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Nomograph for Predicting Swelling Potential of Expansive Subgrade Soil

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Abstract: This paper investigates empirical correlation between expansive soil index properties and soil swelling. The paper uses the concept of Nomographs to develop one for prediction of soil swelling. Disturbed soil samples from different regions in Sudan were collected to represent the most challenging soils in the country. The samples were collected from Al-Qadarif (S1), Wad Medani (S2) and Al-Giraif East in Khartoum (S3). The basic properties of the soil samples were thoroughly measured. The three soils gave high swelling potential and high plasticity. The X-ray diffraction test results showed that S1 has the highest montmorillonite than the other two soils. Therefore S1 is considered as the most expansive soil compared with the other soils. The consistency factor which was developed can be used to correlate the basic properties of the soil with the soil swelling. The consistency factor is a combination of the moisture content, dry density, void ratio, liquid limit and plasticity index. These parameters are combined in a way reflecting the influence of each of them on the soil property. The swelling properties were measured for the soil samples compacted at different moisture content and different dry densities. Very good linear relationships were developed between the swelling properties and the consistency factor. The correlations developed were verified by using data reported by some previous researchers. Using the relationships developed in this study, Nomograph was designed so as to make easy to predict swelling potential.

Keywords: *Consistency Factor, Nomographs, Swelling Potential, Swelling Pressure.*

1. INTRODUCTION

Expansive soil in general is that soil which has a potential to increase in volume upon wetting and decrease upon drying. Appearance of expansive soil is high plasticity clay, slippery and very sticky if watered. It imbibes water during fall season which results in a dramatic heave, minimizes shear strength and tend to be compressible.

Moisture differential along seasons, affect lightly loaded foundations on expansive soil. Such foundations are subjected to two movement components upon moisture differential, heave and subsidence.The expansive soil by virtue of its mineralogical composition exhibits significant volume changes due to changes in its moisture content.

The presence of montmorillonite clay in these soils imparts them high swell-shrink potentials, [1]. Differential Thermal Analysis and X-ray diffraction pattern analysis have shown that montmorillonite mineral is predominant in expansive soil, [2].

The swelling phenomenon is known to be a function of two basic variables; the intrinsic soil properties and placement factors. The intrinsic soil properties are those related to the mineralogical composition of the clay fraction, soil gradation and its pore water chemistry. The placement factors are the density, water content and loading whereas the environmental factors are related to the increase and loss of water. Intrinsic swelling is the inherent expansiveness resulting from the intrinsic properties of a soil and the potential of a soil for swelling is explained by combination of the intrinsic soil properties and its placement and environmental Conditions, [3]. An intrinsically high potential expansive soil would not swell if it is below the ground water level, or subjected to loads greater than or equal to its swelling pressure.

The potential of a soil for swelling is assessed, mainly in the laboratory, using different types of test methods. These tests are normally carried out in the Oedometer apparatus and include percentage swell tests and the swelling pressure test. The latter is more standardized and is often used for quantifying the swell potential of swelling clays.

The classification of expansive soils is performed on the basis of its intrinsic expansiveness. The parameters used are therefore combination of intrinsic parameters such as Atterberg's limits, clay fraction, activity and shrinkage index, [4]. However, classifying the soils according to their swelling potential or predicting swell potential test parameter will necessitate using combination of intrinsic parameters and placement parameters.

2. LITERATURE REVIEW

Many researchers found that the initial soil state such as dry density, water content and void ratio greatly influence soil swelling and strength. Zumrawi [5] has found that the soil initial state and testing conditions greatly influenced the un-soaked CBR and shear strength. He proved that a direct linear relationship between swell percent, swelling pressure, un-soaked CBR or shear strength and the soil initial state. The data reported by the previous researchers show that the swelling of soil is influenced by the surcharge pressure imposed on the soil as well as the initial state of the soil as described by the dry density, water content and void ratio. On the other hand, the CBR and shear strength of soil is greatly influenced by the initial dry density, water content and void ratio of the soil as well as the testing conditions, [5].

The factors which influence swelling pressure could be grouped into compositional intrinsic factors such as clay mineralogy, clay content, gradation and pore water chemistry; environmental or placement factors such as water content, density, soil structure, stress history and temperature and procedural factors such as size and shape of the tested specimen, its level of disturbance, methods of swell and load measurements, [4]. Previous studies have shown that for a certain soil type, swelling pressure is function of dry density and initial moisture content, [6].

