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Correction of SPT (Standard Penetration Test) between Comparison of Energy Measurement in the Field and Seed Method (1985)

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Abstract. The use of *the Standard Penetration Test* (SPT) method has a very important role in the field of geotechnical engineering, especially in obtaining information related to soil characteristics under the surface. The data obtained from the SPT test is widely used in various applications, one of which is slope stability analysis, especially in areas with high potential for landslide disasters. This research was conducted as a form of the author's scientific contribution in highlighting the difference in energy produced by the SPT tool in the field compared to the results of the theoretical calculation approach. The research methodology includes the collection of data from the results of tax return testing in the field, which is then analyzed using the calculation method of the Seed method (1985). In the energy measurement in the field, *the energy ratio* (ER) was obtained of 56.3-77.7%. The average energy measurement at the BH-1, BH-2, and BH-3 test points was obtained at 70.9% each; 70.4%; and 64.8%. The results of the correction comparison showed the difference between the energy return from the energy measurement test in the field and the theoretical calculation. At depths of 0-10m it is 7-32% and at depths of 10-20m it is 7-15%. Corrections using the Seed method (1985) showed a relatively higher error rate compared to the results of direct energy measurements in the field. Taking this into account, the use of energy data obtained directly is considered more representative of actual conditions in the field and more reliable in the correction value of tax returns.

Keywords : *Standard Penetration Test*; Energy Measurement SPT; Seed Method

INTRODUCTION

Testing with *standard penetration test* (SPT) is quite popular and widely applied in the geotechnical field. The SPT test was carried out by freely dropping a hammer weighing 63.5 kg from a height of 76 cm, thus pushing the standard penetration tool into the ground (Ji et al., 2023). The energy that falls depends on several factors such as the type of hammer, operator, SPT testing method, drill pipe length and test depth, so some researchers recommend standardizing the SPT energy efficiency ratio of 60% as a benchmark (Schmertmann & Palacios, 1979; Seed et al., 1985). Seed et al. (1985) recommend the correction of energy from the SPT test which is hereinafter referred to in this article as the Seed (1985) method.

According to Adam (1971), it shows that *stress wave* consistency can be used in predicting the force and speed of the SPT drill rod. Schmertmann & Palacios (1979) used *wave theory* to analyze the SPT *stress wave measurement*. Morgano & Liang (1992) adopted *accelerometers* and *strain gauges* used for SPT testing systems. Because they measured the impact velocity and *stress wave (FV) energy*, the reduced fall height did not affect their conclusions. There is a significant difference between *hammer impact energy* and *stress wave energy* associated with drill rod length, thus increasing the benefits of *stress wave measurement* and reducing the importance of *impact velocity*.

This article discusses the difference between the results of correction of SPT-N using direct energy measurement in the field and the Seed method (1985). Measurements were taken in the Petobo landslide area, Palu with the measurement location shown in Figure 1. In this study, the energy measurement of SPT using *SPT Analyzer* products from *Pile Dynamics, Inc.* The measured energy will be automatically recorded in the logger.

