Reliability and Applicability of SPT Correlations with Shear Wave Velocity

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1. Introduction

Shear wave velocity (Vs) is widely used by earthquake and geotechnical engineers to model the seismic behavior of the sites. For example, site specific response spectrum is usually derived from subsurface stratigraphy and variation of shear wave velocity versus depth, using computer programs such as SHAKE. However, in most cases an on-site measurement of Vs may not be feasible due to comparatively high cost of Down-hole and Cross-hole tests and/or other considerations.

On the other hand, Standard Penetration Test (SPT) is the most common in-situ geotechnical test which is almost carried out in every geotechnical investigation program. Other penetrometers such as Wildcat, Durham, etc may be correlated to SPT blow counts to provide the engineer with a global interpretation for consistency of the subsurface layers.

Geoscientists and engineers have done several studies to provide correlations of SPT blow counts to shear wave velocity. Many of the available correlations are derived for specific soil types while others are suggested without any specific limitation. In this article, author provides a brief comparison of existing Vs-SPT correlations by using NovoSPT software.

2. Database of Vs-SPT Correlations

Total of 59 equations for estimation of Vs based on SPT blow counts have been collected and implemented in this software. The oldest correlation belongs to Kanai et al (1966) and the most recent equation proposed by Unal Dikmen (2008).

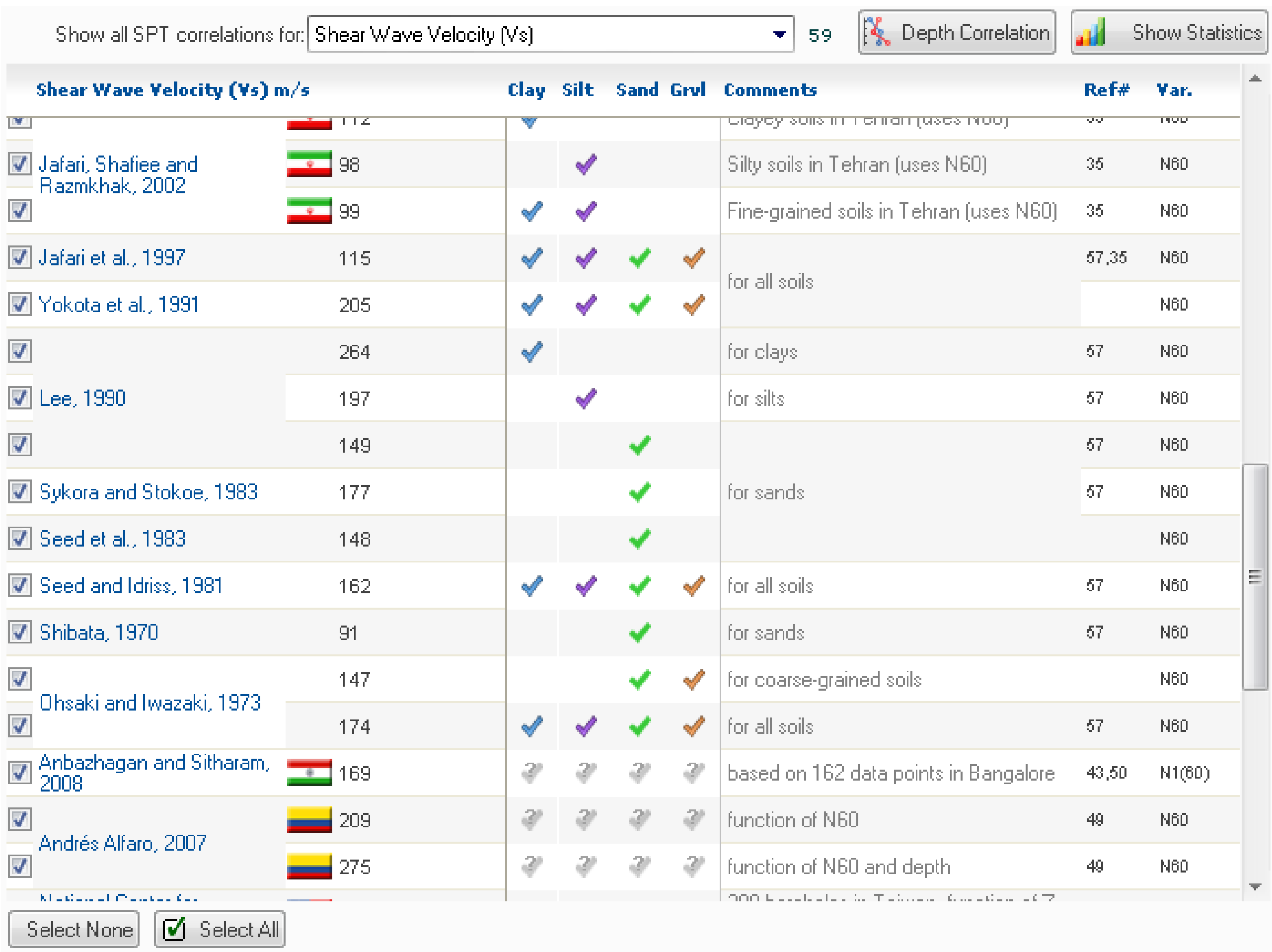
Study of the existing correlation, indicates that early equations were essentially simpler and were recommended for a broad range of soil types, whereas due to technological advancements and availability of computer programs and spreadsheets, recent correlations are more complicated and employed more parameters. For instance, Baziar and Fallah (1998), Andres Alfaro (2007), and a few other researchers have incorporated the depth of test (Z) in their formula. In addition, in each correlation author has used N, N_{60} or $N1_{(60)}$.

