International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 6, October 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Proposition of Empirical Correlation Equation for Swell Parameters of Expansive Soil from Monwya Township

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ABSTRACT

This study presents the swelling parameters for expansive soil from Monywa Township, Saging Region. In various civil engineering projects, soil is used as a construction material and it supports structural foundation. Expansive clay soils swell when they are wetted and shrink when they are dried out. Volume changes of expansive soils can cause damages to structure resting on them. Therefore, it is essential to identify the existence of expansive soil at proposed construction site. The present study deals with the properties of expansive soils from Institute of Economic (IE), Industrial Zone (IZ) and Hospital of Traditional Medicine (HTM) which are situated in Monywa Township, Sagaing Region. In order to identify and classify the expansive potential of expansive soils, performed tests on soils under study are Atterberg limit tests, Grain-size analysis, Specific gravity test, Standard compaction test, Modified free swell index test and Consolidation test. Then, the expansive potential is qualitatively classified by various classification methods. In this study, swell potential and swell pressure are considered as the swell parameters. Empirical correlations for swell parameters of expansive soil from Monywa Township are proposed by using multiple linear regression analysis for three dimensional models based on free swell test results.

KEYWORDS: *Expansive Soils, Swelling Potential, Swelling Pressure, Dry Density, Liquid Limit, Initial Water Content, Plasticity Index*

How to cite this paper: Yee Win Shwe | Khin Myo Nwet "Proposition of Empirical Correlation Equation for Swell Parameters of Expansive Soil from Monwya Township" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-6, October 2019, pp.1289-1295, URL: https://www.ijtsrd.com/papers/ijtsrd29384.pdf

IJTSRD29384

1. INTRODUCTION

Soil is an essential component in the construction and stability of houses, commercial buildings, and other structures. Since structures are built on soil, structural damage to a structure can occur if the soil expands or contracts. There are three basic types of naturally occurring soil: sand, silt and clay. Clay soils are generally classified "expansive." Expansive soils are unsaturated clayey soils which show considerable volume changes upon wetting and drying. Wetting of expansive soil causes increase in volume; drying of expansive soil decreases in volume.

Expansive soils in Myanmar are locally well known as "Black Cotton Soil". In this study, Institute of Economic (IE), Industrial Zone (IZ) and Hospital of Traditional Medicine (HTM) are studied to know the amount of swelling and to determine degree of expansion for this areas. Some construction guidelines such as increasing embedded depth and strengthening of foundation are practiced for the structures in expansive soil. Since these measures are costly, it is very crucial to recognize the existence of expansive soil and intensity of volume change capacity in proposed construction area to achieve the optimal solution.

Swell parameters; namely, swell potential (ε_s), and swell pressure (p_s), are fundamental properties of expansive soils. Swell potential is the percentage of volume change with reference to original volume when soil moisture increases from initial condition to saturated condition. Swell pressure is required pressure to keep the soil at original volume while soil moisture is increasing. Swell parameters are key indicators for identification of expansive soils and prediction of probable volume change due to moisture changes.

Swell parameters can be determined by direct measurements such as oedometer tests, or by empirical correlations using simple soil properties such as plasticity index, initial moisture content, initial dry density, and surcharge pressure. Empirical correlations can be applied at preliminary investigation stage, and swell tests are to be carried out for design stage. Several empirical correlations for the prediction of swell parameters of expansive soils from specific locations are used. However, these correlations should be checked whether modifications are required for other locations. It is more reliable to derive the empirical correlation from test results of particular location. Therefore, the empirical correlations of expansive soil from Monywa Township are proposed in this study.

2. Study Area

The study area is situated in Monywa Township, Saging Region. It lies between North Latitude of 22 ° 00′ to 22° 18′ and East Longitude of 95° 05′ to 95°23′. It is located in the eastern bank of Chindwin River. The location map of the study area is shown in Figure 1.

