Comparison of C_N Values between SNI 4153:2008 with Other Methods in Standard Penetration Test

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Abstract. This study investigates the variability of overburden pressure correction factors (C_N) derived from SNI 4153:2008 and six widely used international methods based on Standard Penetration Test (SPT) data obtained from three investigation points. The objective is to evaluate how differences in C_N values influence bearing capacity and settlement analyses for building foundations. The results reveal substantial variation among the correction methods, with C_N values increasing from Peck et al. (1975) to Liao and Whitman (1986). The SNI 4153:2008 method consistently produces moderate C_N values, positioned between conservative and aggressive correction schemes. Higher C_N values lead to increased estimated bearing capacity but tend to underestimate soil settlement due to overestimation of stiffness. Conversely, lower C_N values yield more conservative bearing capacity and larger settlement predictions. The findings demonstrate that SNI 4153:2008 provides a balanced correction approach, producing reliable bearing capacity estimates while maintaining realistic settlement predictions. This balance supports its applicability as a national standard aligned with contemporary international geotechnical design practice

Keywords: Correction N values; standard penetration test; bearing capacity; settlement analysis; SNI 4153:2008.

1 Introduction

Civil engineering infrastructure design must begin with soil investigation work, both soil as construction material and soil as the final foundation. Soil as the final foundation of civil engineering buildings must have a reliable bearing capacity and subsidence that does not cause the building to collapse, such as buildings, highways, railways, bridges, dams, terminals, seaports, and airport runways (Das BM, 2019). The bearing capacity and settlement of the soil due to the construction of deep and shallow foundations must meet certain limit requirements so that the pressure that occurs does not exceed the allowable pressure of the soil at the base of the foundation (Pratama RT, 2021). The Standard Penetration Test (SPT) is a widely utilized field test for assessing soil engineering properties and evaluating geotechnical risks, such as soil liquefaction potential (Thakur IC, 2022 Dec 15)

Soil data for designing deep and shallow foundations can be obtained through laboratory and field tests. Laboratory tests include soil physical properties, such as water content (w,%), specific gravity (Gs), grain size distribution, liquid limit, plastic limit, shrinkage limit, unit weight, and engineering properties, such as shear strength (c and φ), compressibility, such as void ratio (e) preconsolidation pressure, (pc), compaction (maximum dry density and w

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optimimum), abrasion, California Bearing Ratio (CBR), and Unconfined Compression Test (UCT). In situ tests such as Standard Penetration Test (SPT), Cone Penetration Test (CPT), Pressuremeter Test (PMT), Vane Shear Test (VST), Dynamic Penetration Test (DCP), LWD (Light Deflectometer Test), Plate Load Test (PLT). The field soil investigation method used depends on design needs, field conditions, and availability of testing equipment [, 6], [7], [8].

One of the most widely used field soil investigation methods is the Standard Penetration Test. Several reasons can be put forward, namely easy to mobilize, affordable costs, easy to operate, and more importantly, SPT test data can be used to meet various design needs [9]. Field data obtained through SPT includes the depth of the soil layer, the N-SPT value of the spade field at a depth of 45 centimeters for every 15 centimeters, disturbed soil samples for laboratory testing [3] , [4]

The N-SPT field data obtained is not directly used for designing building foundations. The N-SPT value is first corrected for the hammer energy (C_E), rope length (C_R), borehole diameter (C_B), and split spoon sampler or split barrel sampler (C_S) so that the field N data becomes N_{60}. Effective overburden pressure plays a major role in calculating the corrected N value (C_N) to obtain the value $(N_1)_{60}$ (Yusof NQ, 2018).The methods often used to calculate the correction factor (C_N) to obtain the value $(N_1)_{60}$, namely the Liao & Whitman (1986), Skempton (1986), Tokimatsu & Yoshimi (1983), Seed et al (1974), Peck et al (1975), Bazaraa (1967) method based on soil research (Victoria LC, 2020) and SNI 4153:2008 [7]

This research was conducted with the aim of comparing the C_N value of soil at the location of the Civil Engineering Laboratory Building Construction of the Catholic University of Indonesia, Santu Paulus Ruteng between SNI 4153:2008 and the Liao & Whitman (1986), Skempton (1986), Tokimatsu & Yoshimi (1983), Seed et al (1974), Peck et al (1975), Bazaraa (1967) methods based on SPT and how the variation in CN value affects the analysis of bearing capacity and soil settlement due to building foundations.

2. Methodology

This research was conducted at the location of the Civil Engineering Laboratory Building Construction of the Catholic University of Indonesia, Santu Paulus Ruteng, at 3 points as shown in Figure 1.

Fig 1. Site research (S: $8^0$36’49.56   E: $120^0$28’13.356)

2.1. Research process

Field testing using SPT equipment is the initial stage carried out to obtain the N_{field} or N_M. The value in question is corrected against the length of the rope, hammer, diameter of the split spoon sampler to obtain the N_{60} value, then a correlation is carried out to obtain the value of the soil unit weight and overburden pressure. The N_{60} value needs to be corrected according to the formula SNI 4153:2008, Skempton (1986), Peck et al (1974), Tokimatsu & Yoshimi (1983), Seed et al (1975), Bazaraa (1967), and Liao & Whitman (1986) to obtain the corrected N (C_N) value and then compare it. For more details, see the flowchart in Figure 2.

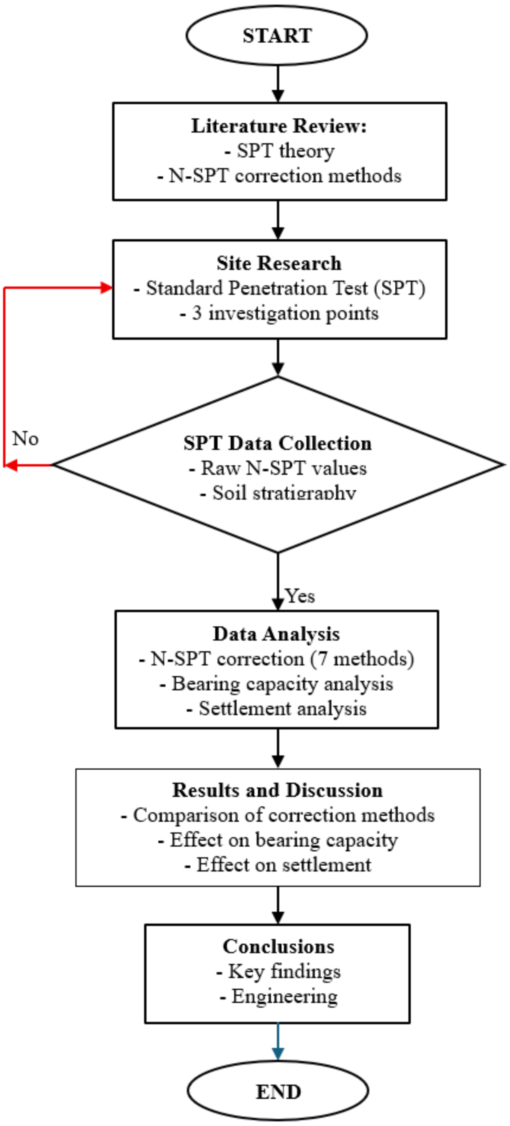


Fig 2. Research flowchart

The study began with a literature review aimed at synthesizing established theories, design standards, and recent research related to the Standard Penetration Test (SPT). Particular emphasis was placed on commonly used N-SPT correction methods and their application in evaluating bearing capacity and soil settlement. This stage provided the conceptual framework and identified research gaps addressed in the present study.

The next stage involved site research, which focused on acquiring in-situ soil data through field investigations. Standard Penetration Tests were conducted at three selected locations to capture the variability of subsurface conditions across the study area. These test locations were determined based on site accessibility and the representativeness of soil strata. Following field investigations, SPT data collection was carried out by compiling raw N-SPT values, soil stratification, and groundwater level information. These parameters served as the primary input data for subsequent analyses and ensured consistency in data processing across different correction methods.