Most of the proposed correlations are the result of case studies based on the field tests in a specific geographical region. Those correlations are known to be reliable only on that area. For example, Anbazhagan and Sitharam (2008) provided correlation for Bangalore soils and National Centre for Research on Earthquake (NCREE) has provided correlations based on 200 boreholes in Taiwan. These equations may not be reliable in other regions and should be used with cautious.

However, the most important point when using a correlation –which is sometimes ignored by the engineers- is applicability of the correlation to the subject stratigraphy. For example Okamoto et al. (1989) proposed an equation to estimate Vs based on SPT blow counts in Pleistocene sand. It is obvious that the use of this formula for clays is not recommended.

Thus, although many equations are available and being proposed for shear wave velocity, it is up to the geotechnical engineer to be aware of applicability of each method and to choose the most reliable range of Vs based on SPT results. Usually, engineers use only a few correlations to simplify the analysis, regardless of whether those formulas are available for the subject site or not.

NovoSPT software provides more than 270 SPT correlations to geotechnical soil properties (including shear wave velocity). As it can be seen in the following screenshot, recommended soil type(s) and geographical region are specified for each correlation.



Shear Wave Velocity (Vs) m/s		Clay	Silt	Sand	Grvl	Comments	Ref#	Var.
Jafari, Shafiee and Razmkhak, 2002	98		✓			Silty soils in Tehran (uses N60)	35	N60
	99	✓	✓			Fine-grained soils in Tehran (uses N60)	35	N60
Jafari et al., 1997	115	✓	✓	✓	✓	for all soils	57,35	N60
Yokota et al., 1991	205	✓	✓	✓	✓			N60
	264	✓				for clays	57	N60
Lee, 1990	197		✓			for silts	57	N60
	149			✓			57	N60
Sykora and Stokoe, 1983	177			✓		for sands	57	N60
Seed et al., 1983	148			✓				N60
Seed and Idriss, 1981	162	✓	✓	✓	✓	for all soils	57	N60
Shibata, 1970	91			✓		for sands	57	N60
Ohsaki and Iwazaki, 1973	147			✓	✓	for coarse-grained soils		N60
	174	✓	✓	✓	✓	for all soils	57	N60
Anbazhagan and Sitharam, 2008	169	?	?	?	?	based on 162 data points in Bangalore	43,50	N1(60)
Andrés Alfaro, 2007	209	?	?	?	?	function of N60	49	N60
	275	?	?	?	?	function of N60 and depth	49	N60