Analysis of the experimental results indicated that it is possible to combine the initial state parameters such as dry density, water content and void ratio in a way reflecting the influence of each of them on the swell percent, swelling pressure, un-soaked CBR and shear strength. Therefore a new concept was developed; this is called the initial state factor [5].

Attempts have been made to predict swelling pressure and percentage swelling using a single factor that combines more than one soil intrinsic or placement parameter. Mohamed [7] introduced the placement condition factor (F) which combines two placement parameters, dry density and moisture content and is defined as:

$$F = \frac{\gamma d}{mc} \quad (1)$$

Where (γd) is the dry density and (mc) is the water content.

The factor (F) was applied to swell percent data of compacted swelling soils from Sudan presented by Mohamed [7]. It was found that (F) predicts very well the swell percent for the same soil.

Zumrawi [8] modified the placement factor (Fi) to a new one called the initial state factor, (Fi) and is defined by:

$$Fi = \frac{\gamma d}{\gamma w.mc.e} \quad (2)$$

Where (γw) is the density of water and (e) is the void ratio. A linear relationship was found between (Fi) and swelling pressure for the same soil, the coefficients of which depends on plasticity index and clay content. It is noted that the two factors (F) and (Fi) considered only placement parameters, i.e., moisture content, dry density and void ratio [9]. Several statistical multiple regression relationships using intrinsic and placement parameters were developed by Zumrawi [8] for the prediction of swelling pressure and California Bearing Ratio.

Chen [10] has suggested that the initial state factor (Fi) was empirically formulated upon three liner relationships between swell percent vs. initial dry density, swell percent vs. moisture content and swell percent vs. void ratio depend on an experimental results. He indicated a liner relationship between swell percent and initial dry density and between swell percent and moisture content for the same soil. Zumrawi [5] has indicated an inverse relationship between swell percent and void ratio of the same soil at the same moisture content.

A well-known consistency factor combining placement parameter (mc) and Atterberg's limit is the liquidity index (LI). Liquidity index is a good indicator of where the soil moisture content lies in relation to its Atterberg's limits and is defined as:

$$LI = \frac{mc - PL}{PI} \quad (3)$$

The LI is negative when the moisture content is lower than the plastic limit and is zero when the moisture content equals to the plastic limit. A less often known consistency indicator is the consistency index, CI. This index is defined as:

$$CI = \frac{LL - mc}{PI} \quad (4)$$

The indicator CI is 1.0 when moisture content equals the plastic limit and zero when moisture content equals the liquid limit. It is noted that the consistency factors LI and CI do not include the dry density which is a major parameter affecting swelling. This study was performed to improve our understanding of the swelling behavior of expansive soils and to develop some models or factors which combine both soil placement conditions and soil intrinsic parameters for predicting swelling pressure.

The consistency factor of compacted soil was introduced by Mohamed [7] and then modified by Zumrawi [8]. The consistency factor (Fc) is defined as a combination of the soil index parameters such as dry density (γd), moisture content (w), void ratio (e) and soil consistency index (CI) and can be expressed as:

$$Fc = \frac{\gamma d * CI}{\gamma w * e} \quad (5)$$

The linear relationship exists between swell percent, swelling pressure, CBR or shear strength and soil state factors (Fi and Fc) can be of great use of in the characterization of the swelling and strength variation with water content and dry density of a given expansive soil, [11].

3. MATERIALS AND METHODS OF TESTING

Disturb soil samples from different regions in Sudan were collected to represent the most expansively soils. The samples were collected from Al-Qadarif (**S1**), Wad Medani (**S2**) and Al-Giraif East in Khartoum (**S3**). The soil samples were taken from depth between 0.5 to 1m.

3.1 Specimen Preparation and Testing Procedure

The soils were initially air dried, crushed into small sizes and pulverized. The tested samples were prepared by sieving the soil through sieve No.4 (4.75mm). The fine materials passing sieve No.4 were used in the experimental work. The soil samples were oven dried at 105-110 C for 24 hours.