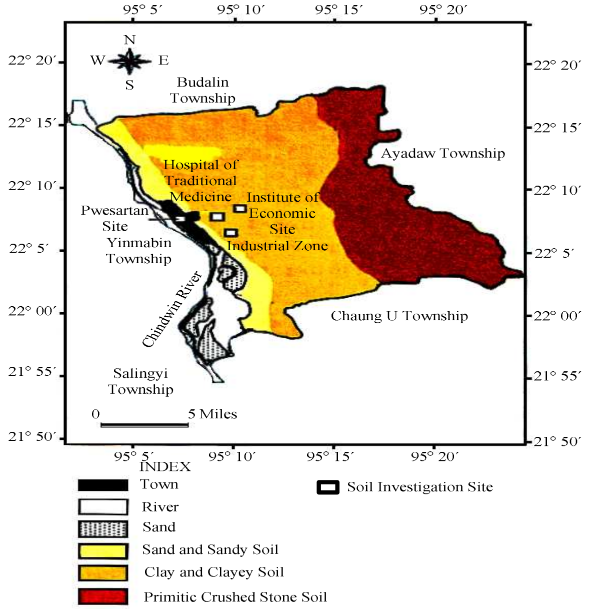


Figure1. Distribution of Soil in Monywa Area (Data source: Land Use Bureau, Yangon)

3. Identification and Classification of Expansive Soils

Several investigators in the past reported methods for identification and classification of soils as well as interpretation of classification in terms of probable range of engineering properties and engineering use of soils. Based on this several investigators developed criteria for classification of expansive soils and their potential for expansion making use of two or more of these properties. The expansion potential is qualitatively expressed by descriptor terms like very high, high, Marginal, critical and so on. For each descriptor of expansion potential, the probable ranges of liquid limit, plasticity index are suggested based on their experience and perception keeping in view the characteristics of expanding material. In this study the following identification tests are performed:

1. Atterberg limit tests
   A. Liquid limit
   B. Plastic limit
   C. Shrinkage limit
2. Grain-size analysis
3. Specific gravity test
4. Standard compaction test
5. Modified free swell test
6. Consolidation test

4. Classification Using Engineering Index Properties

Classification system of expansive soils is based on the problems they create in the construction of foundations (potential swell). Most of the classifications are described.

Table1. Soil Cassification Based on Plasticity Index, Liquid Limit and Shrinkage Limit (after Raman and Holtz Dakshanamurthy, 1973)

I_p (%)	ω_s (%)	ω_l (%)	Swelling Potential
<18	>15	30-35	Low
15-25	10-15	35-50	Moderate
25-35	7-12	50-70	High

Anonymous(1980) suggested that the plasticity index provided and indication of volume change potential as shown in following Table2.

Table2. Volume Change Potential

Plasticity Index (%)	Potential
Over 35	Very high
22-48	High
12-32	Medium
Less than 18	Low

Sivapullaiah et al. (1987) suggested a new method for obtaining a modified swell index for clays, which appears to gives a better indication for the potential of clayey soils. Based on the modified free swell index, swelling potential of a soil may be qualitatively classified as follow:

Table3. Soil Classification Scheme Based on Modified Free Swell Index

Modified Free Swell Index	Swelling Potential
< 2.5	Negligible
2.5 to 10	Moderate
10 to 20	High
>20	Very high

In 1988, Chen propose for predicting swell potential and degree of expansion as shown in Table4 and 5.

Table4. Expansive Soil Classification Based on Plasticity Index

Swelling Potential	Plasticity Index
Low	0-1
Medium	10-35
High	20-55
Very high	35 and above

Table5. Expansive Soil Classification Based on Plasticity and Shrinkage Index.

PI (%)	SI (%)	Degree of Expansion
<12	<15	Low
12-23	15-30	Medium
23-32	30-40	High
>32	>40	Very high

Braja (1998) described a plasticity chart is used to determine whether a soil is silty or clayey. The chart is a plot of plasticity index versus liquid limit. The information provided in the plasicity chart is of great value and is the basis for the classification of fine-grained soils in the Unified Soil Classification System.