The Standard Penetration Test (SPT) was performed at three investigation points to achieve a balance between geotechnical reliability and practical constraints of field investigation. The selection of three test locations is consistent with common geotechnical investigation standards for small to medium-scale construction projects, where lateral soil variability is expected to be limited. These points were positioned to capture representative subsurface conditions by considering site geometry and structural load distribution. The resulting SPT data provide a sufficient basis for evaluating soil stratigraphy and engineering properties. Therefore, the three-point SPT layout can be considered statistically and spatially representative for foundation capacity and settlement analyses.

In the data analysis stage, raw N-SPT values were adjusted using seven different correction methods to obtain corrected N (C_N) values. Variations in C_N values influence the estimation of soil shear strength and deformation characteristics. Higher C_N values generally lead to higher calculated bearing capacity and lower predicted settlement, while lower C_N values result in more conservative bearing capacity estimates and increased settlement predictions. This stage evaluated the sensitivity of bearing capacity and settlement analyses to changes in C_N values and highlights the engineering significance of selecting appropriate correction methods.

Finally, the results and discussion stage presented a comparative assessment of bearing capacity and settlement outcomes derived from each correction method. The conclusions summarize key findings, emphasize the impact of C_N variation on foundation performance, and provide recommendations for geotechnical design practice and future research.

2.2. Overview of SPT apparatus and testing procedures

The SPT equipment used is manual SPT, with equipment parts including a tripod, rod with a length of 12 meters, hammer weight 63.50 kg, split spoon sampler diameter 50 mm (60 mm borehole diameter), and anvil, as seen in Figure 3. The testing procedure is based on the provisions of ASTM D1586 and SNI 4153:2008, namely at every change in soil layers or at intervals of approximately 1.50 m to 2.00 m or as required. Pull the hammer strap until it reaches the mark that has been made (approximately 76 cm), then freely drop a load of 63.50 kg until it hits the load holder on the conductor rod. Repeat the pounding until the first 15 cm penetration (N_1), the second 15 cm (N_2), and the third 15 cm (N_3) are achieved. The number of strokes counted is $N_2 + N_3$. The N_1 value is not taken into account because it is still dirty from drilling; If the N value is greater than 50 strokes, stop the test and increase the test to a minimum of 6 meters.

2.3. N-SPT calculation

Calculation of field N value, N_{60}, soil unit weight, effective overburden pressure, N value correction factor (C_N) and soil profile depiction using Microsoft Excel 2010 media based on the following formulas [17], [18], [19], [20], [21], [22], [23]:

$$N_{field} = N_M = N_2 + N_3 \quad \text{……………………………………………..……….........……} \quad (1)$$

Where:

N_M : Measured N or N field
N_2 : N value for the second 15 cm
N_3 : N value for the third 15 cm.

$$N_{60} = \frac{N_M . E_H . C_B . C_S . C_R}{60} \quad \text{………………………..………………………........…………} \quad (2)$$

Where:

N_{60} : 60% N_{field} (N_M)
N_M : Measured N
E_H : Hammer energy efficiency
C_B : Borehole diameter correction factor
C_S : Split spoon sampler correction factor
C_R : Rod length correction factor

Submerged unit weight, $\gamma_{submerged}$ (kN/m^3):

$$\gamma_{submerged} = 8.8 + 0.01 N_{60} \text{ (kN/m}^3\text{)} \quad \text{……………………………..………………...…..} \quad (3)$$

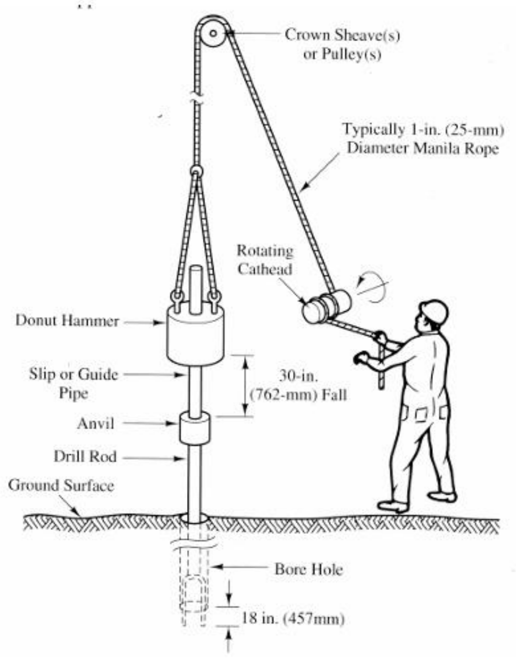


Fig 3. SPT equipment (ASTM D1586) & SNI 4153:2008

2.4 The effecetive overburden pressure, σ'_v

$$\sigma'_v = \gamma'_{submerged} . z \quad \text{……(4)}$$

Where z = 0.45 m.

$(N_1)_{60}$ and C_N

$$\left(N_1\right)_{60} = N_{60} . C_N \quad \text{……(5)}$$

SNI 4153:2008:

$$C_N = \frac{2.2}{\left(1.2 + \left(\frac{\sigma'_v}{p_a}\right)\right)} \quad \text{……(6)}$$

Where:

$(N_1)_{60}$	: corrected SPT value about energy efficiency 60%
C_N	: correction factor due to effective overburden pressure
σ'_v	: effective overburden pressure (kPa)
p_a	: athmospheric pressure 100 kPa

Skempton (1986):

$$C_N = \frac{2}{1+\left(\frac{\sigma'_v}{p_a}\right)} \text{ (for normally consolidated sand)} \quad \ldots\ldots (7)$$

Peck et al (1974):

$$C_N = 0.77\log\left(\frac{20}{\left(\frac{\sigma'_v}{p_a}\right)}\right) \quad \ldots\ldots (8)$$

Tokimatsu & Yoshimi (1983):

$$C_N = \frac{1.7}{0.7+\left(\frac{\sigma'_v}{p_a}\right)} \quad \ldots\ldots (9)$$

Seed et al (1975):

$$C_N = 1-1.25\log\left(\frac{\sigma'_v}{p_a}\right) \quad \ldots\ldots (10)$$

Bazaraa (1967):

$$C_N = \frac{4}{1+4\left(\frac{\sigma'_v}{p_a}\right)} \quad \ldots\ldots (11)$$

Liao & Whitman (1986) [24]:

$$C_N = \left[\frac{1}{\left(\frac{\sigma'_v}{p_a}\right)}\right]^{0.5} \quad \ldots\ldots (12)$$

Hammer energy efficiency (E_H) can be seen in Table 1 and borehole diameter (C_B), split spoon sampler (C_S), and rod length correction factor (C_R) in Table 2.

Table 1. SPT Hammer Efficiency [25], [26], [27]

Hammer Type	Hammer Release Mechanism	Efficiency, E_H
Automatic	Trip	0.70
Donut	Hand dropped	0.60
Donut	Cathead + 2 turns	0.50

Safety	Cathead + 2 turns	0.55 – 0.60
Drop/Pin	Hand dropped	0.45

Table 2. Borehole, Sampler, and Rod Correction Factor [25], [26], [27]

Factor	Equipment Variables	Correction Factor
Borehole diameter, C_B	65 – 115 mm	1.00
	150 mm	1.05
	200 mm	1.15
Split Spoon Sampler Correction, C_S	Standard Sampler	1.00
	Sampler without liner (not recommended)	1.20
Rod Length Correction, C_R	3 – 4 m	0.75
	4 – 6 m	0.85
	6 – 10 m	0.95
	‘> 10 m	1.00

2.5. Research novelty

This research offers novelty through a comparative analysis of corrected N-SPT (CN) values obtained from the application of seven different correction methods and their effects on geotechnical parameters. In foundation design practice, the selection of an N-SPT correction method is often made without considering the resulting variations in results. This study systematically examines the differences in C_N values produced by each correction method and their implications for soil characteristics. This approach allows for identification of the sensitivity of soil parameters to the correction method used. Thus, this research makes a novel contribution to clarifying uncertainties that have been under-recognized in the use of SPT data.

