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PREDICTION OF BEARING CAPACITY OF SHALLOW SITES BY SEISMIC METHOD

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Abstract

This paper presents a study of estimating bearing capacity of shallow sites using an alternatives method, which is nondestructive in nature without performing any borehole. Initially, two important parameters, which are, shear wave velocity profile and damping collected by means of Spectral Analysis of Surface Waves method. Shear waves velocity used to provide an elastic Shear Modulus G, and Young's Modulus, E. Damping at current strain is obtained by using Halfpower Bandwidth Method with various sources from possible low to high frequency. Both parameters, which is measured at low strain, used to adjust to larger strains through hyperbolic relationships with reference strains obtained from the equation. Comparison to conventional method Plate Load Tests and an empirical equation provided previous researcher were made and good agreement achieved by different of 10%.

Keywords: Damping, Low strain, Shallow foundation, Shear wave velocity, Surface wave method.

1. Introduction

One of the important fundamental in geotechnical engineering is to compute bearing capacity of soil and it is determined from laboratory and conventional field tests. It is well known that the conventional method of the sampling and testing in laboratory suffer from disturbance and stress relief. Many researchers have been discussing about the disturbance. Among of them are are Kallstenius [1], Skempton & Sowa [2], Davis and Poulos [3], Clayton et al. [4], Lunne et al. [5] and Noorzad et al. [6]. Conventional field test which has generally used to characterize the soils are also limited to one dimension only [7]. Schnaid [8] stated some advantages using seismic method; significant of them are 1) able to represent a wide area of a project or site 2) provide a general picture of complicated subsurface which involve various space and complex soils strata.

In recent decades, seismic method has been advancing to various aspect in geotechnical engineering and applications; Swiger [9] in settlement analysis of large and heavy structures; Abbiss [10, 11] in predictions of soil stiffness and calculation of elasticities and settlement for high strains and long periods of time; Konstantinidis et al. [12] in settlement analysis of a power plant; Burland [13] in settlement of a water tank; Briaud and Gibbens [14] in settlement analysis of footings; Omar et al. [15] in predicting long-term settlement of soft clay;. These show a very high potential future for seismic application because it is using small strain and free from disturbances.

Recently, Spectral Analysis of Surface Waves (SASW) method is widely used since it is a distinguished type of surface wave method. In this study, SASW method is performed since it has several advantages; 1) best sampling of shallow material 2) high sensitivity measurements for layer stiffness contrast, using apparent velocity inversion analysis [16]. Other surface waves method such as frequency-waves number (F-K) method, Multichannel Analysis of Surface Waves (MASW) method and Continuous Surface Waves (CSW) method suffer from drawbacks such as inaccurate mode separation, limited to fundamental mode only and limited to frequency-content of vibrator, respectively [16].

2. Methodology

Determination of shear waves velocity profile considered in 2 major stages which are 1) Generating dispersion curve 2) Inversion process. First stage includes collecting surface waves data at field sites, Fig. 1(a), convert the data into frequency domain and masking, Fig. 1(b). Then second stage is to convert the dispersion into shear waves velocity profile, Figs. (c) and (d).

Based on elastic formulation, assuming the static and dynamic moduli are equivalent, the elastic shear modulus, G_0 is computed from the Eq. (1). Then Young's modulus determined by Eq. (2).

$$G_0 = \rho V_s^2 \tag{1}$$

$$E_0 = 2G_0(1 + \mu) \tag{2}$$

Ultimate bearing capacity calculated by empirical Eq. (3) developed by Tezcan [17]. The damping of soils computed using Halfpower Bandwidth method as shown in Fig. 3.

$$q_u = 0.1\gamma V_s \tag{3}$$

Abbiss [11] have established an equation based on relationship of damping measured at current strain and characteristic or reference strain as shown in Eq. (4).

$$D = \frac{D_{max}}{1+\ln\left(1+(e-1)\frac{\varepsilon_r}{2\varepsilon}\right)} \quad (4)$$

Initially, Hardin and Drnevich [18] suggested a hyperbolic shear stress-strain model function to represents backbone curve of common hysteristic behaviour of soils (Fig. 3) under cyclic loading as shown in by Eq. (5). Consequently, Nayan et al. [7] suggested the corresponding hyperbolic pattern for stress-strain (Eq. (6)) under assumption that the stress-strain loop of soils is similar to the loop of cyclic shear loading. Therefore bearing capacity of soils is determined when stress is at maximum.