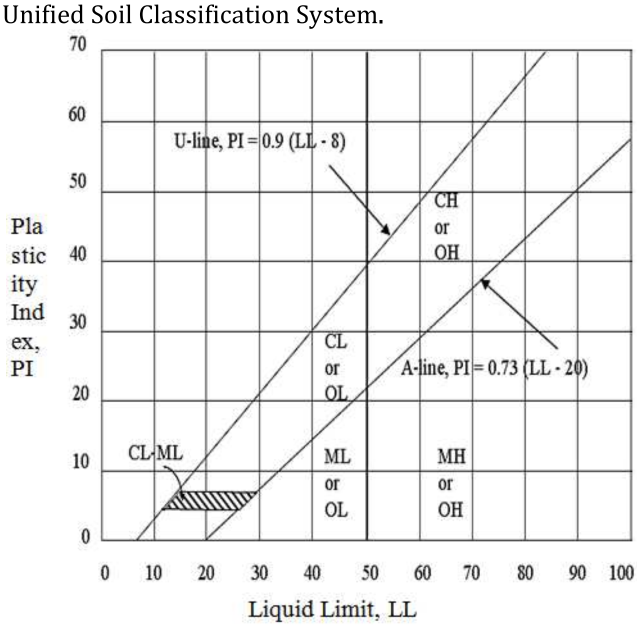


Figure2. Plasticity Chart

Table6. Performed Test Results for Identification and Classification of Soil Samples

Soil Index \ Soil sample	IE (Institute of Economic)	HTM (Hospital of Traditional Medicine)	IZ (Industrial Zone)
Liquid Limit (%)	37	38	40
Plastic Limit (%)	23.06	22.06	22.04
Shrink Limit (%)	13.25	12.43	12.00
Plastic Index (%)	14	16	18
Specific Gravity	2.55	2.56	2.53
Optimum Moisture Content (%)	21	23	23.2
Maximum Dry Unit Weight (pcf)	93.5	93.5	93
Clay (%)	26	26	29
Silt (%)	59	57	61
Sand (%)	12	14	7
Gravel (%)	3	3	3
Modified Free Swell Index	3.46	3.60	3.60
Shrinkage Index (SI = LL - SL, %)	23.57	25.57	28
Soil Color (visual investigation)	Brownish Grey	Brownish Grey	Brownis-h Grey
Soil Type (Unified)	CL	CL	CL

According to identification and classification of expansive soils, soil samples are classified as shown in Table7.

Table7. Rating of Expansive Potentials of Soil Samples

Classification Schemes \ Soil Sample	IE	HTM	IZ	Referenc-e
Based on palasticity index, Liquid limit and Shrinkage Limit. Table 1	Margi-nal	Margi-nal	Margi-nal	Raman, 1973
Based on palasticity index, Table 2	Margi-nal	Margi-nal	Margi-nal	Anonymo-us,1980
Based on modified free swell index, Table 3	Margi-nal	Margi-nal	Margi-nal	Sivap-ullaiah et al. 1987
Based on plasticity index, Table 4	Margi-nal	Margi-nal	Margi-nal	Chen, 1988
Based on plasticity and shrinkage index, Table 5	Margi-nal	Margi-nal	Margi-nal	Chen, 1988

From Table (7), the values of all soil samples seem to be the moderate expansive soil. However, the values of classification for soil sample Industrial Zone (IZ) are more than other locations in this study.
Therefore, this sample is chosen to perform free swell test for the determination of swell parameters and prediction of the volume change of expansive soil from Monywa Township. Five soil specimens (undisturbed samples) from Industrial Zone are collected for the study.

5. Test Result

Atterberg limit tests such as liquid limit and plastic limit test are carried out on all five samples the Industrial Zone (IZ). Combined sieve analysis and pipette method is used to determine particle size distribution of soil samples. The following Tableshows the liquid limit (ω_L), plastic limit (PL), plasticity index (I_P), general particle size distribution and activity of soil specimens. Specific gravity of soil specimens are obtained as 2.53.

Table8. Physical Properties of Soil Specimens

Sample	ω_L (%)	PL (%)	I_p (%)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
I	40	22	18	29	61	10	10
II	40.2	22.0	18.2	29	59	11	1
III	42.8	22.6	20.2	31	56	12	1
IV	39.7	21.4	18.3	28	63	8	1
V	43.1	22.5	20.6	31	57	11	1

All soil specimens can be classified as expansive soil due to moderate clay content, moderate liquid limit values and moderate plasticity values. Free swell tests are carried out on all soil specimens. In this free swell (oedometer) test results, ε_s is swell potential which is swelling before load does not gives on the soil sample and P_s is swell pressure that read at initial height (no swelling and compression) on the applied pressure and sample thickness relation curves .

Free swell test results of Industrial Zone (IZ) samples can be summarized as shown in Table9.