The next novelty lies in the evaluation of the impact of variations in C_N values on the results of the analysis of bearing capacity and soil settlement due to building foundation loads. Each corrected C_N value is used as the basis for calculating bearing capacity and estimating soil settlement, so that differences in design results can be analyzed quantitatively. The results of this study indicate that the choice of correction method has a significant impact on the safety and efficiency of foundation planning. This research is expected to serve as a reference in determining the N-SPT value correction method that best suits soil conditions and design needs.

3. Result and Discussion

3.1 N field

Soil investigations using SPT were carried out at 3 points (sites), namely Site 1 (S1), Site 2 (S2), and Site 3 (S3). The N measurement data ($N_{fielsd} = N_M$) and the results of the correction to the hammer energy (N_{60}) based on Formula Number (2) are read in Table 3.

Table 3. N_M and N_{60} S1, S2, S3

Depth (m)	N_M			N_{60}		
	S1	S2	S3	S1	S2	S3
0.00	0	0	0	0	0	0
0.45	5	6	4	5	6	4
0.90	10	6	6	10	6	6

1.35	15	8	5	15	8	5
1.80	14	12	7	14	12	7
2.25	15	15	9	15	15	9
2.70	18	20	15	18	20	15
3.15	25	28	26	25	28	26
3.60	32	30	33	32	30	33
4.05	24	34	37	24	34	37
4.50	33	30	36	33	30	36
4.95	32	38	38	32	38	38
5.40	22	37	34	22	37	34
5.85	25	29	44	25	29	44
6.30	28	31	45	28	31	45
6.75	35	33	47	35	33	47
7.20	42	36	45	42	36	45
7.65	41	40	47	41	40	47
8.10	43	41	51	43	41	51
8.55	55	52		55	52	-
9.00	66	-		66	-	-

Table 3 details the Standard Penetration Test (SPT) blow counts (NM) and energy-normalized values (N_{60}) at depths of 0.00–9.00 m from three sounding points (S1, S2, S3). The equality between NM and N_{60} indicates effective correction factors applied during testing, confirming standard procedure conditions. The results demonstrate that N-values increase with depth, signifying greater soil density and stiffness due to effective overburden stress. Shallow layers show low N-values (loose soil), while deeper layers have moderate to high N-values (medium-dense to dense soil). Variability in N-values at similar depths suggests lateral heterogeneity, with missing values at greater depths indicating either test refusal or the maximum investigation depth. Figure 4 illustrates the NM vs. depth relationship.

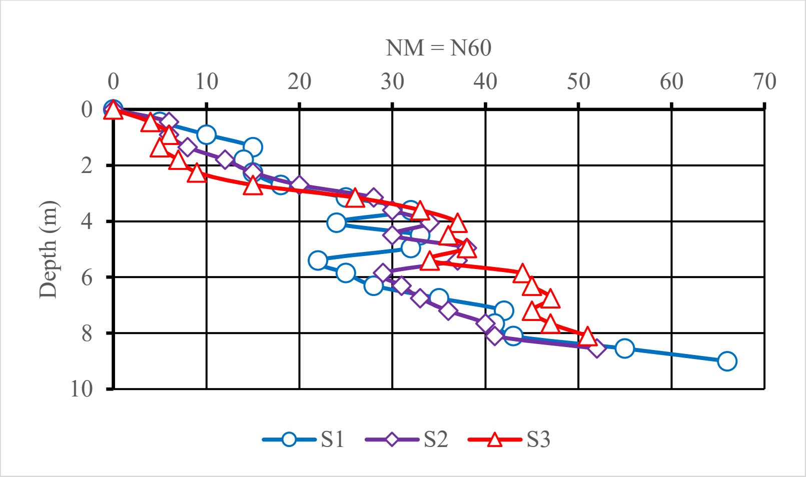


Fig 4. $N_M = N_{60}$ values S1, S2, and S3

Figure 4 illustrates the comparison between measured SPT blow counts (NM) and energy-corrected values (N_{60}) at S1, S2, and S3, showing their curves coinciding at all depths. This indicates the applied correction factors are nearly optimal, confirming near-standard test conditions. The increasing N-values with depth reflect higher soil density and stiffness due to greater effective overburden pressure. Variations in N-values at similar depths highlight lateral subsurface stratigraphy differences. The figure substantiates the reliability of SPT data for subsequent CN correction, bearing capacity assessment, and settlement analysis.

3.2 Submerged unit weight

Based on Formula Number (3), the submeged unit weight is obtained as shown in Table 4.

Table 4. Submerged Unit Weight ($\gamma_{submerged}$)

	$\gamma_{submerged}$ (kN/m^3)		
Depth (m)	S1	S2	S3
0.00	8.80	8.80	8.80
0.45	8.85	8.86	8.84
0.90	8.90	8.86	8.86
1.35	8.95	8.88	8.85
1.80	8.94	8.92	8.87
2.25	8.95	8.95	8.89
2.70	8.98	9.00	8.95
3.15	9.05	9.08	9.06
3.60	9.12	9.10	9.13
4.05	9.04	9.14	9.17

4.50	9.13	9.10	9.16
4.95	9.12	9.18	9.18
5.40	9.02	9.17	9.14
5.85	9.05	9.09	9.24
6.30	9.08	9.11	9.25
6.75	9.15	9.13	9.27
7.20	9.22	9.16	9.25
7.65	9.21	9.20	9.27
8.10	9.23	9.21	9.31
8.55	9.35	9.32	-
9.00	9.46	-	-

The submerged unit weight (γ') is crucial for analyzing bearing capacity and soil settlement in foundation design. Its increase with depth points to higher effective stress, enhancing soil shear strength and bearing capacity, particularly for shallow foundations in saturated conditions. The γ' profile is vital for calculating effective vertical stress and stress distribution, where higher values at greater depths indicate denser soils with lower compressibility, reducing settlement potential. In contrast, lower γ' values in shallow layers may lead to more significant settlement. Therefore, accurately estimating γ' with depth is essential for predicting foundation performance, ensuring safety and serviceability in civil engineering.

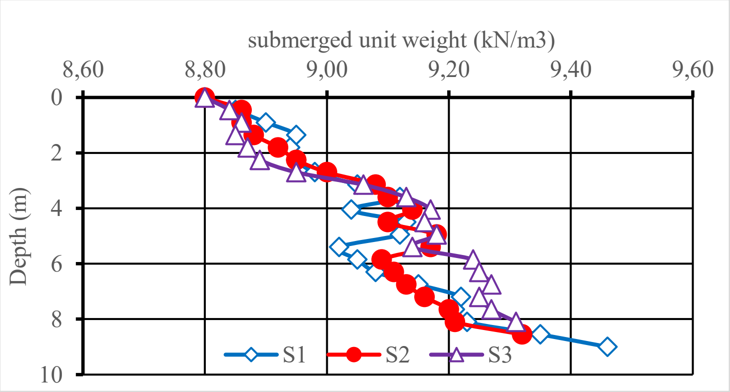


Fig 5. Submerged unit weight values S1, S2, and S3

Figure 5 illustrates the variation of submerged unit weight (γ') with depth for locations S1, S2, and S3, showing an upward trend in γ' values from the surface to deeper layers. This indicates an increase in effective overburden stress and soil density with depth, where near-surface layers are characterized by lower γ' values typical of looser saturated soils, while deeper layers exhibit higher γ' values linked to denser soil strata. Minor differences in γ' profiles among the locations highlight natural lateral heterogeneity in soil composition. Overall, the similarity of these curves suggests comparable subsurface conditions, confirming the γ' distribution necessary for effective stress calculations vital for estimating bearing capacity and analyzing settlement in foundation engineering design.

3.3. Effective overburden pressure

The effective overburden pressure is calculated according to Formula Number (4) and the results are shown in Table 5.