Physical properties of the three soils were measured as well as swelling characteristics. The tests include gradation, consistency limits, specific gravity and compaction. The swelling tests include free swell, swell percent and swell pressure. The tests were conducted according to the standard procedures of BS (1990), [12]. Then the three soils were mixed with distilled water to different initial moisture contents and manually compacted to different dry densities. The swelling potential (swell percent and swelling pressure) of the compacted samples were measured according to the standard procedures of BS (1990), [12].

4. RESULTS AND ANALYSIS

4.1 Basic Properties

The basic properties of the three soils were measured as shown in Table 1. Gradation, Specific gravity, consistency limits, compaction parameters, swelling characteristics and chemical composition.

Depending on the gradation analysis performed, the three soils contain great amount of clay fraction. The consistency tests showed that the three soils demonstrated high plasticity, so they were classified as highly expansive soils. The micro fabric test results showed that the three soils contain montmorillonite mineral more than 70%. The results indicated that soil S1 has the highest montmorillonite than the other two soils. Therefore S1 is considered as the most expansively soil compared with the other soils.

The swelling characteristics tests showed that the three soils are highly swelling soils. S3 gives the highest swelling potential than the other two. Finally the compaction characteristics that is shown in the Table evident the tested soils are likely perform very low strength.

4.2 Development of Linear Relationship

Swelling pressure and swell percent were measured to develop and verify the linear relationships between them and the consistency factor (F_c) which is introduced in Equation 5 above. Swell percent of each soil was measured at 7, 30 and 50kPa. The tests results obtained were analyzed as given in Table 2.

The relationship of the analyzed data for the three soils are shown in Figures 1 to 4. The plot in this Figures and the value of the correlation coefficient, R^2 have clearly shown good linear relationships between the swelling potential and the consistency factor (F_c) for the data analyzed. The straight lines shown in the plots of Figures 1 to 4 can be represented in Figure 5 and Equation 6:

$$S = M\,(F_c - F_0) \qquad (6)$$

Where: F_0 is the value of F_c at zero swelling and M is the gradient of the straight line. The values of M, F_0 and R^2 for the three soils obtained from the plot of Figures 1 to 4 are given in Table 3.

Table 1. Properties of the studied soils.

Property	S1	S2	S3
Gravel (%)	2.8	1.8	0.5
Sand (%)	5.0	10.4	3.4
Silt (%)	16.3	14.1	21.9
Clay (%)	75.9	73.7	74.3
GS	2.712	2.711	2.792
LL (%)	80	72	106
PL (%)	32	30	28
PI (%)	48	42	78
Kaolinite (%)	12.3	42.5	22.9
Illite (%)	1.3	1.3	0.8
Montmorillonite (%)	86.2	55.4	75.9
Chlorite (%)	0.2	0.5	0.3
FSI (%)	205	180	300
S% at 7Kpa (%)	5.3	4.8	9.6
SP (Kpa)	240	286	615
OMC (%)	27.4	27	23.3
MDD (KN/m^3)	13.8	14.2	15.0