$$\tau = \frac{G_0 \gamma}{1+\left(\frac{\gamma}{\gamma_r}\right)} \quad (5)$$

$$\sigma = \frac{E_0 \varepsilon}{1+\left(\frac{\varepsilon}{\varepsilon_r}\right)} \quad (6)$$

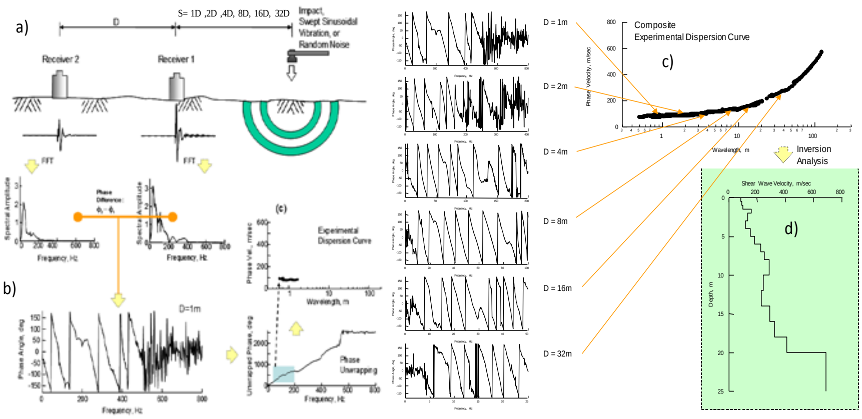


Fig. 1. Determination of dispersion curve [16].

3. Result and Discussions

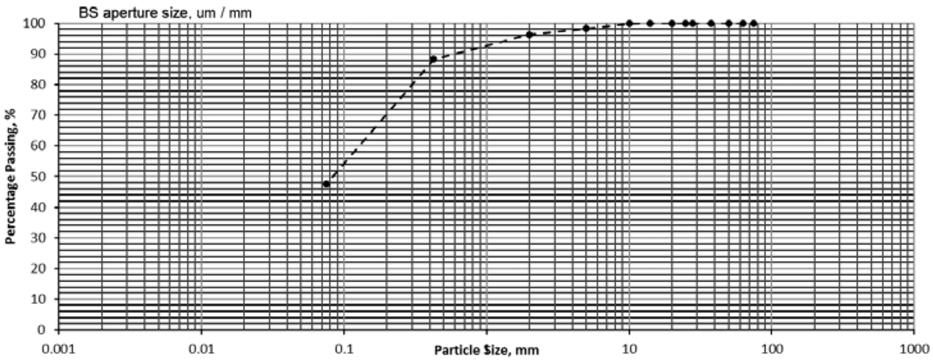
Figs. 2(a), 3(a) and 4(a) showed PLT conducted at Cyberjaya, Subang Point 1 and Subang Point 2. Sieve analysis from the soil sample is shown in Figs. 2(b), 3(b) and 4(c). SASW measurement with 2 geophones attached on the ground illustrated in Figs 2(c), 3(c) and 4(c) at respective sites. Determination of shear waves velocity profiles as explained in Fig. 1 performed, resulting the profiles as shown in Figs. 2(d), 3(d) and 4(d) corresponding to Cyberjaya, Subang Point 1 and Subang Point 2 respectively.

Comparison in graphical form between proposed method, empirical equation by Tezcan [17] and conventional PLT showed in Figs. 5, 6(a) and 6(b) at respective sites. Implementation of Eqs. 1 to 6 were made to generate stress-strain curve and PLT result including first and second cycle superimposed on the same graph. Stress-strain graphs plotted in Figs. 5, 6(a) and 6(b) showed differences on gradual changes in which stresses recorded by PLT increasing with gentle slope compare to the proposed method. On the other hand, stresses obtained from seismic method has a sudden increase and steeper slope than the conventional one.

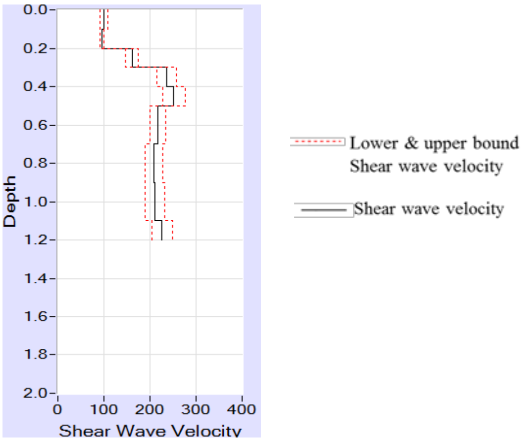
(a) PLT

(c) SASW measurement

Material description: Bright brown sand



(b) Soil information based on Sieve analysis.