Table 5. Effective overburden pressure per layer

	σ'_v = po' (kPa)		
Depth (m)	S1	S2	S3
0.00	3.96	3.96	3.96
0.45	3.98	3.99	3.98
0.90	4.01	3.99	3.99
1.35	4.03	4.00	3.98
1.80	4.02	4.01	3.99
2.25	4.03	4.03	4.00
2.70	4.04	4.05	4.03
3.15	4.07	4.09	4.08
3.60	4.10	4.10	4.11
4.05	4.07	4.11	4.13
4.50	4.11	4.10	4.12
4.95	4.10	4.13	4.13
5.40	4.06	4.13	4.11
5.85	4.07	4.09	4.16
6.30	4.09	4.10	4.16
6.75	4.12	4.11	4.17
7.20	4.15	4.12	4.16
7.65	4.14	4.14	4.17
8.10	4.15	4.14	4.19
8.55	4.21	4.19	
9.00	4.26		

Table 5 indicates that the effective overburden pressure (p_o') increases with depth at SPT locations S1, S2, and S3, reflecting submerged unit weight under saturated conditions. The similarity in p_o' values suggests uniform stress and limited subsurface stratigraphy variation. In terms of bearing capacity, p_o' signifies the effective stress on foundations, enhancing soil shear strength and resistance through increased confinement. Conversely, in settlement analysis, it influences soil compressibility and stiffness, making accurate determination of p_o' vital for predicting foundation performance.

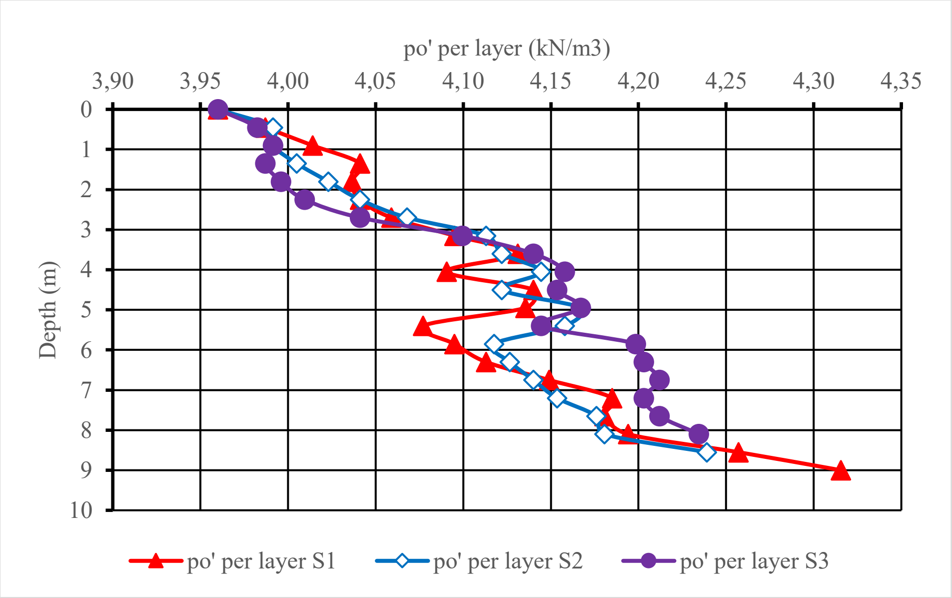


Fig 6. Effective overburden pressure values per layer S1, S2, and S3

Figure 6 illustrates the depth-dependent distribution of effective overburden pressure (p_0') at three investigation points, S1, S2, and S3, showing a nearly linear increase with depth due to the accumulation of submerged unit weight in saturated soil layers. Minor profile differences arise from variations in soil density and stratification, indicating uniform stress conditions across the site. This effective stress profile is crucial for understanding soil strength and compressibility, serving as a foundation for normalizing SPT results and assessing bearing capacity and settlement behavior in building foundations under drained loading conditions.

Table 6. Effective overburden pressure

	$\sigma'_v = po'$ (kPa)		
Depth (m)	S1	S2	S3
0.00	0.00	0.00	0.00
0.45	3.98	3.99	3.98
0.90	7.99	7.97	7.97
1.35	12.02	11.97	11.95
1.80	16.04	15.98	15.94
2.25	20.07	20.01	19.94
2.70	24.11	24.06	23.97
3.15	28.18	28.15	28.04
3.60	32.28	32.24	32.15
4.05	36.35	36.36	36.28

4.50	40.46	40.45	40.40
4.95	44.56	44.58	44.53
5.40	48.62	48.71	48.65
5.85	52.70	52.80	52.80
6.30	56.78	56.90	56.97
6.75	60.90	61.01	61.14
7.20	65.05	65.13	65.30
7.65	69.19	69.27	69.47
8.10	73.35	73.41	73.66
8.55	77.55	77.61	-
9.00	81.81	-	-

Table 6 depicts the cumulative effective vertical overburden pressure (σ′v) as a function of depth for three points, S1, S2, and S3, revealing a near-linear increase from the surface to deeper layers due to submerged unit weight accumulation in saturated soils. The σ′v values are consistent across locations at similar depths, indicating uniform groundwater conditions and soil density, with slight variations at greater depths tied to local soil stratigraphy. This effective stress profile is crucial for understanding soil shear strength, stiffness, and compressibility, and is vital for SPT normalization, bearing capacity analysis, and settlement predictions for foundations. Figure 7 illustrates the increasing σ′v values with depth.

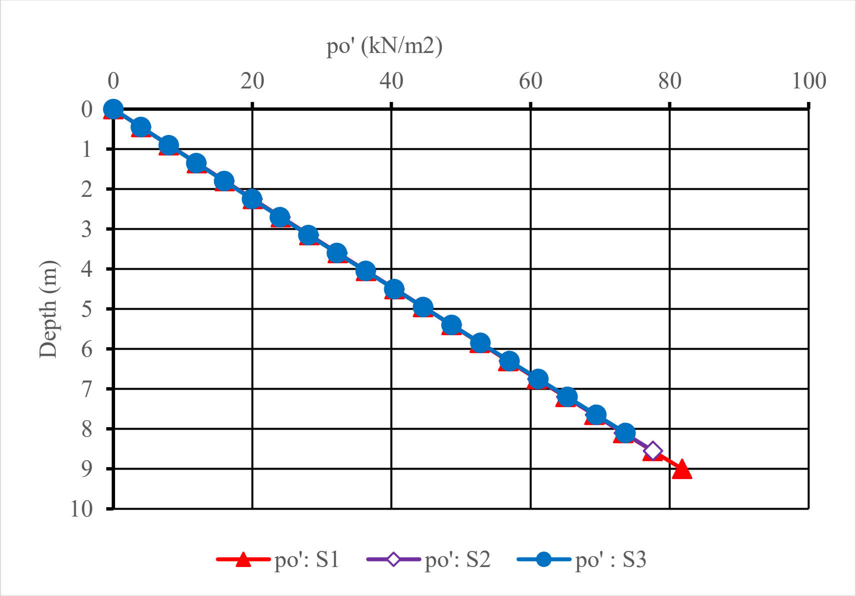


Fig 7. Effective overburden pressure

Figure 7 presents the cumulative effective overburden pressure (p_o') profiles for S1, S2, and S3, showing a nearly linear increase with depth. This trend indicates uniform groundwater conditions and similar soil densities, reflecting effective stress accumulation in saturated soils. This distribution is critical for SPT normalization, bearing capacity, and settlement analyses.