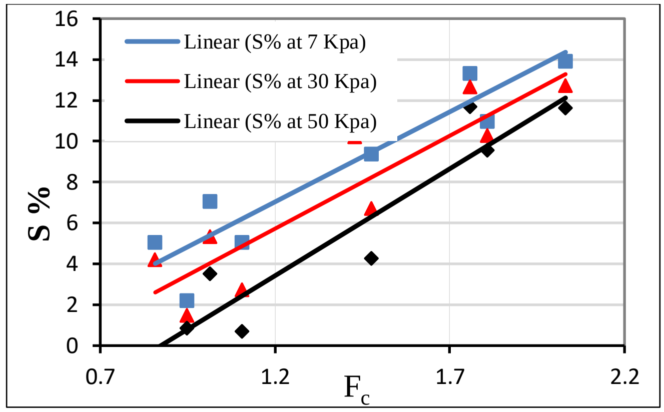

Fig. 1. S% versus F_c of soil S1

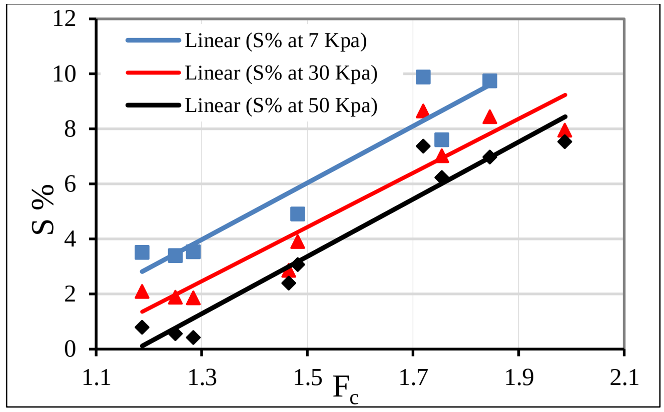

Fig. 2. S% versus F_c of soil S2

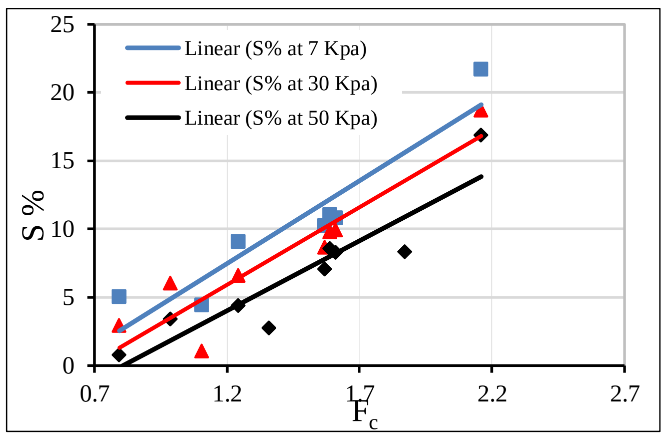

Fig. 3. S% versus F_c of soil S3

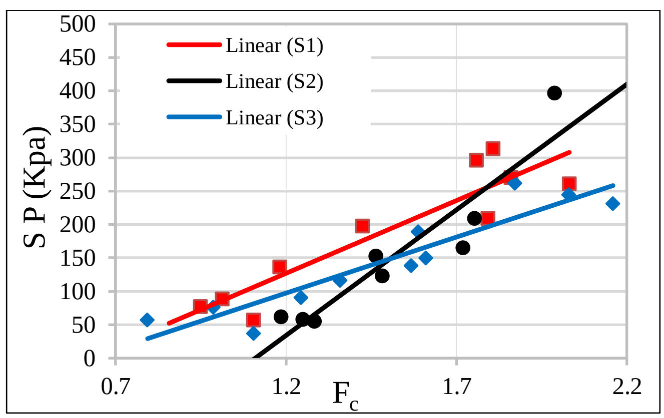

Fig. 4. SP versus F_c of the three soils

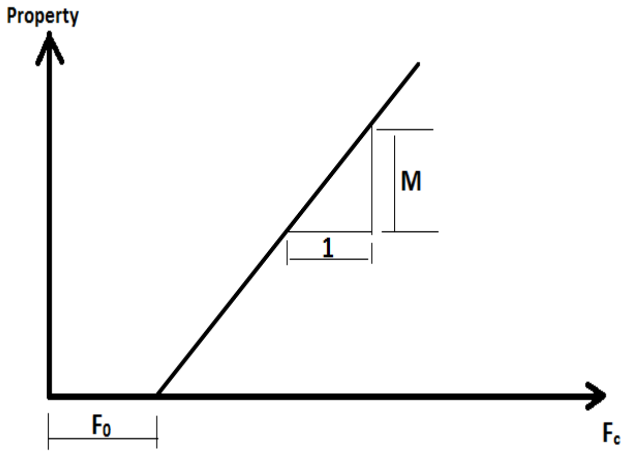

Fig. 5. Expression of relationship (Equation 6) between soil properties and Fc.

Table 3. Values of M, F_0 and R^2 of the three soils

Property		S1	S2	S3
S% at 7 kPa	M	8.81	10.31	12.14
	F_0	0.40	0.91	0.58
	R^2	0.85	0.90	0.87
S% at 30 kPa	M	9.10	9.83	11.36
	F_0	0.57	1.05	0.68
	R^2	0.82	0.88	0.85
S% at 50 kPa	M	10.47	10.40	10.24
	F_0	0.90	1.18	0.81
	R^2	0.88	0.93	0.84
SP (kPa)	M	218	376	168
	F_0	0.62	1.11	0.62
	R^2	0.85	0.87	0.87

5. PREVIOUS DATA

For validation of the developed empirical correlation in this paper (Equation 6), related data of previous researches were analyzed. The data of some selected researchers involved soil swelling soil strength and soil index properties. The selected researchers are [13], [14], [15], [9] and [8]

5.1 Swell Percent

Zain [13] studied the swell percent at 7 kPa of expansive soil from Sudan at different placement condition. The soil studied had LL = 77 and PI = 34. The experimental data as reported by [13] are given in Table 4. The data are analyzed as shown Figure 6.