Table9. Summary of Free Swell Test Results of Soil Sample No. I, II, III, IV and V

Soil Sample	Initial Water Content ω_o (%)	Dry Density γ_d (kN/m³)	Measured Swell Potential ε_s (%)	Measured Swell Pressure P_s (kN/m²)
I	20.61	14.49	3.04	67.03
II	20	14.56	3.12	71.82
III	19.1	14.82	4.2	95.76
IV	20.5	14.45	3.32	76.61
V	21.0	14.44	2.32	57.46

6. Prediction of Swell Parameters Using Empirical Correlations

Several researchers proposed empirical correlations for prediction of swell potential and swell pressure based on laboratory and field measurements. Since the empirical correlations are derived for specific expansive soil type and location. Validity of these correlations is not unlimited. Validity of a correlation should be checked carefully before adopting it for another location and soil type. Empirical correlations for swell potential and swell pressure are as follow:

O' Neil & Ghazzaly: for free swell

$$\varepsilon_s = 2.77 + 0.131\omega_L - 0.27\omega_o \quad (1)$$

Johnson & Snethen: for free swell

$$\log \varepsilon_s = 0.0367\omega_L - 0.0833\omega_o + 0.458 \quad (2)$$

Schneider & Poor: for no fill or weight on the swelling soil

$$\log \varepsilon_s = 0.9\left(\frac{I_p}{\omega_o}\right) - 1.19 \quad (3)$$

Johnson: for 1psi surcharge pressure & $I_p \le 40$

$$\varepsilon_s = -9.18 + 1.5546Ip - 0.08424H + 0.1\omega_o - 0.0432Ip\omega_o - 0.01215IpH \quad (4)$$

Vijayavergiy & Ghazzaly-2: for 0.1tsf surcharge pressure

$$\log \varepsilon_s = \frac{1}{12}(0.44\omega_L - \omega_0 + 5.5) \quad (5)$$

where,

ε_s = measured swell potential (%)

ω_L = liquid limit(%)

ω_o = initial water content (%)

γ_d = dry density (kN/m³)

P_s = measured swell pressure (kN/m²)

I_p = Plasticity index (%)

H = initial thickness of specimen (in)

The measured swell potential values and calculated swell potential values are compared in Table10 and Figure 3 shows the comparison in graphical form.

Table10. Comparison between Measured Swell Potential and Calculated Swell Potential Values by Using Empirical Correlations

Sample	Measured Swell potential	O'Neil and Ghazzaly	Johnson And Snethen	Schneider and Poor	Johnson	Vijayavergiy and Ghazzaly-2
I	3.04	2.45	1.62	0.39	4.73	1.61
II	3.12	2.64	1.85	0.43	5.28	1.84
III	4.2	3.22	2.74	0.58	7.34	2.73
IV	3.32	2.88	2.15	0.52	5.36	2.14
V	2.32	2.06	1.23	0.36	4.04	1.23

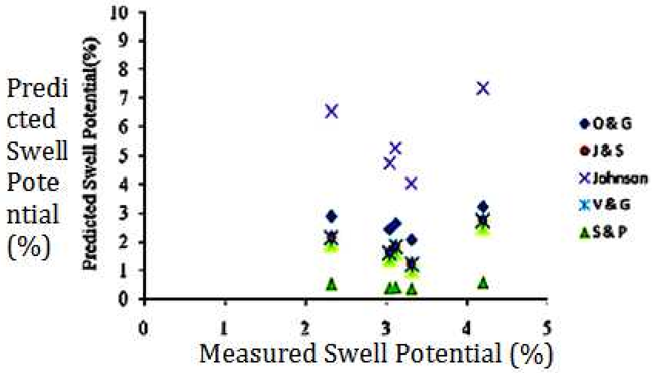


Figure3. Comparison between Measured Swell Potential and Calculated Swell Potential Values by Using Correlations in Literature

The empirical correlations for swell pressure values are:
Vijayavergiyw & Ghazzaly

$$(1)\log p_s = \frac{1}{19.5}(6.242\gamma_d + 0.65\omega_L - 100) \qquad (6)$$

$$(2)\log p_s = \frac{1}{12}(0.44\omega_L - \omega_o - 0.4) \qquad (7)$$

Where, P_s = Measured swell pressure in kN/m²
γ_d = dry density in kN/m³

Table11. Comparison between Measured Swell Pressure and Calculated Swell Pressure Values by Using Empirical Correlations

