

## INTRODUCTION & OBJETIVES

Empirical correlations are usually used as a predictive tool in geotechnical engineering. However, equations calculated for soils different to the ones to be characterized are frequently used, and so they are not representative of their mechanical properties.

This fact, added to the increasing interest of civil engineering in knowing the shear wave velocity ( $V_s$ ) of the ground, has led to the calculation of different empirical equations to predict the  $V_s$  value of the soils.

The most frequent correlation is the one that links  $V_s$  to the results of the Standard Penetration Test ( $N_{SPT}$ ) as it is a much extended and widely used parameter.

As seen in Figure 1. each area of investigation is characterized by a different geological history so the empirical correlations calculated for a specific location may not be valid in other locations.

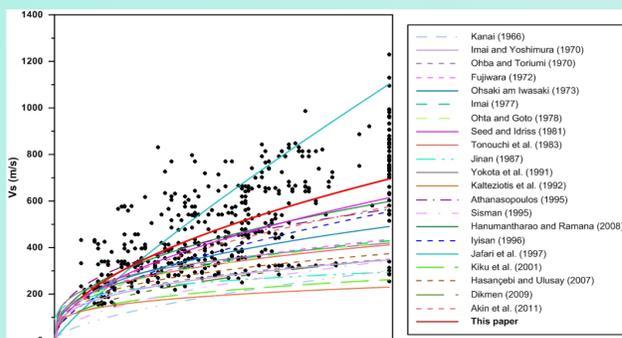


Fig. 1 Comparison of the correlation between  $V_s$  and  $N_{SPT}$  for the soils of Madrid and the equations proposed in the bibliography.

Consequently, to obtain predictive equations suitable for the soils of Madrid, it will be necessary to perform a complete statistical analysis for a sufficiently representative amount of soils samples.

This study's goal is to predict the stiffness and deformability of the soils of Madrid. To do so, the statistical correlation between  $V_s$  measured with ReMi (*Refraction Microtremor*) technique and the Standard Penetration test (500  $N_{SPT}$  values) has been analysed.

## SOILS OF MADRID

Madrid soils are made of Miocene materials that resulted from a sedimentary system based on alluvial fans that converged in an evaporite lake. It is common in Madrid to refer to the different facies through the following nomenclature, normally used in the geotechnical descriptions and publications:

**Arena de Miga:** Sand with less than 25% fines.

**Toscós:** Sandy clays or clays with more than 40% fines.

**Peñuelas:** High plasticity clays of the transition facies.

**Gypsiferous clay:** Interbedded clays with gypsum from the evaporite facies.

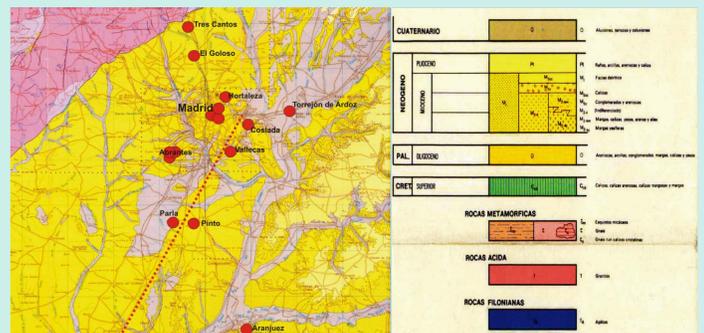


Fig. 2 Location of studies on the geological map of Madrid.

## RELATIONSHIP BETWEEN $V_s$ AND $N_{SPT}$ FOR THE SOILS OF MADRID

Statistical analysis (lineal regression) between  $V_s$  and the results of the SPT tests of the soils of Madrid shows poor correlation between both geotechnical parameters:

$V_s$  cannot be explained only in terms of SPT, so the need to include another parameter in the equation has to be considered.

Statistical analysis shows that there is a variable that has not been taken into consideration: DEPTH.

Previous equations introduce a bias, so if the depth is not included as an explanatory variable, the values of  $V_s$  calculated below 10-12 m are underestimated.

When depth is included in the equation, it improves the quality of the correlation.

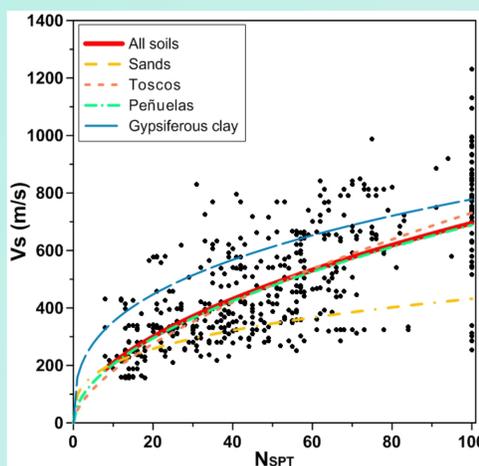


Fig 3. Correlation between  $V_s$  and  $N_{SPT}$  for the soils of Madrid.