Table 7. Correction Factor (C_N) S1

Depth (m)	C_N						
	Peck et al (1974)	SNI 4153:2008	Skempton (1986)	Seed et al (1975)	Tokimatsu & Yoshimi (1983)	Bazaraa (1967)	Liao % Whitmann (1986)
0.00	0.00	1.83	2.00	0.00	2.43	4.00	0.00
0.45	2.08	1.77	1.92	2.75	2.30	3.45	5.01
0.90	1.85	1.72	1.85	2.37	2.18	3.03	3.54
1.35	1.71	1.67	1.79	2.15	2.07	2.70	2.88
1.80	1.61	1.62	1.72	1.99	1.98	2.44	2.50
2.25	1.54	1.57	1.67	1.87	1.89	2.22	2.23
2.70	1.48	1.53	1.61	1.77	1.81	2.04	2.04
3.15	1.43	1.48	1.56	1.69	1.73	1.88	1.88
3.60	1.38	1.44	1.51	1.61	1.66	1.75	1.76
4.05	1.34	1.41	1.47	1.55	1.60	1.63	1.66
4.50	1.30	1.37	1.42	1.49	1.54	1.53	1.57
4.95	1.27	1.34	1.38	1.44	1.48	1.44	1.50
5.40	1.24	1.30	1.35	1.39	1.43	1.36	1.43
5.85	1.22	1.27	1.31	1.35	1.39	1.29	1.38
6.30	1.19	1.24	1.28	1.31	1.34	1.22	1.33
6.75	1.17	1.22	1.24	1.27	1.30	1.16	1.28
7.20	1.15	1.19	1.21	1.23	1.26	1.11	1.24
7.65	1.12	1.16	1.18	1.20	1.22	1.06	1.20
8.10	1.11	1.14	1.15	1.17	1.19	1.02	1.17
8.55	1.09	1.11	1.13	1.14	1.15	0.98	1.14
9.00	1.07	1.09	1.10	1.11	1.12	0.94	1.11

Table 7 illustrates the correction factor (CN) for Standard Penetration Test (SPT) data at location S1, utilizing seven empirical formulations. The study reveals a trend of decreasing CN as depth increases, correlating with a rise in effective overburden pressure ($\sigma'v$) against reference atmospheric pressure (pa). Higher CN values occur at shallower depths where $\sigma'v$ is lower relative to pa, while deeper layers require smaller normalization factors. Discrepancies between methodologies are particularly notable in upper soil layers with low effective overburden pressure. Bazaraa (1967) and Liao and Whitman (1986) yield higher CN values, suggesting acute sensitivity to low $\sigma'v/pa$ ratios, whereas Peck et al. (1974), SNI 4153:2008, and Skempton (1986) offer conservative corrections to mitigate overestimation of normalized N-values near the surface. As depth increases, CN values converge towards unity as σ′v surpasses typical threshold values. These variations in CN significantly influence normalized SPT resistance and impact assessments of soil density, bearing capacity, and settlement behavior.

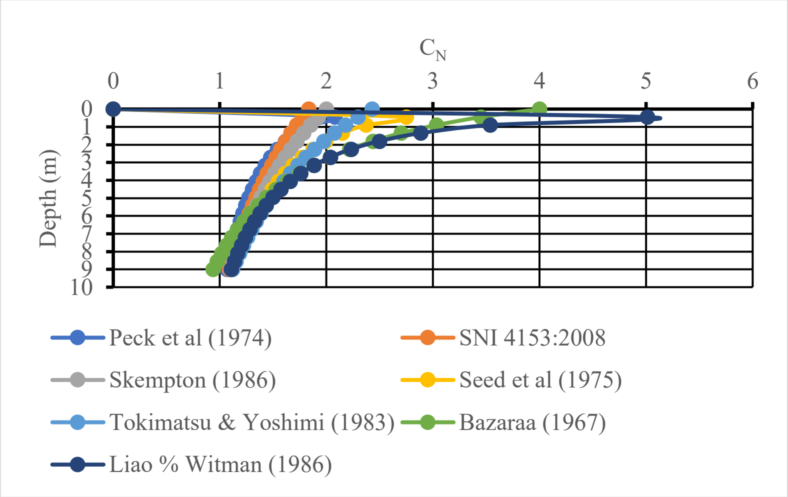


Fig 8. C_N values S1

Figure 8 demonstrates that the variation of CN values at S1 illustrates differences in how methods account for overburden stress on SPT resistance. Methods like Peck et al. and Bazaraa show higher CN values, suggesting greater normalization at shallow depths, which may lead to overestimated soil stiffness and bearing capacity. In contrast, methods such as SNI 4153:2008 and Liao & Whitman offer more restrained corrections, better reflecting the gradual stress increase with depth. These variations emphasize the sensitivity of interpreted strength, compressibility, and foundation performance to the chosen CN formulation.

Table 8. Correction Factor (C_N) S2

Depth (m)	C_N						
	Peck et al (1974)	SNI 4153:2008	Skempton (1986)	Seed et al (1975)	Tokimatsu & Yoshimi (1983)	Bazaraa (1967)	Liao & Whitmann (1986)
0.00	0.00	1.83	2.00	0.00	2.43	4.00	0.00
0.45	2.08	1.77	1.92	2.75	2.30	3.45	5.01
0.90	1.85	1.72	1.85	2.37	2.18	3.03	3.54
1.35	1.71	1.67	1.79	2.15	2.07	2.70	2.89
1.80	1.61	1.62	1.72	2.00	1.98	2.44	2.50
2.25	1.54	1.57	1.67	1.87	1.89	2.22	2.24
2.70	1.48	1.53	1.61	1.77	1.81	2.04	2.04
3.15	1.43	1.49	1.56	1.69	1.73	1.88	1.88

3.60	1.38	1.45	1.51	1.61	1.66	1.75	1.76
4.05	1.34	1.41	1.47	1.55	1.60	1.63	1.66
4.50	1.30	1.37	1.42	1.49	1.54	1.53	1.57
4.95	1.27	1.34	1.38	1.44	1.48	1.44	1.50
5.40	1.24	1.30	1.34	1.39	1.43	1.36	1.43
5.85	1.22	1.27	1.31	1.35	1.38	1.29	1.38
6.30	1.19	1.24	1.27	1.31	1.34	1.22	1.33
6.75	1.17	1.22	1.24	1.27	1.30	1.16	1.28
7.20	1.15	1.19	1.21	1.23	1.26	1.11	1.24
7.65	1.12	1.16	1.18	1.20	1.22	1.06	1.20
8.10	1.11	1.14	1.15	1.17	1.19	1.02	1.17
8.55	1.09	1.11	1.13	1.14	1.15	0.97	1.14

Table 8 presents depth-dependent C_N correction factors at S2 across seven SPT methods. At shallow depths (≤1.0 m), values diverge significantly; Bazaraa (1967) and Liao & Whitman (1986) yield the highest corrections, while SNI 4153:2008 and Skempton (1986) remain more conservative. As effective vertical stress increases, C_N values across all methods converge, with negligible differences appearing beyond 6 m.

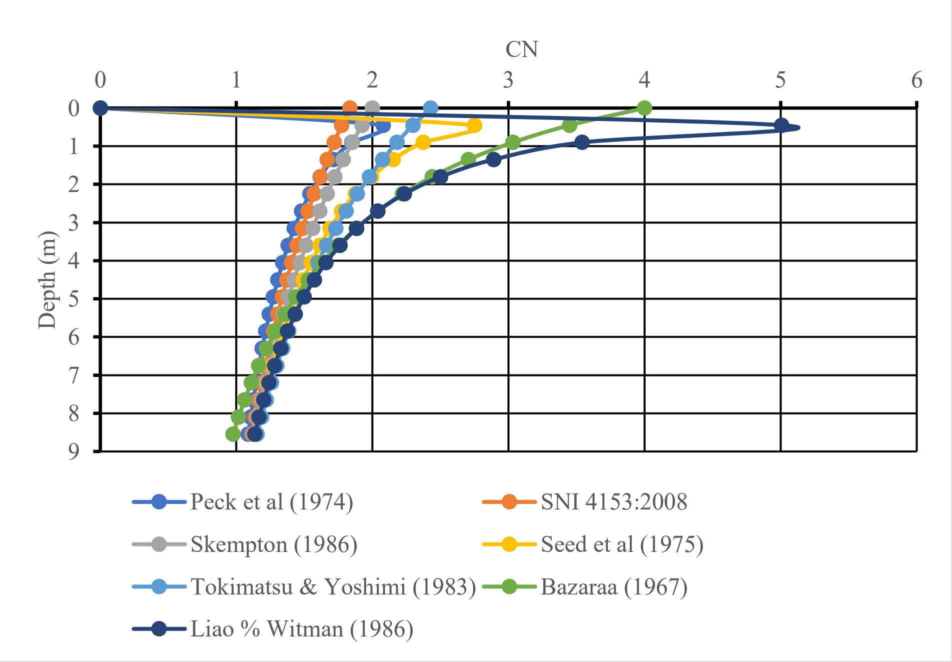


Fig 9. CN values S2

Figure 9 illustrates that CN values at S2 correlate strongly with soil characteristics at varying depths. High CN values in shallow layers indicate low effective overburden stress, typical of loose granular or lightly overconsolidated fine-grained soils, which are highly responsive to stress changes. Methods increasing CN values highlight this situation by raising corrected N-values significantly. As depth increases, CN values decrease and converge, indicating higher effective stress and stiffer soil conditions. This trend implies reduced compressibility and increased shear strength in deeper layers, while shallow soils remain sensitive to correction methods.