Sample	Measured Swell Pressure, P_s (kN/m²)	Vijayavergiy and Ghazzzly-1 (kN/m²)	Vijayavergiy and Ghazzzly -2 (kN/m²)
I	67.03	53.22	72.07
II	71.82	54.86	76.39
III	95.76	64.94	90.58
IV	76.61	52.05	71.94
V	57.46	58	72.52

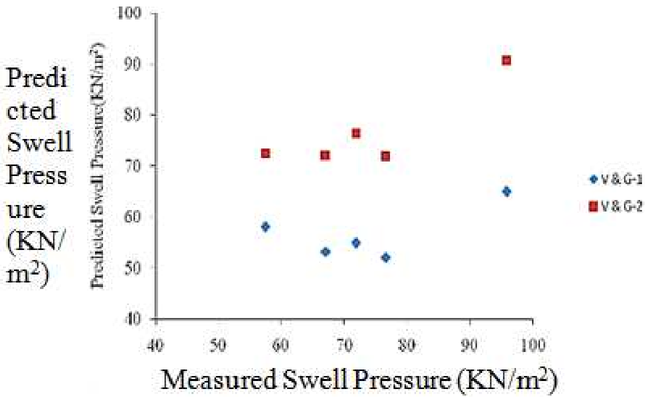


Figure4. Comparison between Measured Swell Pressure and Calculated Swell Pressure Values by Using Correlations in Literature

7. Proposed Empirical Correlations for Swell Parameters of Expansive Soils From Monywa Township

For the soil sample from IZ, the coefficient of correlations for liquid limit and dry density is more reliable than that of plasticity index by comparison these values. So, the values of liquid limit and dry density are used for the empirical correlations. The empirical correlations are proposed in two parts. In first part, results of five samples are considered, and in second part, results of four samples are considered. Then, Multiple linear regression analysis for three dimensional models are used in proposing empirical correlation. By considering samples I, II, III, IV, V, the empirical correlations obtained are as follows;

$\varepsilon_s = 0.197\omega_l + 2.8304\gamma_d - 46.1191$ ($R = 0.958957$) (8)
$P_s = 4.4085\omega_l + 60.1215\gamma_d - 983.087$ ($R = 0.988603$) (9)

By considering samples I, II, III, IV, the empirical correlations obtained are as;
$\varepsilon_s = 0.1442\,\omega_l + 2.5064\gamma_d - 39.1362$ ($R = 0.995487$) (10) $P_s = 3.804\,\omega_l + 56.4024\gamma_d - 907.925$ ($R = 0.999997$) (11)

where,
ε_s = swell potential (%)
ω_l = liquid limit (%)
γ_d = dry density in kN/m^3
P_s = swell pressure (kN/m^2)

By comparing the correlation coefficients, the correlations obtained from considering five samples are more reliable than four samples. Therefore five samples correlations are chosen to predict the swell parameter for the most expansive soil in this study. The measured swell parameters are compared with calculated swell parameters by using proposed empirical correlations equation as shown in Table11, 12 and Figure 5, 6 for respective site.

Table11. Comparison between Measured Swell Potential and Calculated Swell Potential Values by Using Proposed Empirical Correlation

Sample	Liquid Limit ω_L (%)	Dry Density γ_d(kN/m^3)	Measured Swell Potential (%)	Calculated Swell Potential (%)
I	40	14.5	3.04	2.98
II	40.2	14.57	3.12	3.18
III	42.8	14.82	4.2	4.18
VI	43.1	14.46	3.32	3.33

Table12. Comparison between Measured Swell Pressures and Calculated Swell Pressure Values by Using Proposed Empirical Correlation

Sample	Liquid Limit ω_L (%)	Dry Density γ_d(kN/m^3)	Measured Swell Pressure (kN/m^2)	Calculated Swell Pressure (kN/m^2)
I	40	14.5	67.03	67.07
II	40.2	14.57	71.82	71.78
III	42.8	14.82	95.76	95.77
V	43.1	14.46	76.61	76.61

Figure6. Comparison between Measured Swell Pressure and Calculated Swell Pressure Values by Using Chosen Correlations

