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COMPUTATIONALPROGRAM FOR EVALUATING PRESSUREMETER TEST RESULTS OF CLAY SOIL

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ABSTRACT: Pressuremeters are often used in applications to test soils onsite; major developments for these devices are related to methods of manufacturing and analytical solutions to enable operation with different types of soils. In this study, pressuremeter tests were conducted in situ to obtain information on the horizontal at-rest pressure, elastic modulus, undrained shear strength, limit pressure, and horizontal coefficient of consolidation. Owing to the increasing importance of pressuremeter test results and their applicability in determining the engineering properties of soils, different methods and theories have been used to analyze and interpret pressuremeter parameters; many of the assumptions for these parameters reflect the uncertainties of soil properties: some assumptions are that the soil is elastic perfectly plastic and that the tests ensure plain strain conditions; furthermore, horizontal at-rest and limit pressures are critical to the design of foundations. A computational program was thus developed to explore the results of conventional and theoretical limit pressures using different analysis methods. This program was intended to simplify the methods used to determine the conventional and theoretical limit pressures without obtaining the curves necessary for determining the various parameters used in the conventional analysis; moreover, the program could unify the metrics used in the different analysis methods. Using the proposed program, the results of the conventional and theoretical limit pressures were shown to have distinct differences when using different analysis methods.

Keywords: Site investigation, Conventional limit pressure, Theoretical limit pressure, Pressuremeter

1. INTRODUCTION

Laboratory-based testing for soil samples is generally affected by previous disturbances and activities such as boring operations, sampling, transportation, removal from the sampler, stress relief, and trimming. For more realistic measurements, in-situ testing would be beneficial because it can reduce or eliminate these disturbances. In this context, pressuremeter testing has garnered interest and has been applied in on- site investigations and foundation designs to predict useful parameters. Moayed, Kordnaei, and Mola-Abasi [1] used the limit pressure to calculate the settlement and bearing capacities of foundations. They proposed various empirical relationships to correlate the limit pressure and modulus with other soil parameters, such as moisture content, plasticity index, and SPT counts (N_{60}). Tezel, Hacialioglu, Onal, and Ozmen [2] compared the results of pre-bored and high-pressure pressuremeter tests on soil samples in the construction of a high-rise tower project; they concluded that the net limit pressure values that could be obtained through the HyperPAC test were higher than those obtained using the Menard pressuremeter. Lukas [3] used the Menard pressuremeter to predict the limit pressures of different types of soils to evaluate their settlement; through experience, reliable data that allowed more reliable settlement predictions were obtained. Agan and Algin [4] conducted several pressuremeter tests in clay soil and used nonlinear regression analysis to generate an empirical equation relating the shear strength obtained from unconfined shear strength tests with the limit pressure deduced from pressuremeter testing; they concluded that the equation based on nonlinear regression analysis could be useful for similar soils. Ahmadi and Keshmiri [5] presented a numerical finite difference model of a self-boring pressuremeter (SBPM) test using the FLAC software. Therefore, determination of the limit pressure requires additional investigation. It was suggested that cavity pressure at 10% strain (P_{10}) should be used instead of the limit pressure for interpretation of the in situ horizontal stress from the SBPM test. AlZubaidi [6] developed a new method for analysis of the at-rest horizontal pressure (P_o), known as the "stress relief method." The analysis of a cylindrical cavity in elastic perfectly plastic soil is taken as the reference state, and the size of the pressuremeter cavity at the point where the pressure in the cavity is equal to the in situ horizontal stress in the surrounding soil is measured. Recognition of this point during examination of the data from the pressuremeter test is often difficult. Hamidi, Varaksin, and Nikraz [7] studied the established empirical relationships between the limit pressure and Menard modulus and concluded that the limit pressure method was practically able to provide accurate Menard modulus values.

Monnet [8] theorized the interpretation of pressuremeter tests from cohesive soil and its extension to conventional limit pressures. Monnet computed the conventional limit pressure using the Plaxis program to validate the theoretical results. Frikha and Bouassida [9] investigated the ultimate bearing capacity of an isolated column by combining a stressed state with a failure mechanism through lateral expansion in a cylindrical cavity; they used analytical and empirical methods to determine the limit pressure. The present study discusses the development of a computer program to evaluate the theoretical and conventional limit pressures using different methods. All the metrics used in these different methods have thus been unified.