Erzin and Güneş [15] studied the swell percent of compacted expansive soil. The properties of the soil studied were LL = 58.75, PI = 33.05 and Gs = 2.67. The data of the tested soil as reported by [15] are given in Table 5. The data are analyzed as shown Figure 7.

Swell percent at 7 kPa of compacted expansive soil in China was studied by Zumrawi [8]. The properties of the soil studied were LL = 58.9, PI = 32.8 and Gs = 2.72. The data of the tested soil as reported by [8] are given in Table 6. The data are analyzed as shown Figure 8.

The correlation coefficients of swell percent data of previous researchers are summarized in Table 7.

Table 4. The data of swell percent at 7Kpa of compacted soil as reported by Zain [13]

m.c (%)	**Υ_d (gm/cm3)**	**S% at 7** kPa
15.6	1.64	16.9
21.0	1.38	8.4
21.2	1.64	11.4
24.3	1.63	9.7
24.6	1.34	7.0
28.0	1.34	5.6
31.3	1.38	4.0
34.5	1.37	3.0
41.3	1.26	1.3

Table 5. The data of swell percent at 7Kpa as reported by Erzin and Güneş [15]

m.c (%)	**ϒd (gm/cm3)**	**S% at 7** kPa
10	1.7203	30.2
10	1.7916	33.2
15	1.4857	18.3
15	1.5969	20.5
15	1.6795	24.8
15	1.7254	26.2
20	1.6519	11.1
20	1.6621	13.1
20	1.6662	15.1
20	1.6897	16.8
25	1.5245	5.9
25	1.5357	5.3
25	1.5765	6
25	1.5490	6.3

Table 6. The data of swell percent at 7 kPa of compacted soil reported by Zumrawi [8]

m.c (%)	**ϒd (gm/cm3)**	**S% at 7** kPa
11.94	1.565	13.4
11.99	1.732	21.6
14.97	1.583	10.1
15.29	1.789	19.9
15.46	1.574	11.5
16.76	1.572	9.39
16.76	1.445	7.84
17.38	1.734	15.8
19.76	1.686	8.7
19.76	1.61	8.35
23.03	1.609	7.05
23.56	1.448	5.95
28.73	1.492	5.3

Table 7. Coefficients and linearity of the developed correlation of S%

Reference	**M**	**F_o**	**R^2**
Present study Gedarif clay	8.81	0.40	0.85
Present study Madani clay	10.31	0.91	0.90
Present study Giraif East clay	12.14	0.58	0.87
[13] Sudan clay	4.06	0.59	0.88
[15]	8.74	1.33	0.86
[8] China clay	5.40	0.90	0.86

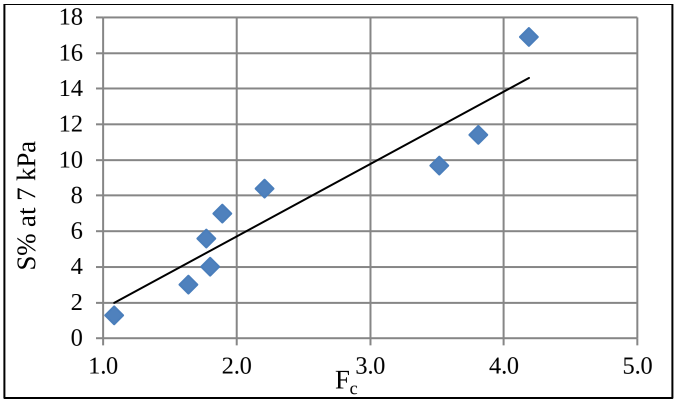

Fig. 6. Relationship between S% and F_c for the analyzed data reported by [13]