Table 9. Correction Factor (C_N) S3

Depth (m)	C_N						
	Peck et al (1974)	SNI 4153:2008	Skempton (1986)	Seed et al (1975)	Tokimatsu & Yoshimi (1983)	Bazaraa (1967)	Liao & Whitmann (1986)
0.00	0.00	1.83	2.00	0.00	2.43	4.00	0.00
0.45	2.08	1.77	1.92	2.75	2.30	3.45	5.01
0.90	1.85	1.72	1.85	2.37	2.18	3.03	3.54
1.35	1.71	1.67	1.79	2.15	2.07	2.71	2.89
1.80	1.62	1.62	1.73	2.00	1.98	2.44	2.50
2.25	1.54	1.57	1.67	1.88	1.89	2.23	2.24
2.70	1.48	1.53	1.61	1.78	1.81	2.04	2.04
3.15	1.43	1.49	1.56	1.69	1.73	1.89	1.89
3.60	1.38	1.45	1.51	1.62	1.66	1.75	1.76
4.05	1.34	1.41	1.47	1.55	1.60	1.63	1.66
4.50	1.30	1.37	1.42	1.49	1.54	1.53	1.57
4.95	1.27	1.34	1.38	1.44	1.48	1.44	1.50
5.40	1.24	1.30	1.35	1.39	1.43	1.36	1.43
5.85	1.22	1.27	1.31	1.35	1.38	1.29	1.38
6.30	1.19	1.24	1.27	1.31	1.34	1.22	1.32
6.75	1.17	1.21	1.24	1.27	1.30	1.16	1.28
7.20	1.14	1.19	1.21	1.23	1.26	1.11	1.24
7.65	1.12	1.16	1.18	1.20	1.22	1.06	1.20
8.10	1.10	1.14	1.15	1.17	1.18	1.01	1.17

Table 9 shows a systematic reduction of CN values with depth at S3, highlighting the influence of effective overburden stress on SPT resistance. Higher CN values in upper units suggest shallow soils with low confinement, indicating loose to medium density granular materials or lightly overconsolidated fine-grained soils. Methods that yield elevated CN values may overestimate bearing capacity while underpredicting settlement potential. As depth increases, CN values among methods converge, indicating more homogeneous strata where soil stiffness and shear strength are less affected by stress normalization. This leads to more reliable bearing capacity estimates, with settlement predictions primarily influenced by elastic compression instead of stress correction uncertainty, as illustrated in Figure 9.

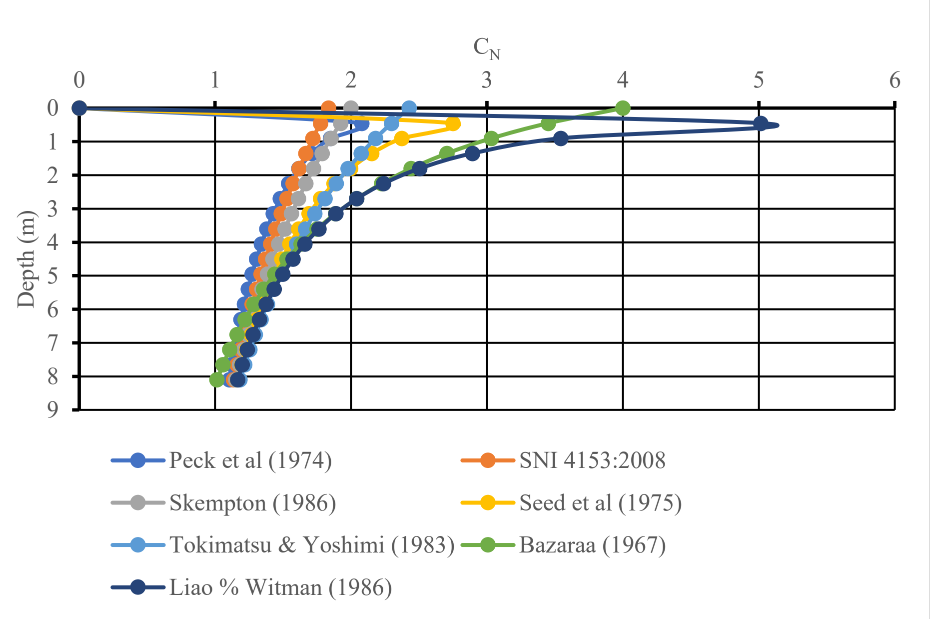


Fig 10. C_N values S3

Figure 10 illustrates the comparison of CN values at S3, revealing the mechanical behavior of soil and the uncertainty in SPT interpretations. The shallow zone shows a broad CN value dispersion due to low effective overburden stress and variable soil conditions, resulting in skewed corrected N-values and inaccurate bearing capacity estimations. In contrast, deeper zones demonstrate reduced and converged CN values, indicating better confinement and more stable soil behavior, where stiffness and shear strength become more critical in foundation response, lessening the impact of the correction method on design uncertainty.

3.4. Average corrected N (C_N) values

The corrected N (C_N) values as listed in Tables 7, 8, 9 and Figures 7, 8, 9 are read in Table 10 as the average values.

Table 10. Average correction factor (C_N) values

	Methods	Average C_N		
Depth (m)		S1	S2	S3
1	Peck et al (1974)	1.37	1.38	1.40
2	SNI 4153:2008	1.40	1.42	1.44
3	Skempton (1986)	1.54	1.57	1.59

4	Seed et al (1975)	1.59	1.62	1.65
5	Tokimatsu & Yoshimi (1983)	1.62	1.65	1.67
6	Bazaraa (1967)	1.82	1.86	1.91
7	Liao % Whitmann (1986)	1.89	1.93	1.98

Table 10 outlines systematic differences in average CN values from seven correction methods across S1, S2, and S3, revealing insights into methodological assumptions and subsurface conditions. Lower CN values indicated by Peck et al. and SNI 4153:2008 suggest restrained normalization, representative of moderate density stratigraphy, while higher values from Bazaraa and Liao & Whitman indicate amplification in low effective stress strata, typically in loose soils. The average CN increases from S1 to S3, suggesting systematic stratigraphic variability linked to soil fabric or consolidation state. High CN values may overestimate stiffness and bearing capacity, posing risks in design, whereas lower values provide more conservative predictions of bearing capacity and settlement, reflecting real interactions between soil behavior and foundation performance. Figure 10 illustrates the average CN for point 1.