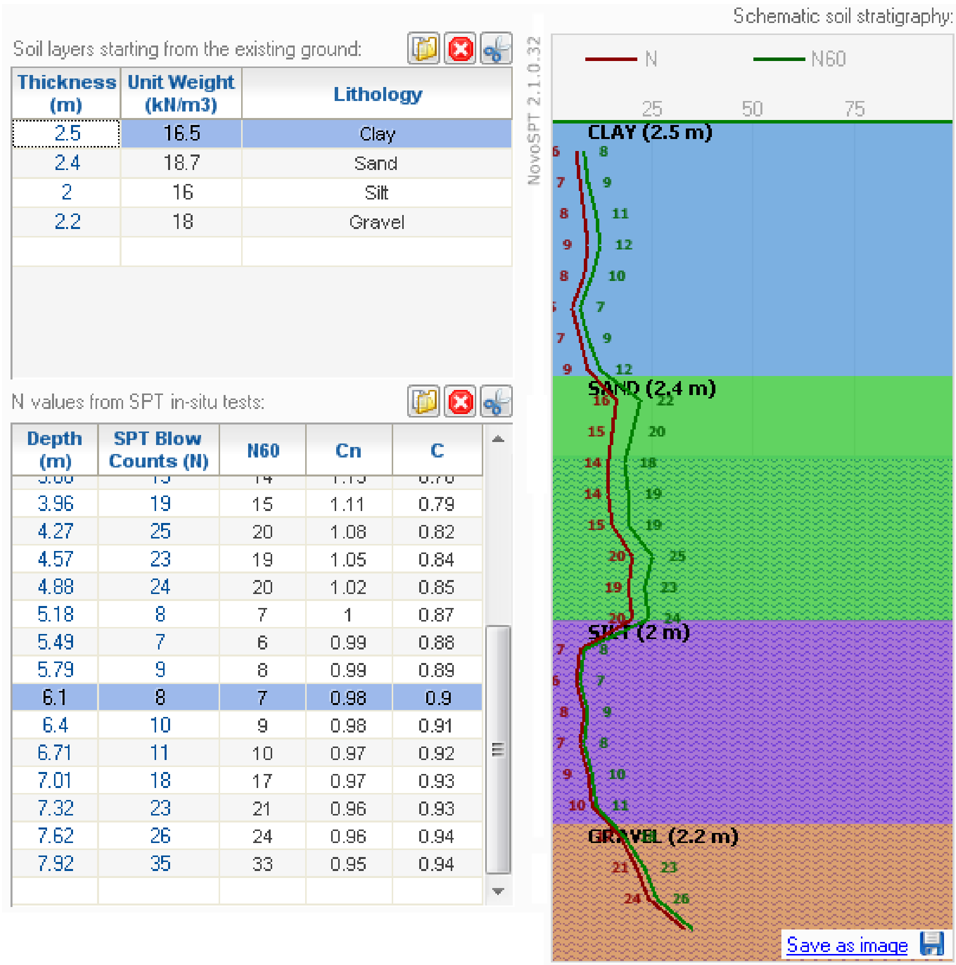
Figure 1: Correlated Vs values based on SPT blow counts

3. Analysis of Sample Dataset

To compare the Vs-SPT correlations, a sample dataset comprising different soil types and SPT blow counts are assumed. The following sections describe the assumptions:

3.1. Soil Stratigraphy

Subsurface layers consist of 2.5 m thick clay underlain by 2.4 m thick sand layer which in turn, is underlain by 2 m of silt, overlying the 2.2 m thick gravel layer. SPT blow counts shown on Figure 2, indicates on a stiff to firm clay, compact sand, stiff to firm silt and compact to dense gravel. All SPT corrections including overburden stress corrections are automatically applied to SPT blow counts by software.



Thickness (m)	Unit Weight (kN/m3)	Lithology
2.5	16.5	Clay
2.4	18.7	Sand
2	16	Silt
2.2	18	Gravel

Depth (m)	SPT Blow Counts (N)	N60	Cn	C
3.96	19	15	1.11	0.79
4.27	25	20	1.08	0.82
4.57	23	19	1.05	0.84
4.88	24	20	1.02	0.85
5.18	8	7	1	0.87
5.49	7	6	0.99	0.88
5.79	9	8	0.99	0.89
6.1	8	7	0.98	0.9
6.4	10	9	0.98	0.91
6.71	11	10	0.97	0.92
7.01	18	17	0.97	0.93
7.32	23	21	0.96	0.93
7.62	26	24	0.96	0.94
7.92	35	33	0.95	0.94

Figure 2: Assumed soil stratigraphy and SPT blow counts (can be imported from gINT database) for the sample problem.

Using "Soil Type Filter" feature in NovoSPT, 59 general correlations can be filtered for the specific soil type at selected depth. In this case, soil type is "silt" and the program provides 31applicable correlations after filtration.

3.2. Comparison of Correlated Vs Based on Different Methods

Figure 3 presents the distribution of correlated values for the shear wave velocity. An average, minimum and maximum values of 169.6, 57 and 451 m/s is calculated for the existing dataset.