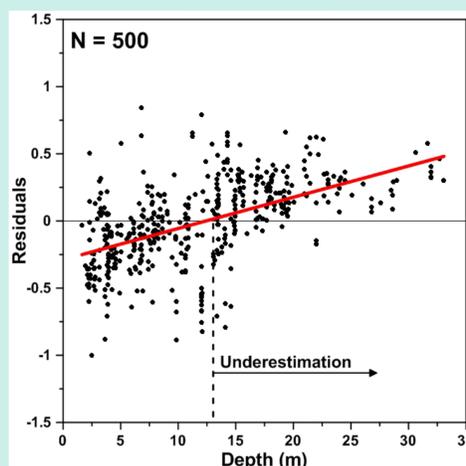


Fig 4. Statistical analysis of  $V_s$ - $N_{SPT}$  equations and depth.

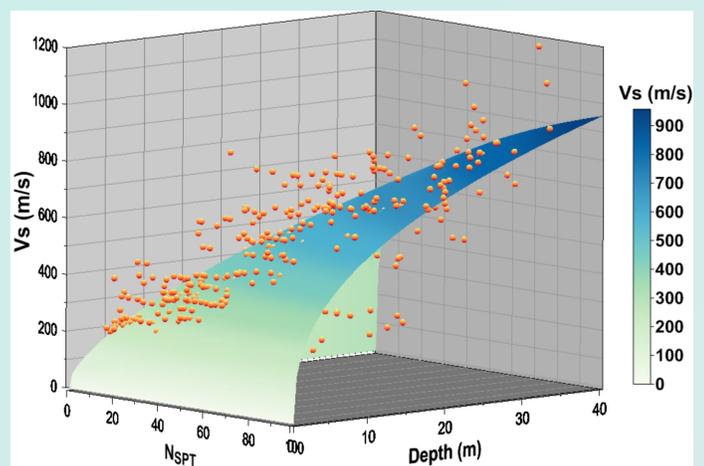


Fig 5. Model showing the relation of  $V_s$  with depth and  $N_{SPT}$ .

## CONCLUSIONS

Empirical correlations are a very useful tool to estimate  $V_s$  when other direct tests are not available.

### LITHOLOGY

- Empirical correlations calculated for a specific location are not valid in other locations.
- It is indispensable to use equations calculated for the same soils that are to be characterized, and if possible, based on its lithology.
- The correlations presented in this study were calculated for number of parameters sufficiently representative of all the lithologies and at different depths and can be extrapolated to all soils of Madrid.

### DEPTH

- Depth is an indispensable parameter to predict the stiffness of soils.
- Soils under high confining tensions behave as more rigid materials than identical soils under less confining tensions.
- The influence of depth is greater in the younger lithologies, with less cohesion, pre-consolidation and without diagenesis.

| Lithologies       | $V_s - N_{SPT}$                      |             | $V_s - N_{SPT} - Z$                                  |             |
|-------------------|--------------------------------------|-------------|--|-------------|
|                   | Empirical Correlation                | $R^2$       | Empirical Correlation                                | $R^2$       |
| All Madrid soils  | $V_s = 62.6 \cdot N_{SPT}^{0.52}$    | <b>0,5</b>  | $V_s = 77.85 \cdot N_{SPT}^{0.121} \cdot Z^{0.619}$  | <b>0,76</b> |
| Sands             | $V_s = 98.69 \cdot N_{SPT}^{0.321}$  | <b>0,37</b> | $V_s = 77.85 \cdot N_{SPT}^{0.121} \cdot Z^{0.619}$  | <b>0,78</b> |
| Toscós            | $V_s = 44.87 \cdot N_{SPT}^{0.606}$  | <b>0,42</b> | $V_s = 110 \cdot N_{SPT}^{0.147} \cdot Z^{0.397}$    | <b>0,72</b> |
| Peñuelas          | $V_s = 60.79 \cdot N_{SPT}^{0.527}$  | <b>0,58</b> | $V_s = 60.59 \cdot N_{SPT}^{0.213} \cdot Z^{0.479}$  | <b>0,77</b> |
| Gypsiferous clays | $V_s = 159.43 \cdot N_{SPT}^{0.344}$ | <b>0,68</b> | $V_s = 128.67 \cdot N_{SPT}^{0.273} \cdot Z^{0.188}$ | <b>0,82</b> |

Chart 1. Improvement of empirical correlations for soils in Madrid when depth is included.

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