2. PRESSUREMETER TESTS

The site for conducting the pressuremeter tests was located on Baghdad–Kut road at the proposed site of Al-Rashid University. The soil consisted mainly of brown silty clay layers with different consistencies and gypsum contents; the analysis and application of the computer program in the present study were performed as per Al-Kanim [10], using the test results of Al-Rawi [11]. Menard pressuremeter tests were conducted at this site, and Fig. 1 shows the pressure increment with volume changes recorded 60 s after the application of pressure. The pressure readings recorded during the tests were adjusted to compensate for both the head of water in the central cell tubing of the probe and the inertia of the rubber.

3. COMPUTER PROGRAM

The computer program was designed to predict the values of the horizontal at-rest pressure and limit pressure using different interpretation methods. The program evaluates the horizontal at-rest pressure using the inflection point method and predicts the conventional and theoretical limit pressures using five and three methods respectively. The methods used to evaluate the conventional limit pressure are as follows:

1- Expansion P-ΔV curve method.
2- Upside-down curve method.
3- P-ln (ΔV/V) method
4- Relative volume method
5- Log–log method

The methods used to evaluate the theoretical limit pressure are as follows:

1- Upside-down method
2- P-1/ε_o method
3- P-ln (ΔV/V) method

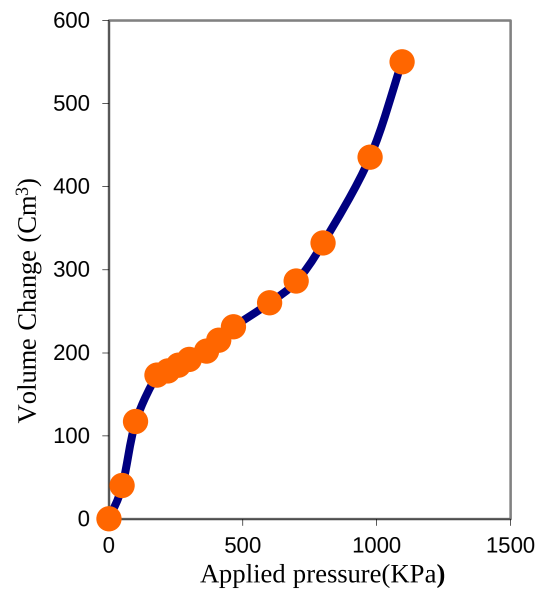

Fig. 1 Pressuremeter test curve for the Al-Rashid University site (Al-Rawi, 1985)

4. RESULTS FOR CONVENTIONAL LIMIT PRESSURE

The values of the conventional limit pressures were determined using the five analysis methods mentioned in Section 3, and the results are shown in Figs. 2–5 for four boreholes (BHs) with different depths. It was observed that the P-ΔV method predicted higher values for conventional limit pressure, whereas the upside-down curve and P-ln (ΔV/V) methods produced lower values; the log–log and relative-volume methods produced intermediate values. The values of the conventional limit pressure in BH No. 87 (Fig. 2) determined using the P-ΔV method are higher than those determined using the upside-down curve, P-ln (ΔV/V), log–log, and relative-volume methods in the ranges of 5–48%, 1–48%, 3–24%, and 5–25%, respectively. The same trends as those found in BH No. 62 are seen in Fig. 3, where the values of the conventional limit pressure determined using the P-ΔV method are higher than those determined using the upside-down curve, P-ln (ΔV/V), log–log, and relative-volume methods in the ranges of 1–42%, 1–36%, 0.5–19%, and 0.4–20% respectively. In Fig. 4, the values of the conventional limit pressures at BH No. 61 determined using the P-ΔV method are higher than those determined using the upside-down curve, P-ln (ΔV/V), log–log, and relative-volume methods in the ranges of 4–28%, 4–29%, 3–26%, and 3–16%, respectively. At BH No. 92, the results of the conventional limit pressures obtained using different methods are as shown in Fig. 5; the values obtained using the P-ΔV method are higher than those obtained using the upside-down curve, P-ln (ΔV/V), log–log, and relative-volume methods in the ranges of 2–25%, 3–24%, 3–26%, and 0.5–14%, respectively. Manual calculations of the conventional limit pressures agreed well with the results obtained using the computer program for all methods of interpretation.