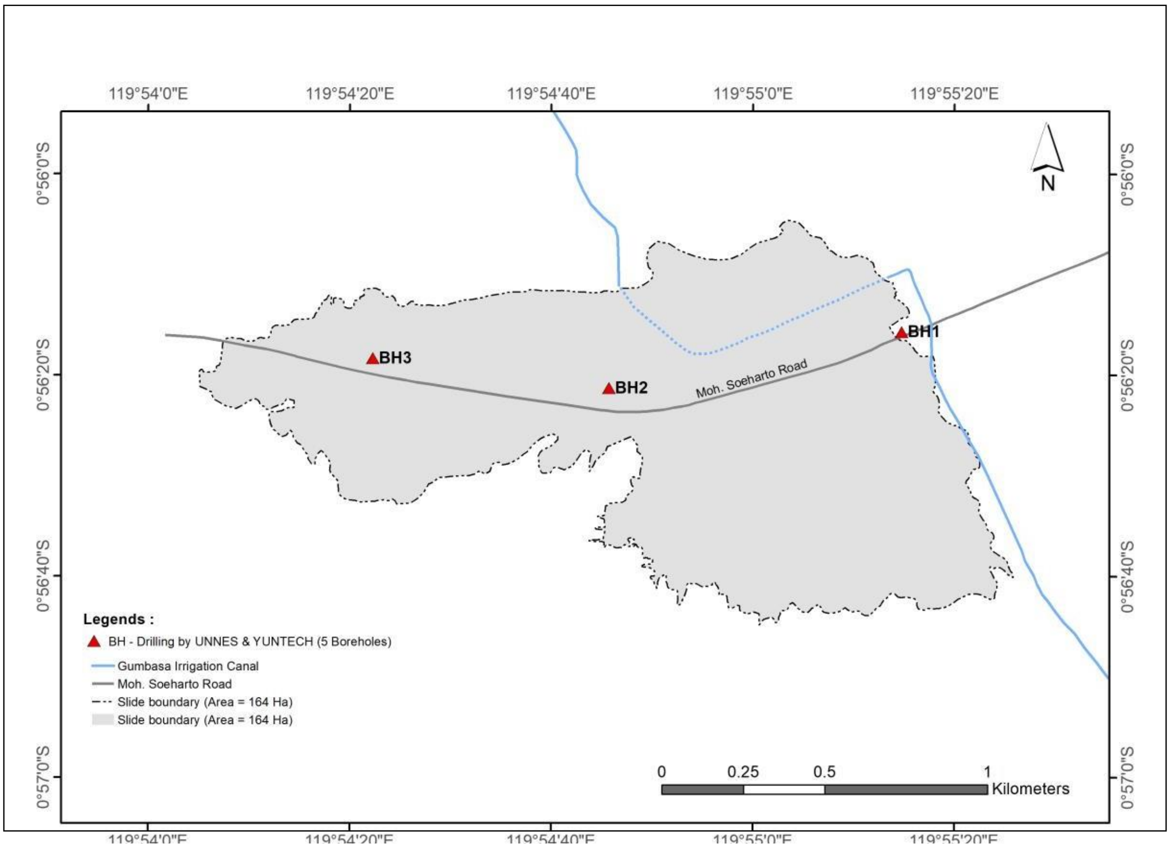

FIGURE 1. Location of drilling points and SPT testing

METHOD

In general, the equation of the energy efficiency ratio can be seen in the following equation:

$$N60 = \frac{ER}{60} \times N \quad (1)$$

with N60 = the standard penetration test that has been corrected against energy (blows/feet) and N = the number of strokes resulting from the SPT test (blows/feet).

Correction to the energy value can be made by measuring energy directly in the field using *accelerometers* and *strain gauges* or referring to the Seed method (1985).

In addition to corrections to energy, tax returns also need to be corrected to *overburden pressure*. The concept of N1 is the value of the tax return that is corrected to *the overburden pressure* (Seed, 1987). The equation of the tax return value after being corrected for *overburden pressure* and energy is shown in equation 2.

$$(N1)_{60} = N.\ CN.\ 60\% \quad (2)$$

with $(N1)_{60}$ = standard penetration test of corrected N values for energy and overburden stress (blows/feet), CN = correction of overburden pressure *voltage factor.*

The CN value commonly used for correction of *overburden pressure* refers to the equation proposed by Liao and Whitman (1986) as seen in equation 3.

$$C_N = \left(\frac{Pa}{\sigma'_{VC}}\right)^{0.5} \leq 1.7 \quad (3)$$

According to Seed et al. (1985) in determining $(N_1)_{60}$, the calculation was carried out using the N-SPT correction factor. To get the value, the following formula is used:

$$(N1)_{60} = CN \times CE \times CB \times CR \times CS \times N \quad (4)$$

with CN = Normalization factor N to *overburden pressure,* CE= correction factor of *hanmmer energy ratio,* CB= correction factor of drill hole diameter, CR=correction of drill rod length, CS= correction factor of sample, N= SPT-N (blows/feet)

TABLE 1. N-SPT Correction Factor
(Youd et al., 2001)