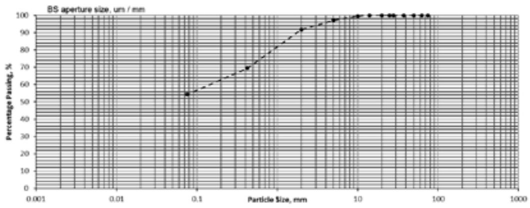
(d) Shear waves velocity profile.

Fig. 2. Field test at Cyberjaya.

This phenomenon can be explained as illustrated in Fig. 7 where shear strain differences in both conventional and dynamic method. Conventional method induces large strain (10^{-3} and above) caused the initial shear modulus G_0 as in Eq.

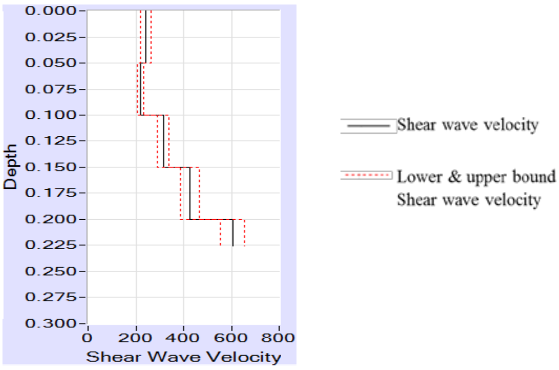
(5), not exponentially increase at reference shear strain γ_r. The same behavior as elastic modulus E_0 with reference strain ε_r. While dynamic or seismic method generates maximum shear modulus at very small strain and allow the proposed method reached maximum stress with steeper slope than the conventional. The conventional method intrinsically does not have the reference strain because the load subjected in the test is increased gradual and slowly with time. While the proposed method is based on wave propagation that induced very small strain start from 10^{-4} and lower.

(a) PLT **(c) SASW Measurement**



Material description: White, with reddish spot, sandy silt & clay

(b) Soil information based on Sieve analysis.



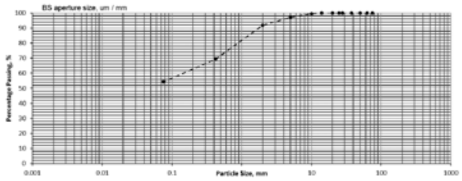
(d) Shear waves velocity profile

Fig. 3. Field test at Subang Point 1.

Table 1 shows comparison of bearing capacity for Cyberjaya, Subang Point 1 and Point 2 obtained through conventional method, empirical equation and the proposed method. The result showed Subang sites have high bearing capacity due compaction for railyway station establishment. The percentage different between all the methods at the respective sites are less than 10 percent. Difference result obtained between both proposed and Tezcan empirical equation is mainly due to the equation do not consider damping factor in the predicting bearing capacity. While main reason that caused the slight differences between the proposed method and PLT is no destructivity of seismic method and intrinsic strain induce.

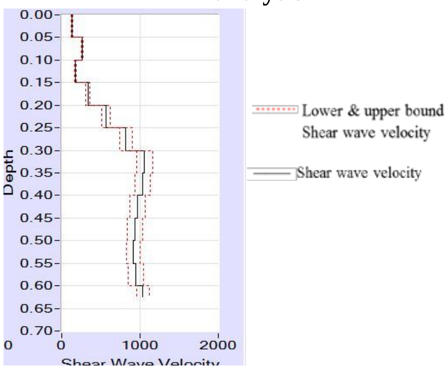
Table 1. Comparison of bearing Capacity including percentage different to proposed method.

	Cyberjaya	Subang Point 1	Subang Point 2
Conventional PLT	270.00	870.00	555.00
Empirical Equation (Tezcan)	278.20	892.23	550.68
Proposed method	282.00	954.86	587.30
Percentage diff. between proposed and PLT(%)	4.5	9.7	5.5
Percentage diff. between proposed and empirical Eq. (%)	1.4	6.6	6.2



Material description: White, with reddish spot, sandy silt & Clay

(a) PLT **(b) Soil information based on Sieve analysis**



(c) SASW Measurement **(d) Shear Waves Velocity Profile**

Fig. 4. Field test at Subang Point 2.