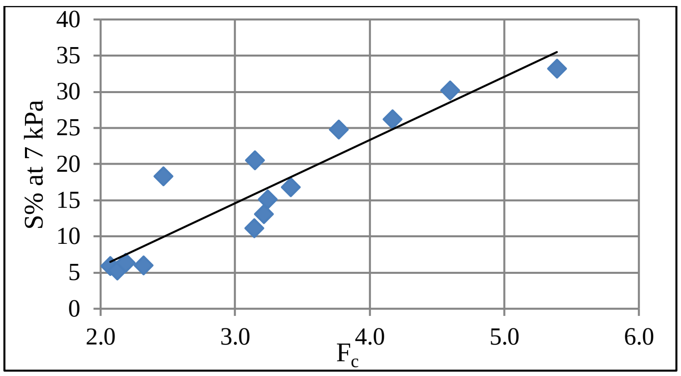

Fig. 7. Relationship between S% and F_c for the analyzed data reported by Erzin and Güneş [15]

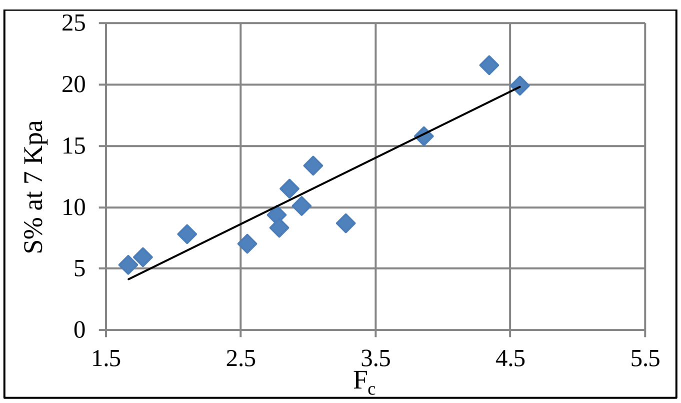

Fig. 8. Relationship between S% and F_c for the analyzed data reported by Zumrawi [8] 5.2 Swelling Pressure

5.2 Swelling Pressure

O'Connor [14] studied two soils, Wadhurst clay *(LL = 57, PI = 33)* and London clay *(LL = 78, PI = 50)*. The test results as reported were given in Table 8 and analyzed as shown Figures 9 and 10.

Elsharief et al. [9] studied two soils from Sudan, Abeyi soil *(LL = 61, PI = 32, Gs = 2.61)* and Alfao soil *(LL = 66, PI = 37, Gs = 2.7)* Their results were given as reported in Table 9 and analyzed as shown Figures 11 and 12.

Zumrawi [8] studied swelling pressure of expansive soil from China *(LL = 58.9, PI = 32.8, Gs = 2.72)*. The data given in Table 10 and were analyzed as shown Figure 13.

The correlation coefficients of swelling pressure data of previous researchers are summarized in Table 11.

Table 8. The data of SP for compacted soils as reported by O'Connor [14]

Wadhurst Clay			London Clay		
m.c (%)	**Υ_d g/cm^3**	**SP (kPa)**	**m.c (%)**	**Υ_d (g/cm^3)**	**SP (kPa)**
15.79	1.881	583.3	24.03	1.653	226.0
20.38	1.588	113.5	24.17	1.600	195.2
20.38	1.549	77.2	24.43	1.625	208.0
20.38	1.495	50.9	25.19	1.607	200.2
20.38	1.483	41.0	30.00	1.447	69.5
20.38	1.397	15.6	30.11	1.457	65.0
20.64	1.730	228.7	31.05	1.434	58.0
22.73	1.650	121.5	31.62	1.452	37.5
22.86	1.734	215.0	31.96	1.398	34.6
22.87	1.727	191.3	34.17	1.384	35.0
23.16	1.640	100.4	34.40	1.362	28.0
23.28	1.655	107.8			
23.86	1.627	68.1			
23.95	1.642	88.9			
23.95	1.621	52.5			

Table 9. The data of SP for compacted soils as reported by Elsharief et al. [9]

m.c (%)	**Υ_d (gm/cm^3)**	**SP (kPa) for Abeyi soil**	**SP (kPa) for Alfao soil**
6.5	1.25	20.02	47.74
20	1.25	16.33	46.51
25	1.25	14.48	41.27
30	1.25	12.63	34.80
35	1.25	7.09	28.95
40	1.25	2.46	14.48
6.5	1.35	41.59	136.14
20	1.35	37.58	89.32
25	1.35	32.96	80.08
30	1.35	19.1	63.45
35	1.35	8.63	30.80
40	1.35	4.93	16.94
6.5	1.45	55.14	158.31
20	1.45	49.29	135.52
25	1.45	44.97	124.43
30	1.45	27.11	71.76
35	1.45	9.55	61.91
40	1.45	-	24.33