Factor	Equipment variables	Symbol	Correction
Overburden pressure	-	CN	
Overburden pressure	-	CN	
Energy Ratio	Doughnut Hammer	CE	0.5-1.0
Energy Ratio	Safety Hammer	CE	0.7-1.2
Energy Ratio	Automatic-trip-Doughnut type Hammer	CE	0.8-1.3
Borehole diameter	65-115 mm	CB	1
Borehole diameter	150 mm	CB	1.05
Borehole diameter	200 mm	CB	1.15
Rod Length	<3 mm	CR	0.75
Rod Length	3-4 mm	CR	0.8
Rod Length	4-6 mm	CR	0.85
Rod Length	6-10 mm	CR	0.95
Rod Length	10-30 mm	CR	1
Sampling method	*Standard sampler*	CS	1
Sampling method	*Sampler without Liners*	CS	1.1-1.3

Figure 2 shows the drilling process of SPT testing with energy measurement. Drilling uses a core barrel with a size of 76mm. The SPT test is carried out using a rope with *a doughnut hammer* and manually dropped, resulting in a non-constant fall height. Under the anvil, a pipe is installed with *accelerometer* sensors and *strain gauges* and connected to a *logger* so that the data obtained will be recorded automatically. When *the hammer* is dropped from a height of 76 cm, then the energy can be estimated from the *accelerometer sensor* and *strain gauges.*

FIGURE 2. Field Tax Return Testing: (A) Doughnut Hammer; (B) Ram Energy (Upomo & Chang, 2023)

In this study, researchers took SPT-N data in the Petobo Village area, Palu City, Central Sulawesi. As a limitation of the problem, it is specified that the diameter of the analyzed pile is 65-115mm. In this study, the research process is divided into several stages, including the following:

- The data collection stage, this stage is the stage of collecting SPT-N field test data in the field by measuring energy. SPT-N was carried out at 3 points in the Petobo avalanche area, Palu City, Central Sulawesi.
- The analytical and data processing stage, this stage processes the data from energy measurements in the field and compares it with the theoretical calculations proposed by Seed (1985).
- The calculation of the error value is carried out by referring to the following equation:

$$\chi = \frac{(N1)_{60\ S.\ S.}(N1)_{60\ Seed(1985)})}{(N1)_{60measurement}} \times 100\% \quad (5)$$

with χ= total error, $(N1)_{60measurement}$= SPT-N result of overburden voltage correction and energy measurement in the field, $N(N1)_{60\ Seed(1985)}$ = SPT Seed method (1985)

RESULT

At the BH-1 point, energy data collection was carried out at a depth between 4.55 to 22.55 meters, with an average energy recorded of 70.9%. Meanwhile, in BH-2, measurements were carried out at a depth of 9.05 to 22.55 meters and produced an average energy value of 70.4%. For the BH-3 point, the test was carried out in a depth range of 6.05 to 22.55 meters, with an average energy obtained of 64.8%. In general, the measured energy value is more than 60%, there are only 3 data with a value of less than 60% as seen in Figure 3.

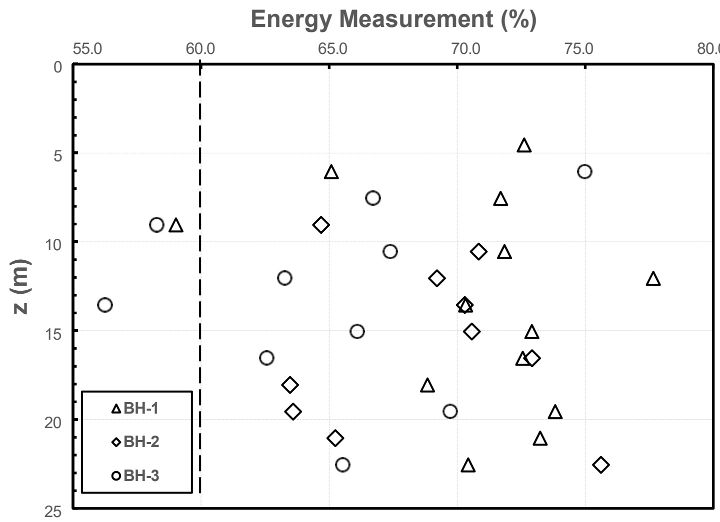

FIGURE 3. Energy measurements are made at the specified depth at the test point.