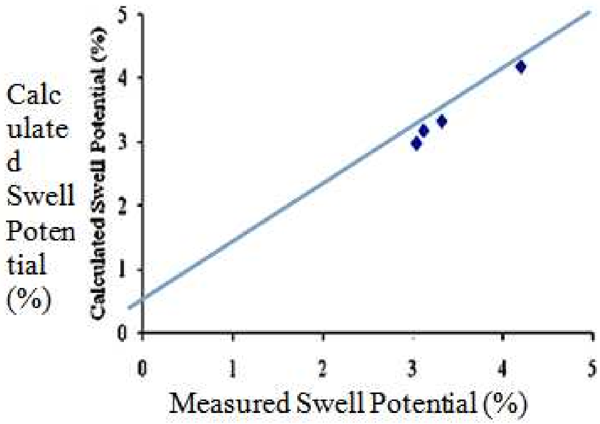
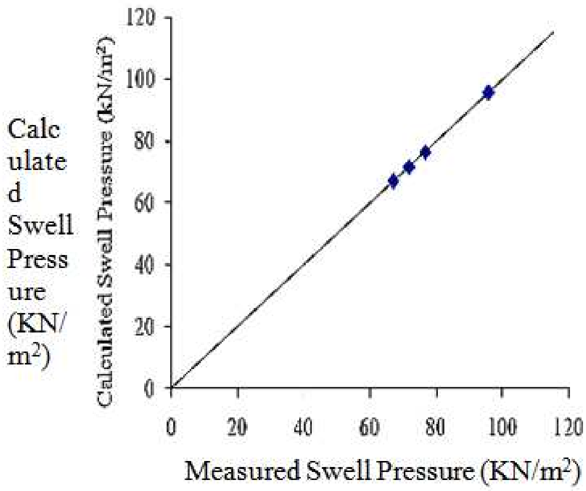


Figure7. Comparison between Measured Swell Pressure and Calculated Swell Pressure Values by Using Chosen Correlations



8. Discussions and Conclusion

Clay soils are characterized by their ability to undergo significant volume changes when they are wetted or they are dried out. The volume change of expansive soil is a complex process that is influenced by several factors. Properties and behavior of expansive soils must be thoroughly understood to identify its existence under a proposed construction project. Physical properties such as moisture content, dry density and index properties extensively influence the shrink-swell behavior of expansive soils. Index properties such as clay content, liquid limit, plasticity and shrinkage index can be used for identification and classification of expansive soils. Many classification schemes provide an "expansion rating" to provide a qualitive expansive rating, i.e., low, medium, high, very high expansion potential

In this study, clay content, liquid limit and plasticity index, shrinkage index are obtained from Grain-size analysis and Atterberg limit tests. According to expansive soil classification based on liquid limit, plasticity and shrinkage index, it is found that soil samples are medium in degree of expansion. Depending on liquid limit and plasticity index, the soil types for this study can be defined as CL in USCS. Moreover, degree of swelling potential for soil samples are determined by modified free swell index test. Based on the values of free swell index obtained, the soil samples are also identified as medium in swelling potential. Generally, soil samples with high initial water content, low dry density and low clay content have low swell potential and low swell pressure. Soil stabilization is improving the undesirable physical properties of a soil to achieve the desired shear strength and void ratio. Soil compaction is generally the cheapest method of soil stabilization available. However, although the amount of swelling is small structural damage to a structure above them can occur due to environmental condition. Mostly, the values obtained from the classification and swelling for soil IZ are more than those of other locations. Therefore, the soil from IZ is the most expansive for this study. Then, this sample is chosen to perform free swell test for the determination of swell parameters and prediction of the volume change of expansive soil from Monywa Township and also compared with available in literature by using empirical correlation equation.

In this study, swell potential and swell pressure are considered as the swell parameters. For swell parameters, correlation equation is calculated by using multiple linear regression analysis. There are three parameters namely: γ_d, ω_L and I_p correlated with both swell potential and swell pressure. Among them, γ_d is the most correlated with swell parameters and ω_L is the second most. Therefore, the multiple linear regression analysis is performed considering the independent variable of γ_d and ω_L. From this analysis, the empirical correlation equation can be proposed. It is found that measured swell parameters (from oedometer test) and calculated swell parameters (by using proposed empirical correlation equation) is almost equal. Finally, it can be concluded that the swell parameters of all soil samples are medium and prediction of swell parameters of expansive soils from Monywa Township can be calculated by using this proposed empirical correlation equation.

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