AI–Vs: Predicting shear wave velocity (V_s) of soils from CPTu test data using AI

Student competition: NextGen session, FOMLIG 2025: https://fomlig2025.com/

Deadline: 10 October 2025

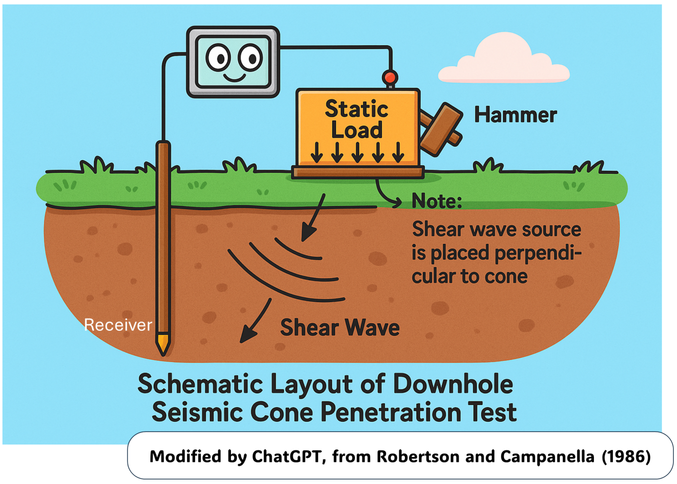
On Kaggle: "AI-Vs: Predicting Vs from CPTu for OWTs"
https://www.kaggle.com/competitions/AI-Vs-2025

Overview

Offshore wind turbine (OWT) farms are growing rapidly, throughout the world. Accurate, depth-dependent modeling of soil properties like shear wave velocity, V_s, and small-strain shear modulus, G_{max}, is critical for safe designs. This challenge invites AI researchers, data scientists, and geotechnical engineers to collaborate and develop predictive models using (piezo-)cone penetration test (CPTu) data.

Background

Normally, a shear wave is generated at the ground surface using an impact method –such as striking a beam with a hammer– to induce horizontal wave motion. This wave, known as S-wave, travels through the soil and is detected after a time delay by geophones. These geophones act as wave receivers and are embedded at various depths in the subsurface, by means of a module attached to piezocone [1].



In geotechnical design, V_s is calculated from:

$$V_S = \frac{L}{t}$$

where, L is the wave 1–D travel distance toward the receiver, and t is the time of travel. And, G_{max} is derived from:

$$G_{max} = \rho V_s^2, \qquad where \quad \rho = \frac{\gamma}{g} \tag{1}$$

These values are essential for modeling soil-structure interaction, particularly under dynamic and cyclic loads (e.g. wind, waves). However, V_s and unit weight, γ, are not readily available at all depths, and errors in V_s estimation propagate quadratically into G_{max}.

Your mission

Utilize the so-called "AI" techniques to predict:

- Shear wave velocity, V_s, and,
- Small-strain shear modulus, G_{max},

using a provided real-world CPT dataset, "Train.csv", compiled from offshore projects. You can add your own data sets also.

Database

The database can be found as an attachment file, "Train.csv". For more information on the database refer to [5]. The provided data sets include the information on:

Parameter	Definition	Type
Project	Project name of ID	Raw data
Testing spot	Location of the testing	
Z [m]	Depth	
V_s [m/s]	Shear wave velocity (from seismic test)	
q_c, q_t, f_s, u_2 [MPa]	Cone tip resistance, corrected cone tip resistance, sleeve friction, pore pressure	
Q_t [-], F_r [%], B_q [-], I_c [-]	CPTu-based soil behavior indicators	Interpreted
σ_{v0} [kPa]	Vertical in-situ total stress	
σ'_{v0} [kPa]	Vertical in-situ effective stress	
e_0 [-]	Void ratio (from CPTu)	
γ [kN/m^3]	Bulk unit weight (from CPTu)	

The interpretation equations are mentioned in Appendix A. **Feel free to use your own interpreted values!**

Test data

To evaluate the accuracy, it is required to test your model for the data provided in 'Test.csv'.

Evaluation

For evaluating the models, *Accuracy* of predictions and *innovation* of models play roles. Provided that you want your model to be evaluated at FOMLIG2025, upload a two-page summary of your developed model, to present the innovation also. Though, single-page graphical abstracts are more than welcome to be presented at FOMLIG workshop in Florence, Italy, 15-17 October. If not, you can evaluate your model here on Kaggle.
The winners:

- One winner from Kaggle (based on the Kaggle Leaderboard ranking),
- Two winners from FOMLIG participants (based on the accuracy and innovation criteria evaluated at FOMLIG),
- One winner from open participants who may not have the opportunity to join us in Italy (based on the accuracy and innovation criteria evaluated at FOMLIG),

will be awarded Certificates.

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References

[1] RG Campanella and WP Stewart. "Seismic cone analysis using digital signal processing for dynamic site characterization". In: *Canadian Geotechnical Journal* 29.3 (1992), pp. 477–486.

[2] PW Mayne, E Cargill, and J Greig. *The Cone Penetration Test: Better Information, Better Decisions*. 2023.

[3] Peter K Robertson. "Interpretation of cone penetration tests—a unified approach". In: *Canadian geotechnical journal* 46.11 (2009), pp. 1337–1355.

[4] Peter K Robertson and KL Cabal. "Guide to cone penetration testing for geotechnical engineering". In: *Signal Hill, CA: Gregg Drilling & Testing* (2022).

[5] Bruno Stuyts et al. "A critical review of cone penetration test-based correlations for estimating small-strain shear modulus in north sea soils". In: *Geotechnics* 4.2 (2024).

Appendix A

The interpreted parameters in the databases are based on the equations show in the following table.

Parameter	Description	Equation
γ_w [kN/m^3]	Unit weight of water	$\simeq 9.81$
γ_s [kN/m^3]	Unit weight of soil	[2] and [4] can be referred to!
F_r [%]	Normalized friction ratio	$F_r = \dfrac{f_s}{(q_t - \sigma_{v0})} \cdot 100\%$
σ_{v0} [kPa]	Vertical stress	$\sigma_{v0} = \gamma_s z = \rho_s g z$
σ'_{v0} [kPa]	Vertical effective stress	$\sigma'_{v0} = \gamma_s z_s - \gamma_w z_w$
B_q [-]	Normalized pore pressure parameter	$B_q = \dfrac{\Delta u}{q_t - \sigma_{v0}}$
Q_{tn} [-]	Normalized cone tip resistance	$Q_{tn} = \left(\dfrac{q_t - \sigma_{v0}}{\sigma_{atm}}\right)\left(\dfrac{\sigma_{atm}}{\sigma'_{v0}}\right)^n$, ref. [3]
I_c [-]	Soil index property	$I_c = \sqrt{(3.47 - logQ_{tn})^2 + (logF_r + 1.22)^2}$
e_0	Initial void ratio	Derived from CPTu; refer to [5]