5. RESULTS FOR THEORETICAL LIMIT PRESSURE

The values of the theoretical limit pressures were computed using the three analysis methods mentioned in Section 3, and the results for the four boreholes are shown in Figs. 6–9. As can be seen from the results, the values of the theoretical limit pressures determined using the P-ln (ΔV/V) method are slightly higher than those obtained using the other two methods in BH No. 87, as shown in Fig. 6; the values obtained using the P ln (ΔV/V) method are higher than those obtained using the upside-down and P-1/ε_o methods in the ranges of 2–17% and 3–12%, respectively.
Fig. 7 presents the results at BH No. 62. The results of the theoretical limit pressures obtained using the P-ln (ΔV/V) method are higher than those obtained using the upside-down and P-1/ε_o methods in the ranges of 9–12% and 2–11%, respectively. The results of the theoretical limit pressures at BH No. 61 obtained using the P-ln (ΔV/V) method are shown in Fig. 8; these values are higher than those obtained using the upside-down and P-1/ε_o methods in the ranges of 3–21% and 2–13%, respectively. The same trends can be observed at BH No. 92, as shown in Fig. 9; the values of the theoretical limit pressures obtained using the P-ln (ΔV/V) method are higher than those obtained using the upside-down and P-1/ε_o methods in the ranges of 4–15% and 1–8% respectively. Manual calculations of the theoretical limit pressures were in agreement with the results obtained using the computer program for all analysis methods.

6. CONCLUSIONS

This study focused on the development and analysis of a new computer program to analyze pressuremeter test data to calculate the values of the conventional and theoretical limit pressures using different analysis methods. Based on the results obtained, the following conclusions can be drawn:

1- The computer program developed herein using different analysis methods can unify the metrics used in these methods.

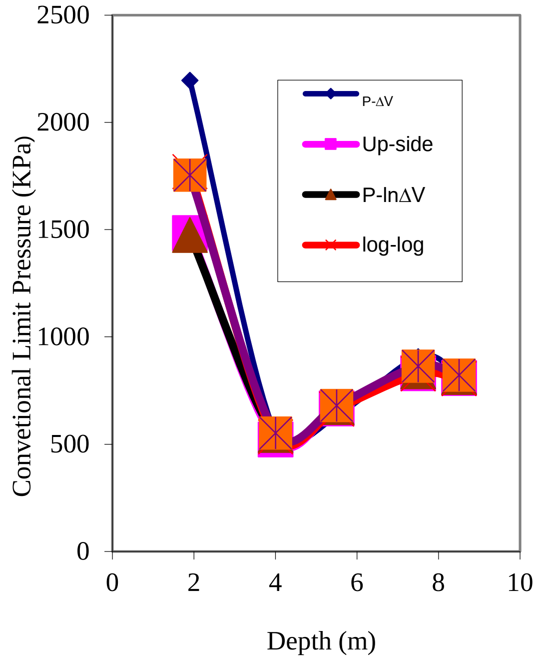

Fig. 2 Conventional limit pressures obtained using different methods at BH No. 87

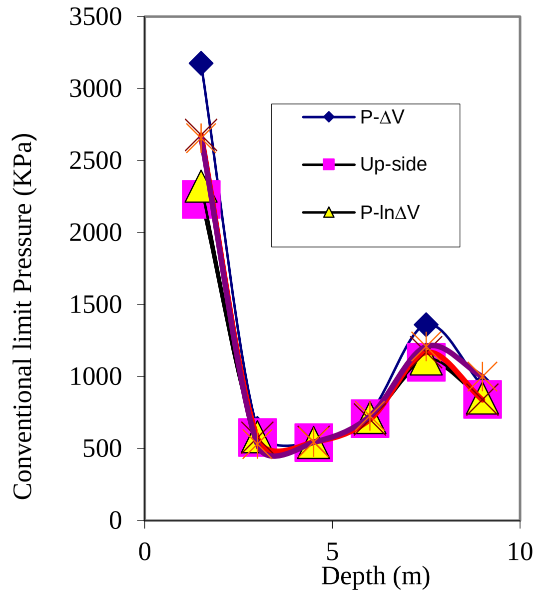

Fig. 3 Conventional limit pressures obtained using different methods at BH No. 62