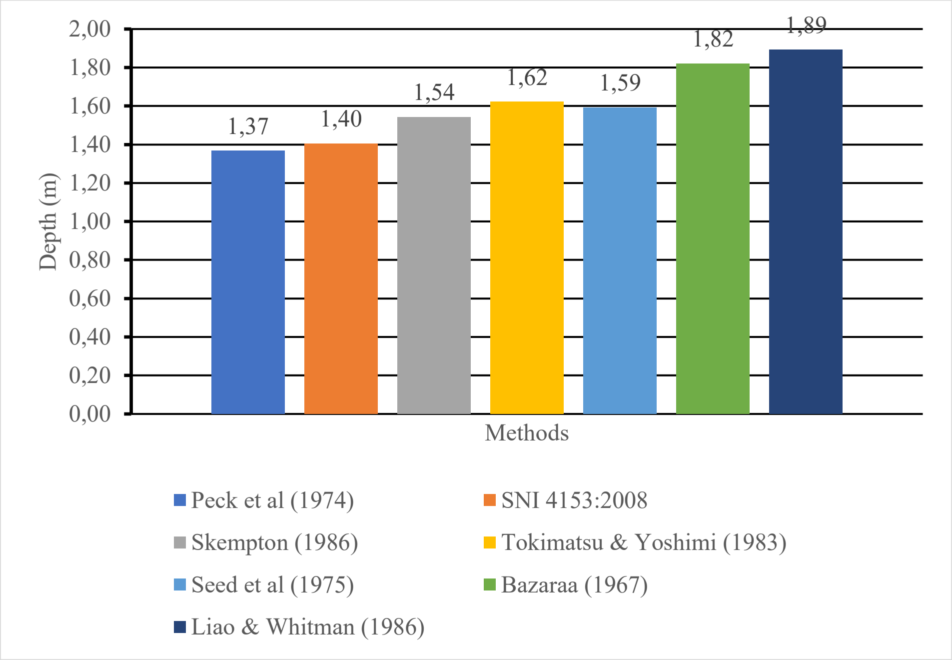
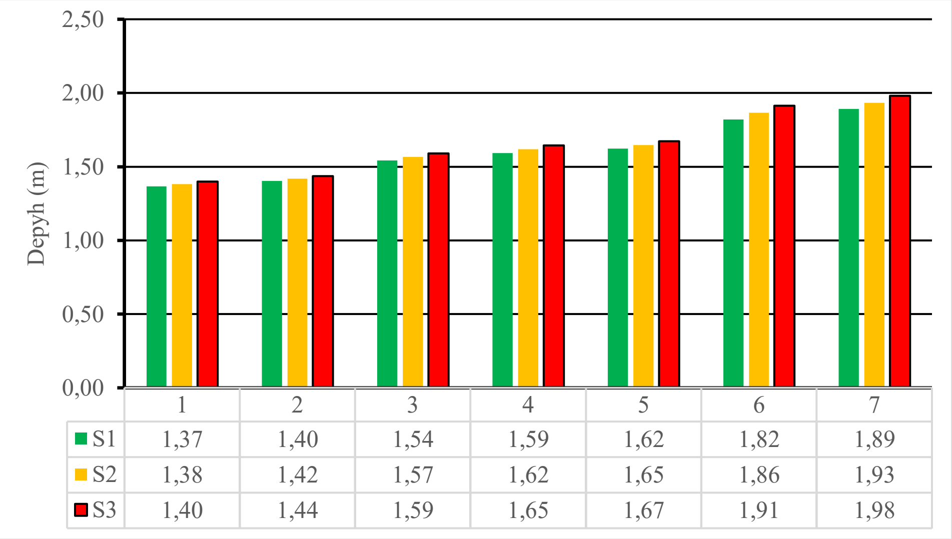


Fig 11. Average C_N values S1

Figure 11 illustrates that the average correction number (CN) from SNI 4153:2008 at S1 offers a balanced midpoint among various methods, both statistically and geotechnically. This midrange CN minimizes the impact of low effective overburden stress without disproportionately increasing corrected N-values. This is especially significant for stratified soil profiles with variable density and compressibility. By using a moderate correction, SNI 4153:2008 provides corrected N-values that more accurately represent the actual stiffness and shear strength under working stress conditions. As a result, the bearing capacity estimates are less likely to be overestimated, and settlement analyses effectively account for compressible layers affecting foundation performance. In comparison to higher-CN methods, the SNI method reduces uncertainty related to stress normalization, thus furnishing a more reliable foundation for geotechnical design in layered soils. The average CN values for S1, S2, and S3 across all methods are presented in Figure 12.



	1	2	3	4	5	6	7
🟩 S1	1,37	1,40	1,54	1,59	1,62	1,82	1,89
🟨 S2	1,38	1,42	1,57	1,62	1,65	1,86	1,93
🟥 S3	1,40	1,44	1,59	1,65	1,67	1,91	1,98

Fig 12. Average C_N S1, S2, S3

Figure 12 shows that average corrected N (CN) values at S1, S2, and S3 maintain a hierarchy across seven correction methods, suggesting similar stratigraphic conditions and stress regimes. Higher average CN values indicate stronger overburden stress amplification, while lower values reflect conservative normalization. The SNI 4153:2008 method displays tightly grouped average CN values, implying minimal spatial variability and stability in stress correction. This suggests that the SNI method effectively represents soil stiffness and compressibility without distorting bearing capacity or settlement predictions. Comparatively, CN values vary across methods, with Peck et al. (1974) consistently yielding the lowest values, while Liao & Whitman (1986) yields the highest. Peck et al. (1974) average of 1.37 serves as a critical reference for evaluating other methods, as highlighted in Table 11.

Table 11. Comparison of average C_N values

No.	Methods	C_N			Average C_N
		S1	S2	S3	
1	Peck et al (1974)	1.00	1.00	1.00	1.00
2	SNI 4153:2008	1.03	1.03	1.03	1.03
3	Skempton (1986)	1.13	1.13	1.14	1.13
4	Seed et al (1975)	1.17	1.17	1.18	1.17
5	Tokimatsu & Yoshimi (1983)	1.19	1.19	1.20	1.19
6	Bazaraa (1967)	1.33	1.35	1.37	1.35
7	Liao & Whitmann (1986)	1.38	1.40	1.41	1.40

In fact, all methods are based on the same effective overburden and atmospheric pressure. The differences in question come from the formulas applied to each method, as can be seen in Formulas Numbers (6), (7), (8), (9), (10), (11), and (12). Comparison of C_N values between SNI 4153:2008 and other method in Standard Penetration Test for this research shown in Figure 13

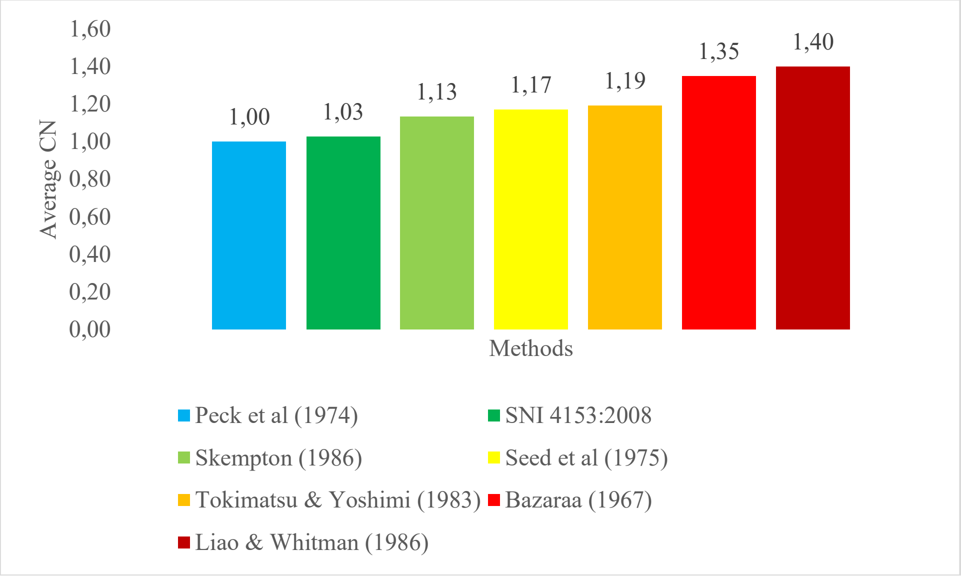


Fig 13. Comparison of C_N values

3.5. Variation of CN Values among Different Correction Methods

The results of the overburden pressure correction analysis indicate a pronounced variation in the average correction factor (CN) among the seven evaluated methods across the three SPT locations (S1, S2, and S3). As summarized in Table 10, the CN values systematically increase from the Peck et al. (1975) method to the Liao and Whitman (1986) method, reflecting fundamental differences in their conceptual treatment of effective overburden stress.