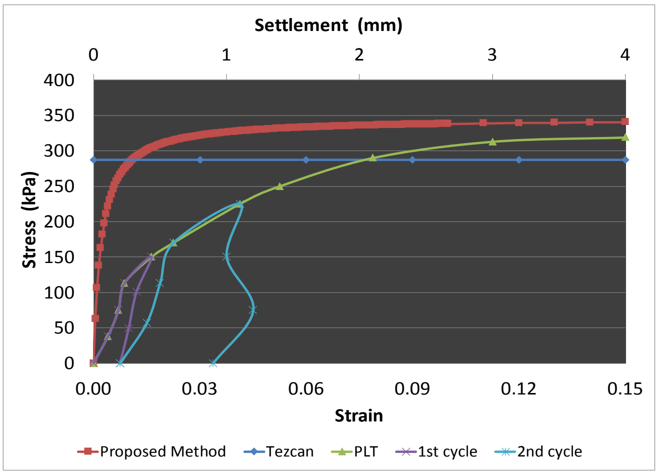
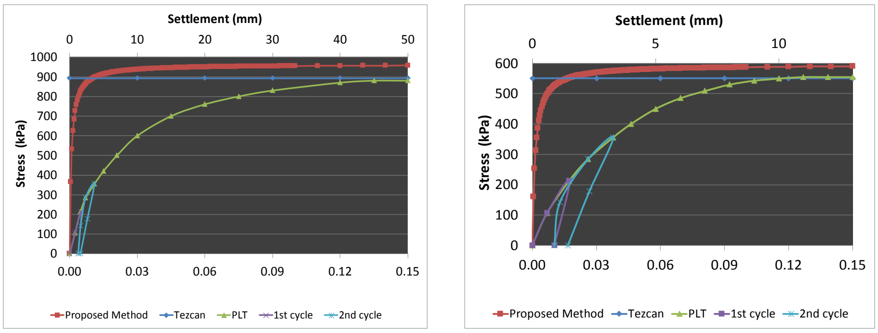


Fig. 5. Comparison of bearing capacity at Cyberjaya including PLT cycles.



(a) Subang Point 1 **(b) Subang Point 2**

Fig. 6. Comparison of bearing capacity.

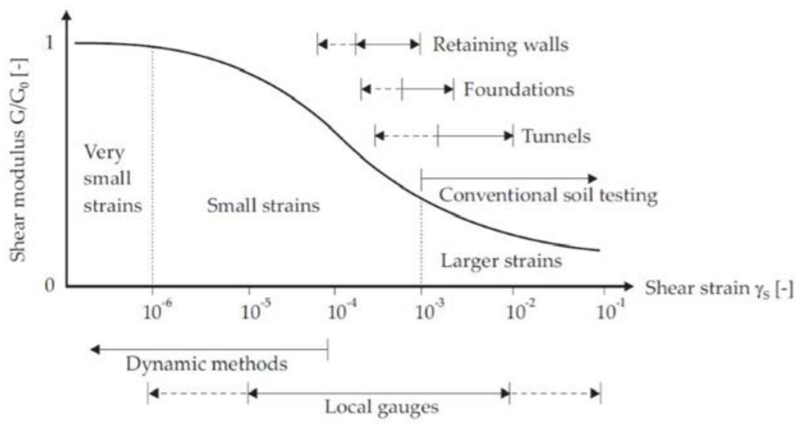


Fig. 7. Modulus and shear strain based on geotechnical method [19].

4. Conclusion

Based on description of result, proposed method shows a good agreement with the conventional PLT and empirical equation establish by Tezcan [17] with a different not more than 10 percent. The main limitation of the proposed method is it requires expert and trained personnel in conducting the test and perform overall analysis. Further comparison between other methods could be made to discover wider applicability of the proposed method.

Nomenclatures

D	Damping
D_{max}	Maximum damping, 0.33
E_0	Elastic Young's modulus
G_0	Elastic shear modulus
q_u	Ultimate bearing capacity
V_s	Shear wave velocity, m/s

Greek Symbols

γ	Shear strain
ε	strain
ε_r	Reference or characteristic strain
μ	Poisson's ratio
ρ	Density
σ	Normal Stress
τ	Shear stress

Abbreviations

SASW	Spectral Analysis of Surface Waves

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