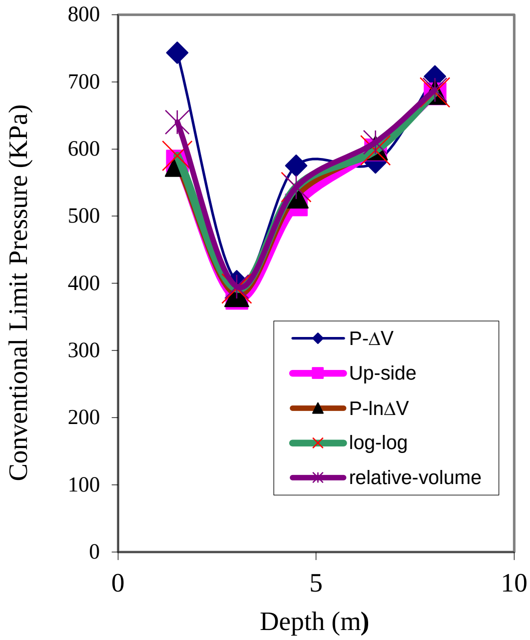

Fig. 4 Conventional limit pressures obtained using different methods at BH No. 61

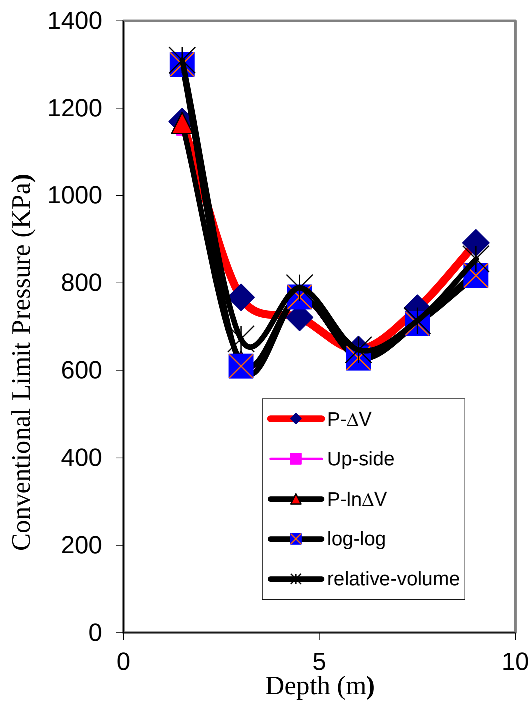

Fig. 5 Conventional limit pressures obtained using different methods at BH No. 92