Table 10. The data of SP for compacted soil as reported by Zumrawi [8]

m.c (%)	**Υ_d (gm/cm^3)**	**Measured SP (kPa)**
11.94	1.565	220
11.99	1.732	300
14.97	1.583	150
15.29	1.789	260
15.46	1.574	115
16.76	1.572	125
16.76	1.445	28
17.38	1.734	200
19.76	1.686	120
19.76	1.610	95
23.03	1.609	112
23.56	1.448	50
28.73	1.492	38

Table 11. Coefficients and linearity of the developed correlation of SP

Reference	M	F_o	R^2
Present study Gedarif clay	218.0	0.62	0.85
Present study Madani clay	376.0	1.11	0.87
Present study Giraif East clay	168.0	0.62	0.87
[14] Wadhurst clay	157.4	1.88	0.97
[14] London clay	147.5	1.04	0.98
[9] Abeyi clay	25.2	0.69	0.85
[9] Alfao clay	84.0	0.68	0.89
[8] China clay	87.3	1.37	0.85

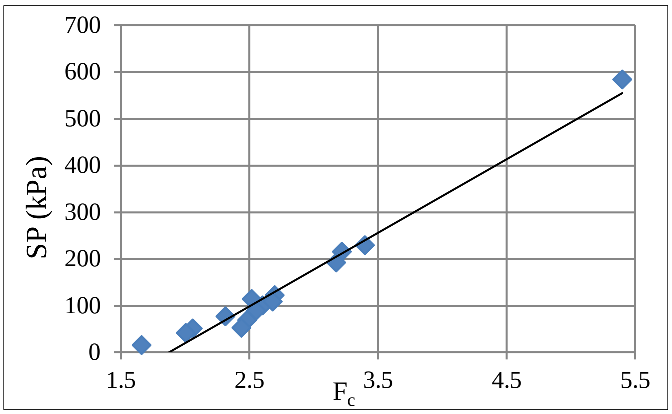

Fig. 9. Relationship between SP and F_c for the analyzed data reported by O'Connor [14] (Wadhurst clay)

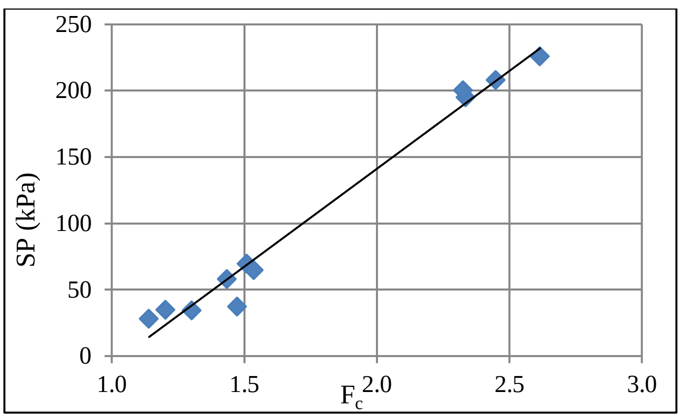

Fig. 10. Relationship between SP and F_c for the analyzed data reported by O'Connor [14] (London clay**)**

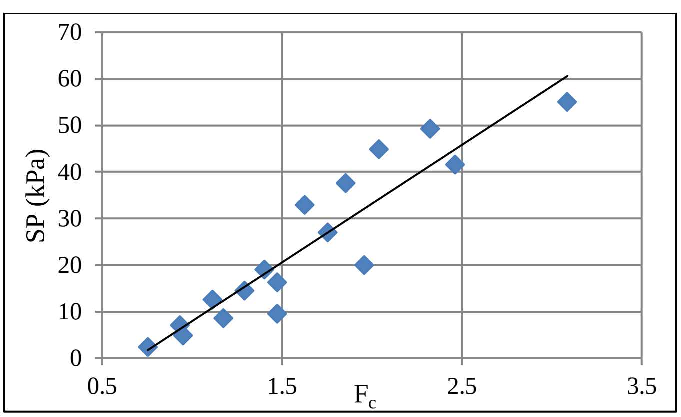

Fig. 11. Relationship between SP and F_c for the analyzed data reported by Elsharief et al. [9] (Abeyi clay)