Energy measurement is directly considered as a reference in the comparison of the corrected SPT-N values against overburden and energy pressure. Energy correction refers to field testing, the Seed method (1985) and the average of energy measurements at drill points in BH-1, BH-2 and BH-3. Figure 4~6 is the result of a comparison between energy measurement in the field, the seed method (1985) and the average energy measurement.

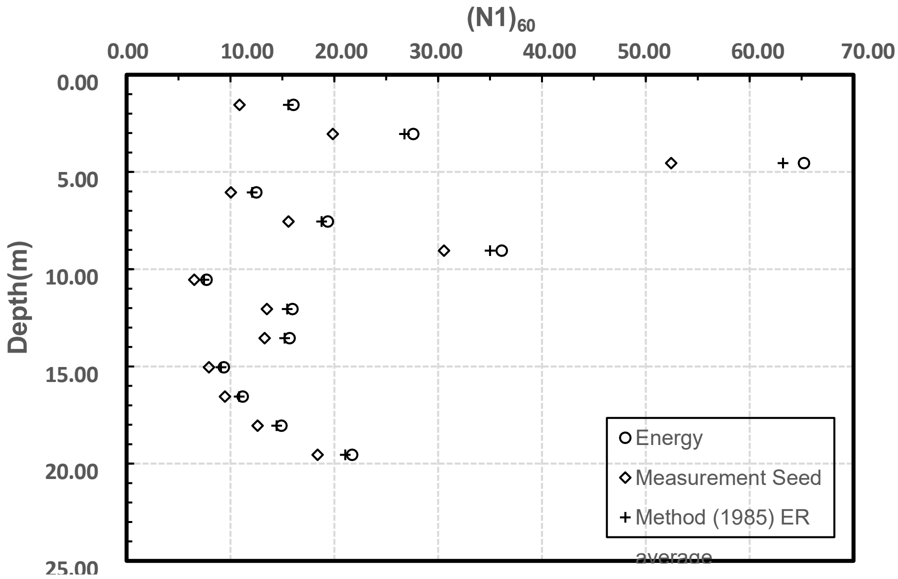

FIGURE 4. Value (N1)60 with energy measurement correction, Seed method (1985), and BH-1 mean energy correction

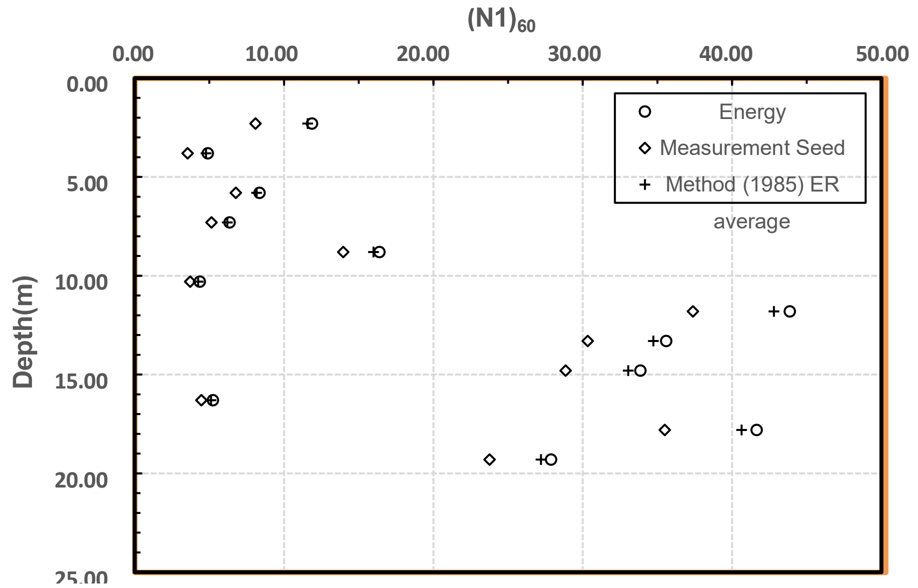

FIGURE 5. Value (N1)60 with energy measurement correction, Seed method (1985), and BH-2 mean energy correction

