$$E = 17.6(CBR)^{0.64}$$

Rearranging gives:

$$CBR = (E / 17.6)^{1.5625}$$

This relationship is based upon work undertaken by Jones (1958), who compared seismically measured stiffness values with CBR tests on remoulded and undisturbed soils. Consequently, the relationship is particularly appropriate to stiffness values obtained from seismic techniques such as ACSW testing.

Fig. 1. General view of the operation of the vibration apparatus

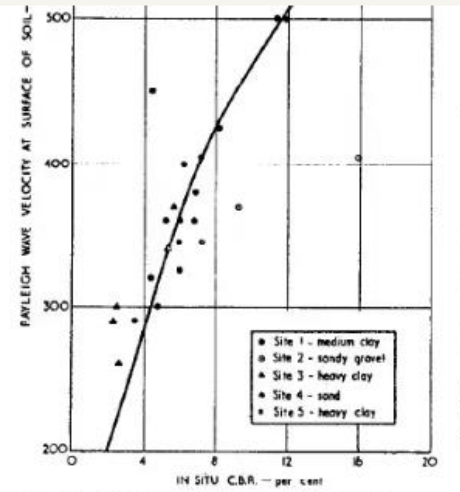


Fig. 8. Relation between Rayleigh-wave velocity at the surface of soil and the C.B.R. value (in situ)

STRAIN COMPATIBILITY

A key consideration when relating ACSW-derived stiffness values to CBR or surface stiffness modulus is the effect of strain level on soil stiffness.

ACSW testing measures stiffness at very small strain levels, typically in the order of 10^{-6} to 10^{-4} strain, where soil behaviour remains essentially elastic and stiffness approaches the maximum small-strain modulus (G_0).

However, the resilient modulus associated with pavement response and the Heukelom and Klomp (1962) relationship is generally considered to correspond to operational strain levels in the order of approximately 0.01% to 0.05% strain.

For pavement assessment purposes, a representative operational strain level of 0.05% strain is considered appropriate for modulus softening prior to application of CBR relationships or comparison with pavement surface stiffness modulus criteria.

RELATIONSHIP WITH SURFACE STIFFNESS MODULUS

Whilst CBR remains widely used within earthworks and pavement practice, current pavement design approaches increasingly rely upon stiffness-based parameters.

CD225 places greater emphasis on foundation surface stiffness modulus rather than solely empirical CBR classification. Since ACSW testing directly measures representative in-situ stiffness, the technique is naturally suited to stiffness-based pavement assessment.

Accordingly, ACSW data may be used in two complementary ways:

- conversion into equivalent CBR values for compatibility with traditional pavement practice; and
- direct assessment of representative stiffness modulus for modern pavement design methodologies.

WORKED EXAMPLE

Assume:

- V_s = 150 m/s
- ρ = 1900 kg/m^3
- ν = 0.3

The very small-strain shear modulus is:

$$G_0 = \rho V_s^2$$

$$G_0 = 42.75 \text{ MPa}$$

Young's modulus at very small strain becomes:

$$E = 2G(1+\nu)$$

$$E_0 \approx 111 \text{ MPa}$$

Applying the relationship:

$$CBR = (75 / 17.6)^{1.5625}$$

$$CBR \approx 9.7\%$$

SUMMARY

ACSW testing provides a rapid, economical and non-intrusive means of obtaining representative ground stiffness profiles for pavement investigation.

When appropriately strain-softened and calibrated against local ground conditions, ACSW testing provides a practical means of bridging conventional CBR-based pavement assessment and modern stiffness-based pavement design approaches.

REFERENCES

BS EN 1997-1:2024 Eurocode 7: Geotechnical Design – Part 1 General Rules.

CD225 (2025) Design for New Pavement Foundations, National Highways.

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, pp.25–31.

Heukelom, W. and Klomp, A.J.G. (1962) Dynamic Testing as a Means of Controlling Pavement during and after Construction. *Proceedings of the 1st International Conference on the Structural Design of Asphalt Pavement, Ann Arbor, Michigan*, 20-24 August 1962, 667-685.

Jones, R. (1958) In situ measurements of the dynamic properties of soil by vibration methods. Geotechnique, Vol.8(1).

Powell, W.D., Potter, J.F., Mayhew, H.C. and Nunn, M.E. (1984) The Structural Design of Bituminous Roads. TRRL Laboratory Report 1132.

Rigby-Jones, J. and Milne, C.A. (2016) Continuous Surface Wave testing in UK practice.

Rollins, K.M., Evans, M.D., Diehl, N.B. and Daily, W.D. III (1998) Shear modulus and damping relationships for gravels.

SoilSafe Ltd (2025) SSGN001 – Specifying ACSW Testing. Available at: www.soilsafe.co.uk

SoilSafe Ltd (2025) SSGN011 – An Introduction to ACSW Testing. Available at: www.soilsafe.co.uk

SoilSafe Ltd (2025) SSGN027 – ACSW Pavement Investigations. Available at: www.soilsafe.co.uk

SoilSafe Ltd (2025) SSREF01 – Useful ACSW References. Available at: www.soilsafe.co.uk