



# IMPACT OF POISSON'S RATIO & SOIL DENSITY ON ACSW DATA

Guidance Note SSGN030

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## Introduction

Assumptions for soil Poisson's ratio and soil density (unit weight) are commonly required for geotechnical evaluation, and this is also the case for Advanced Continuous Surface Wave (ACSW) data. Both Poisson's ratio and soil density have well defined ranges for normal soils and can be estimated with reasonable accuracy for known soil types.

Soil densities range between 14kN/m<sup>3</sup> to 24kN/m<sup>3</sup> as extreme values but are typically between 16kN/m<sup>3</sup> & 21kN/m<sup>3</sup> (Fig 1, BS8002:2015)

Tomlinson, 2001 gives the following summary of Poisson's ratios:

<i>Clays (undrained)</i>	<i>0.5</i>
<i>Clays (stiff, drained)</i>	<i>0.1 to 0.2</i>
<i>Silt</i>	<i>0.3</i>
<i>Sands</i>	<i>0.1 to 0.3</i>
<i>Rocks</i>	<i>0.2</i>

This guidance note sets out how Poisson's ratio and soil density values are used in ACSW data and the relatively limited impacts of variations between assumed and actual values, provide suitable professional judgment is used.

## Within CDAS

SoilSafe CDAS software converts ACSW measurement of Rayleigh wave velocity ( $V_r$ ) to shear wave velocity using Poisson's ratio ( $\nu$ ) and the formula by Heymann, 2007:

$$\frac{V_r}{V_s} \approx \frac{0.874 + 1.117\nu}{1 + \nu}$$

For this this process of inversion (conversion of  $V_r$  against frequency data to a  $V_s$  depth profile) CDAS usually uses a default value Poisson's ratio ( $\nu$ ) of 0.5; this is the maximum possible value of Poisson's ratio. In the above equation increasing Poisson's ratio reduces the value of  $V_s$  i.e. the default of 0.5 is conservative in ultimately generating lower stiffnesses. The variation in  $V_s$  generated between a Poisson's ratio of 0.1 and 0.5 (the maximum possible range in normal soils) is less than 7%.

Note that the default soil density in CDAS (18kN/m<sup>3</sup>) only affects the generation of  $G_0$  (very small-strain shear modulus) based on  $V_s$  displayed on screen (see below for CDAS output of stiffness values). However, this soil density is also normally a moderately conservative value since higher soil density generates higher values of  $G$  (see below).





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## Conversion of $V_s$ to $G_0$

SoilSafe converts  $V_s$  profile data to  $G_0$  (very small-strain shear modulus) using standard elastic theory:

$$G = \rho \cdot V_s^2 \text{ (where } \rho \text{ is soil density).}$$

As noted above, for on-screen output, CDAS uses as default soil density of  $18\text{kN/m}^3$ .

However, for final data outputs SoilSafe converts  $V_s$  to  $G_0$  using a spreadsheet which allows any value of soil density to be entered by the user for each layer, irrespective of the value set in CDAS. Using elastic theory, the default soil density value of  $18\text{kN/m}^3$  will give a value only 13% higher and 17% lower respectively than the typical soil density range of  $16\text{kN/m}^3$  to  $21\text{kN/m}^3$ .

## Conversion of $G_0$ to $E_0$

Very small-strain shear modulus ( $G_0$ ) is converted to very small-strain Young's modulus ( $E_0$ ) using standard elastic theory:

$$E = G \cdot (2 \cdot (1 + \nu)) \text{ where } \nu \text{ is Poisson's ratio}$$

The SoilSafe ACSW output spreadsheet allows any value of soil density to be entered by the user for each layer, irrespective of the value set in CDAS, but a default drained value of 0.26 is used in the absence of other information (based on the typical drained soil range of 0.2 to 0.3).

Using the above formula,  $E_0$  increases with increasing Poisson's ratio. However, variation in  $E_0$  using Poisson's ratios of 0.2 & 0.3 is only 8%.

## Strain softening

Values of  $E_0$  are strain softened within the SoilSafe ACSW output spreadsheet to a value of strain which can be adjusted by the user. The Rollins et al/ 1998 strain softening formula is used based on soil density:

$$\frac{G}{G_0} = \frac{1}{[1 + 16\gamma(1.2 + 10^{-20\gamma})]}$$

Where  $\gamma$  is shear strain

Using the Rollins formula, strain softening decreases with unit weight, however the variation is relatively small – the difference in strain softened value between a soil density of  $18\text{kN/m}^3$  and  $19\text{kN/m}^3$  is 6%.





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## Summary

Estimation of soil density and Poisson's ratio is commonly required for many geotechnical assessments, however the normal range of these values is well known.

Provided suitable professional judgment is made in selecting Poisson's ratio and soil density values, the potential for significant variation in resultant soil stiffness values from ACSW data is low. As supported by case studies, more significant design stiffness variations are generated by using data from soil tests where soils may be disturbed by sampling, initial strain levels must be estimated or where empirical correlations are used.

## References

- SSGN013 Comparison of ACSW testing with stiffness measurement by empirical relationships with other soil properties
- SSGN016 Comparison of ACSW testing with stiffness measurement by other seismic techniques
- BS8002 (2015) Code of Practice for Earth Retaining Structures
- Heymann, G. (2007) Ground stiffness measurement by the continuous surface wave test, *Journal of the South African Institution of Civil Engineering*, Vol 49 No1, Pages 25–31, Paper 631
- 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.
- Tomlinson, M. J., *Foundation Design & Construction*, 7th Edition, 2001