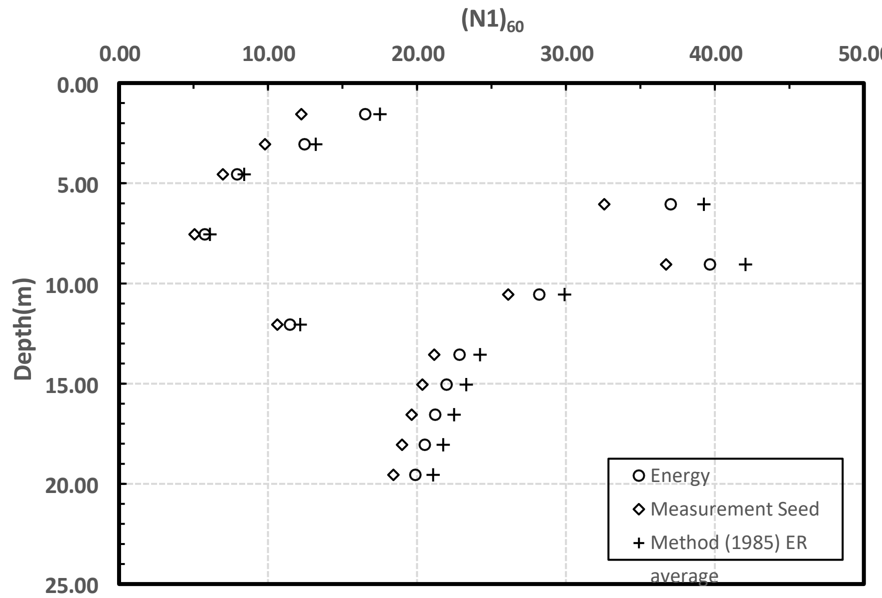

FIGURE 6. Value (N1)60 with energy measurement correction, Seed method (1985), and BH-3 mean energy correction

Figure 4~6 shows the same trend in BH-1, BH-2 and BH-3. The correction using energy measurement gave a higher value of $(N_1)_{60}$ when compared to the Seed method (1985) and was quite close to the average energy correction. If the assumption that direct energy measurements are correct, then the error rate of the Seed (1985) method and the average approach on BH-1 with depths between 0–10 m ranges from 15% to 32%. Meanwhile, at a depth of 10–20 m, the *error* value reaches about 15%. In contrast, when comparing direct energy measurements with average energy, the *error* was relatively smaller, at about 3% for an overall depth of 0–20 m.

The value $(N1)_{60}$ at the BH-2 point that the value at a depth of 0–10 m indicates the error rate of the Seed method (1985) and the average approach at a depth of 10–20 m is in the range of 14% to 31%, while at a depth of 10–20 meters, the error value recorded reaches 14%.

When compared to the average value of energy, the direct energy measurements show a much smaller error rate, which is about 2% for the entire depth of 0-20 m

The value of $(N1)_{60}$ at the BH-3 point at a depth of 0–10 m in a comparison between the values from direct energy measurements and the Seed (1985) method showed an error rate of between 25% to 7%. Meanwhile, for a depth of 10–20 m, the *error* difference was recorded at 7%. However, when compared to the average value of energy, direct energy measurements show a much smaller error rate, which is about -6% at depths of 0–20 m.

CONCLUSION

Field energy measurements on the Standard Penetration Test (SPT) test show that the actual energy value that occurs during the test can differ significantly from the theoretical assumed standard energy value by 60%. From the data obtained at three test points, namely BH-1, BH-2, and BH-3, it can be seen that the energy recorded in the field ranges from 56.3% to 77.7%. This shows that there is considerable variation in the energy measured.

The increase in energy value has a direct impact on the results of the tax return value obtained. The higher the percentage of energy given into the ground, the smaller the value of the hit recorded. The results of the analysis of the correction of SPT values with two approaches—direct energy measurement in the field and the theoretical correction method based on Seed (1985) showed a significant difference, especially at a depth of 0–10 meters. Corrections using the Seed method (1985) tend to produce greater errors when compared to energy measurements in the field. The error value recorded in the Seed (1985) approach ranged from 7% to 32%. Therefore, the assumption of energy in the Seed method (1985) is larger, which gives more conservative results, so in the tax return test it is better to measure the amount of energy for correction.

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