Since many correlations are proposed for a specific region and may not be applicable to the specific site, users may decide to remove them from the results. On the other hand, some correlated Vs values in Figure 3 are too lower or higher than the mean range of dataset. After applying all updates, the following methods provide more consistency with average value:

- Imai 1975
- Imai and Tonouchi 1982
- Seed and Idriss 1981

- Ohsaki and Iwasaki 1973
- Anbazhagan and Sitharam 2008
- NCREE
- Fujiwara 1972

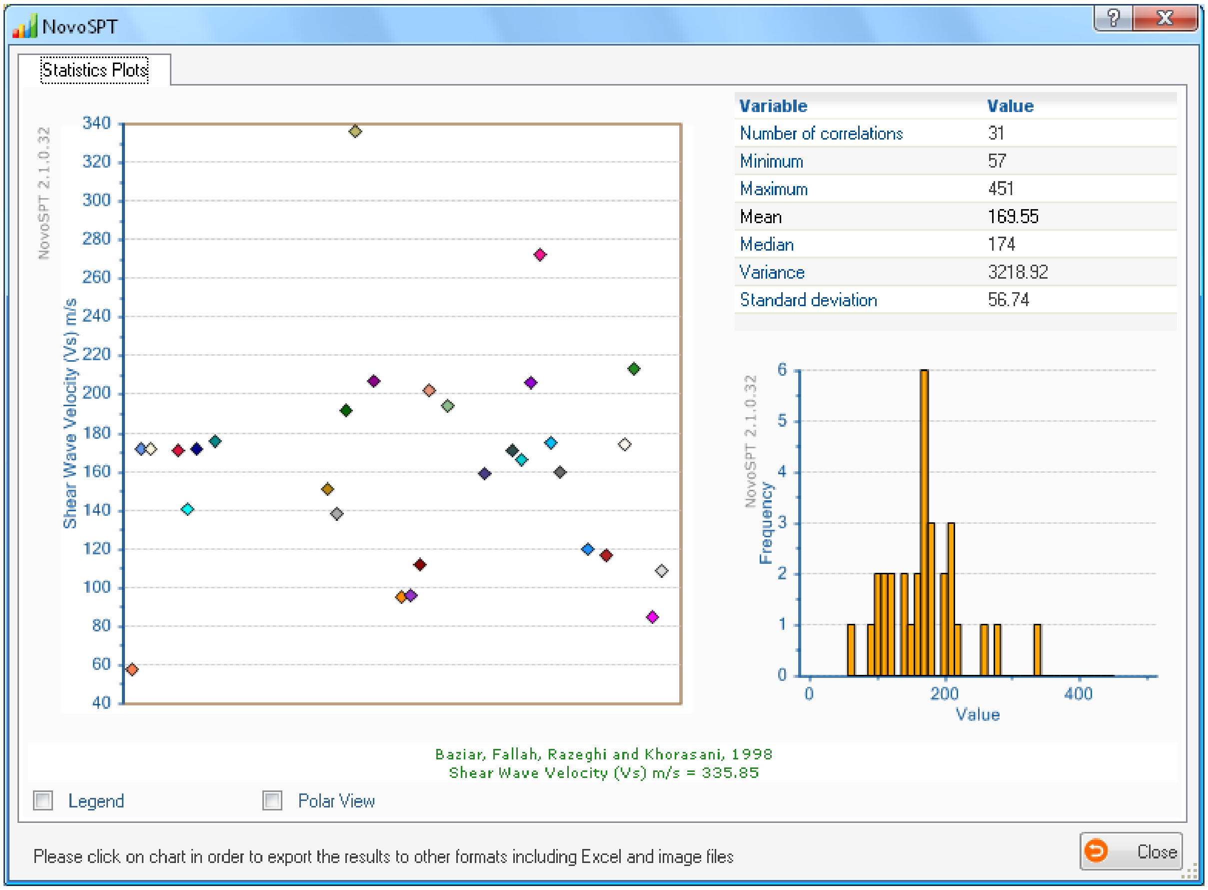


Figure 3: Distribution of correlated Vs values for sample dataset.

4. Conclusion

In absence of in-situ measurement of shear wave velocity, SPT blow count is the most common data used for estimation of this parameter. It is crucial to understand the limitations of each correlation among them: applicable soil type, geographical region (geology formation), and type of the blow count number (N, N_{60}, $N_{1(60)}$) used in the formula have the most importance.

Computer programs can be used to ease the analysis of available correlations and estimation of the most reasonable range of soil parameter for a specific site. In this paper, NovoSPT program was briefly introduced and a sample dataset was used to show the distribution of correlated shear wave velocity values. Users can filter the results based on target soil type and distribution of the correlated values to obtain the most reasonable range of Vs.