Peck et al. (1975) yields the lowest average CN values, ranging from 1.37 to 1.40, suggesting a relatively mild correction for low effective stress conditions. In contrast, the Liao and Whitman (1986) method produces the highest CN values, between 1.89 and 1.98, indicating a much stronger amplification of the measured SPT blow count at shallow depths. Intermediate CN values are observed for Skempton (1986), Seed et al. (1974), Tokimatsu and Yoshimi (1983), and Bazaraa (1967), with a consistent increasing trend that reflects their progressively more aggressive stress normalization schemes.

The SNI 4153:2008 method generates average CN values between 1.40 and 1.44, placing it close to the lower-middle range of the dataset. The relatively narrow variation of CN across S1, S2, and S3 indicates that the SNI formulation provides stable correction behavior despite spatial variability in soil conditions. This stability is a critical attribute for routine engineering applications where site heterogeneity is unavoidable.

3.6. Relative Position of SNI 4153:2008

When compared directly with the six international methods, SNI 4153:2008 consistently produces CN values higher than Peck et al. (1975) but lower than all other evaluated approaches. This positioning demonstrates that SNI 4153:2008 adopts a conservative yet not overly restrictive correction philosophy. The results suggest that the Indonesian standard deliberately limits the magnitude of overburden correction to prevent excessive inflation of corrected N-values (N_{60}), particularly in shallow soil layers where stress-dependent variability is high.

3.7. Geotechnical interpretation of CN variability

From a geotechnical standpoint, the observed variation in CN values is primarily governed by how each method models the nonlinear relationship between penetration resistance and effective vertical stress. At shallow depths, low effective stress leads to reduced confinement, causing SPT blow counts to underestimate soil density or strength unless appropriately corrected. However, excessive correction can artificially increase N_{60}, masking the true deformability of the soil mass.

Methods such as Bazaraa (1967) and Liao and Whitman (1986) emphasize a strong dependence of penetration resistance on overburden stress, which explains their higher CN values. While this approach may be theoretically justified for clean, loose sands under very low confining pressure, its direct application to natural soil deposits with fines content or cementation can lead to unrealistically high corrected N-values. Recent studies have highlighted that overly aggressive overburden corrections may reduce the reliability of SPT-based correlations for stiffness and strength parameters (Zhang et al. 2021; Phoon and Tang 2023).

In contrast, the SNI 4153:2008 method reflects a more restrained interpretation of stress normalization. By limiting the magnitude of CN, the method implicitly acknowledges the uncertainty associated with empirical SPT correlations and the influence of factors beyond effective stress, such as soil fabric and aging effects. This conservative moderation is consistent with contemporary recommendations that emphasize robustness over precision in empirical geotechnical design (Ching et al. 2020).

3.8. Implications for bearing capacity analysis

Bearing capacity estimations derived from SPT data are highly sensitive to corrected N-values, as these values are commonly correlated with shear strength parameters, particularly the internal friction angle for granular soils. Higher CN values translate directly into higher N_{60}, which increases the estimated bearing resistance of shallow foundations.

The application of high-CN methods, such as Liao and Whitman (1986), leads to significantly larger bearing capacity values. While this may allow for reduced foundation dimensions, it also increases the risk of unconservative design, especially in layered or partially saturated soils. Recent numerical and field-based studies have demonstrated that overestimation of strength from inflated N-values can result in bearing capacity predictions that exceed actual field performance (Lee et al. 2022). Conversely, the relatively moderate CN values obtained using SNI 4153:2008 yield bearing capacity estimates that are lower than those derived from Skempton (1986), Seed et al. (1974), and Tokimatsu and Yoshimi (1983). This outcome enhances safety margins without resorting to excessive conservatism. For public and institutional buildings, such as the Civil Engineering Laboratory Building examined in this study, this balance between safety and economy is particularly critical.

The Peck et al. (1975) method, producing the lowest CN values, results in the most conservative bearing capacity estimates. Although this approach minimizes failure risk, it may lead to inefficient foundation designs and increased construction costs, which may not be justified when sufficient site investigation data are available.

3.9. Implications for settlement analysis

Settlement prediction is generally more sensitive to corrected SPT values than bearing capacity analysis because soil stiffness correlations are strongly influenced by N_{60}. Higher CN values lead to higher estimated soil modulus and, consequently, smaller predicted settlements. The results indicate that methods with high CN values, particularly Bazaraa (1967) and Liao and Whitman (1986), may underestimate settlements due to overestimation of soil stiffness. This underestimation poses a significant serviceability risk, as excessive or differential settlement often governs foundation performance rather than ultimate bearing failure. Recent research emphasizes that serviceability-based design requires cautious interpretation of SPT-derived stiffness, especially in shallow foundations (Salgado et al. 2021; Zhou et al. 2024).

In contrast, SNI 4153:2008 yields moderate settlement predictions that better reflect realistic soil behavior. Although predicted settlements are larger than those obtained using high-CN methods, they remain within acceptable engineering limits and align more closely with observed performance in similar soil conditions. This characteristic supports the use of SNI 4153:2008 for designs where long-term functionality and deformation control are critical.

The Peck et al. (1975) method produces the largest settlement estimates, reflecting its conservative correction approach. While suitable for preliminary assessments or highly sensitive structures, its routine application may result in unnecessary ground improvement or deeper foundation solutions.

3.10. Relevance to contemporary geotechnical practice

Recent international literature increasingly recognizes that no single CN correction method is universally applicable. Instead, the selection of an appropriate method should consider soil type, stress range, and design objectives. The findings of this study align with recent probabilistic and reliability-based approaches, which advocate for moderate correction factors that reduce epistemic uncertainty rather than maximizing corrected strength values (Tang et al. 2020; Phoon et al. 2024). Within this context, SNI 4153:2008 demonstrates strong compatibility with modern geotechnical design philosophy. Its CN values provide a rational compromise between safety and practicality, ensuring reliable bearing capacity estimation while avoiding unconservative settlement predictions.

4. Conclusion

This study was conducted to compare overburden pressure correction factors (CN) obtained from SNI 4153:2008 and six widely adopted international methods and to evaluate their implications for bearing capacity and settlement analyses based on Standard Penetration Test (SPT) data. The results confirm that significant variability exists among the evaluated CN formulations, reflecting fundamental differences in their assumptions regarding stress normalization and soil response under low effective overburden pressure.

The comparative analysis shows that SNI 4153:2008 consistently produces moderate CN values, higher than those proposed by Peck et al. (1975) but lower than those derived from Skempton (1986), Seed et al. (1974), Tokimatsu and Yoshimi (1983), Bazaraa (1967), and Liao and Whitman (1986). This positioning indicates that the Indonesian standard adopts a restrained correction approach that avoids excessive amplification of corrected SPT blow counts, particularly in shallow soil layers where uncertainty is inherently high. As a result, SNI 4153:2008 provides a stable and robust correction framework under varying site conditions.

In bearing capacity analysis, higher CN values obtained from aggressive correction methods lead to increased estimated foundation resistance but may introduce unconservative design outcomes when applied indiscriminately. In contrast, SNI 4153:2008 yields bearing capacity estimates that balance safety and efficiency, making it suitable for building foundations where structural reliability is essential. Regarding settlement analysis, methods with high CN values tend to underestimate soil deformability and predicted settlements, potentially compromising serviceability performance. The moderate CN values produced by SNI 4153:2008 result in more realistic settlement predictions that better reflect the stress-dependent stiffness behavior of natural soils.

Overall, the findings demonstrate that variation in CN values has a decisive influence on both ultimate and serviceability limit state evaluations. Among the examined methods, SNI 4153:2008 offers a rational compromise between conservative and aggressive correction schemes, aligning well with contemporary geotechnical design philosophy. Therefore, SNI 4153:2008 can be considered technically reliable and suitable for routine foundation design, while also providing a consistent reference for comparison with international correction methods.

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