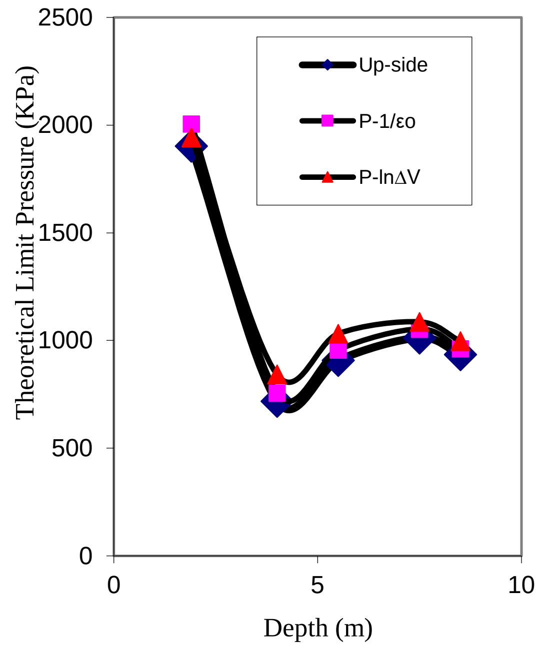

Fig. 6 Theoretical limit pressures obtained using different methods at BH No. 87

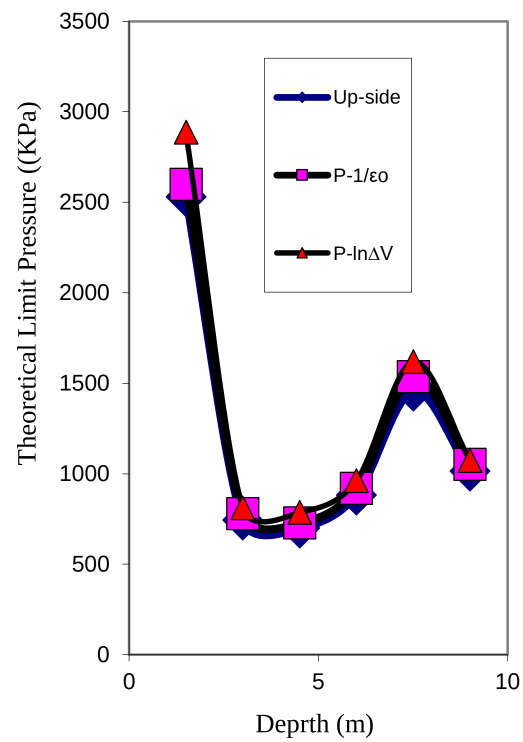

Fig. 7 Theoretical limit pressures using different methods at BH No. 62

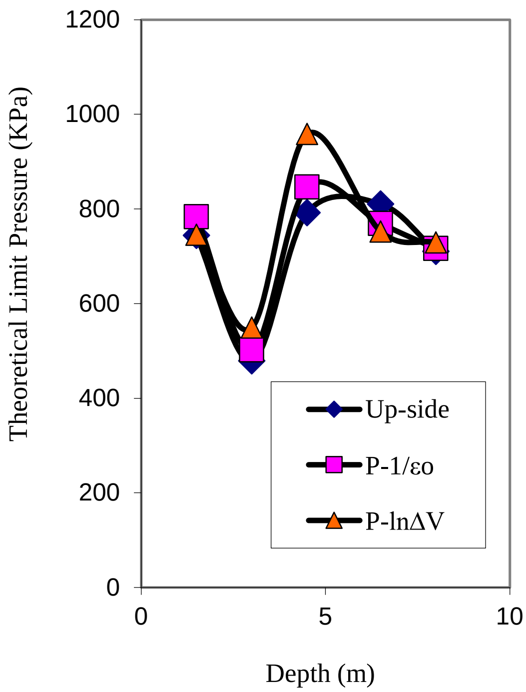

Fig. 8 Theoretical limit pressures using different methods at BH No. 61

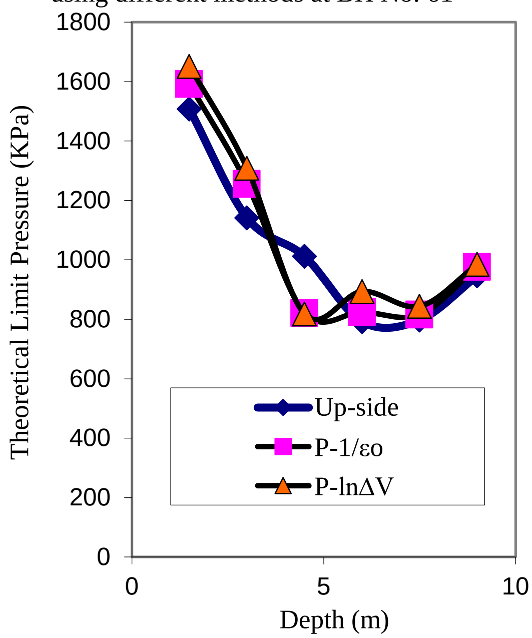

Fig.9 Theoretical limit pressures using different method s at BH No. 92

2- Manual calculations were performed to estimate the values of the conventional and theoretical limit pressures to validate the computer program, and the results are observed to be consistent.
3- The conventional limit pressures were determined using five methods with data from four boreholes in brown silty clay soil.
4- The values of the conventional limit pressures obtained using the P-ΔV method were higher than those obtained using the upside-down curve, P-ln (ΔV/V), log–log, and relative-volume methods in the ranges of 1–48%, 1–48%, 0.5–26%, and 0.4–25%, respectively.
5- The theoretical limit pressures were determined using three methods with the data of the same four boreholes and soil as those used in the conventional case.
6- The values of the theoretical limit pressures determined using the P-ln (ΔV/V) method were higher than those determined using the upside-down and P-1/ε_o methods in the ranges of 2–21% and 1–13%, respectively.

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