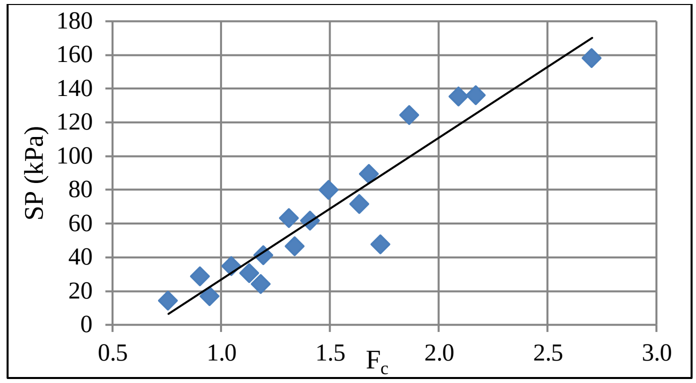

Fig. 12. Relationship between SP and F_c for the analyzed data reported by Elsharief et al. [9] (Alfao clay*)*

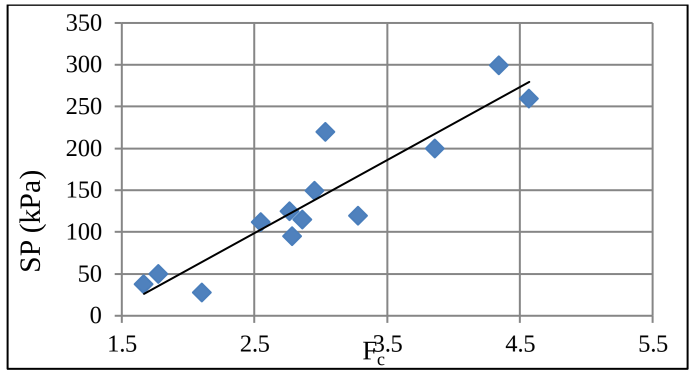

Fig. 13. Relationship between SP and F_c for the analyzed data reported byZumrawi [8]

6. DEVELOPMENT OF NOMOGRAPH

A nomograph or alignment chart or nomogram, is a two-dimensional diagram designed to allow the approximate graphical computation of a mathematical function. The field of nomography was used extensively for many years to provide engineers with fast graphical calculations of complicated formulas to a practical precision. Nomographs use a parallel coordinate system rather than standard Cartesian coordinates.

The relationship between Fc and the soil swelling in this study can be simply plotted by parallel Nomograph as shown in Figure 14. The Nomograph are drawn using AutoCAD program. It is to be noted that different scales are used to draw each property on the Nomograph. The Nomograph plots the SP and S% with the corresponding values of Fc. The predicted soil properties used to draw the Nomograph are the averages values of the tested soils in the present study which is obtained from the devolved equation (Equation 6). The Nomograph is easy and simply describe the relations between Fc and both SP and S% of a soil as exemplified by the index line on the Nomograph. These soil properties correspond together to the Fc horizontally in this Nomograph.

7. DISCUSSION

The developed correlation between soil index properties and soil swelling which is introduced in Equation 6 have demonstrated good linear relationship. The linearity of the correlations is expressed by (R^2) given in Tables 7 and 11. The correlations linearity mentioned in the Tables are almost ranging between 85 to 98% which indicate acceptable linear relationships to predict soil swelling. To verify the validity of the developed correlation, the measured and predicted values of the S% and SP are plotted in Figures 15 and 16 respectively. The measured and predicted values of soil swelling engaged were that experimented results in this study together with selected previous related studies ([13], [14], [15], [9] and [8])

The predicted S% and SP were obtained from the developed Equation 6. The correlation coefficients (M and F_0) of this study were obtained from Table 3. The correlation coefficients (M and F_0) of the previous studies were obtained from Tables 7 and 11 In this study, 26 samples were measured for S% and 29 samples for SP as given before in Table 2. From the previous studies, 36 samples were investigated for S% and 74 samples for SP.

The data provided in Figures 15 and 16 show that all points are almost laying on the Iso-line which indicate considerable rapprochement between the measured and predicted values of S% and SP and this evidenced the validity of the developed equation.

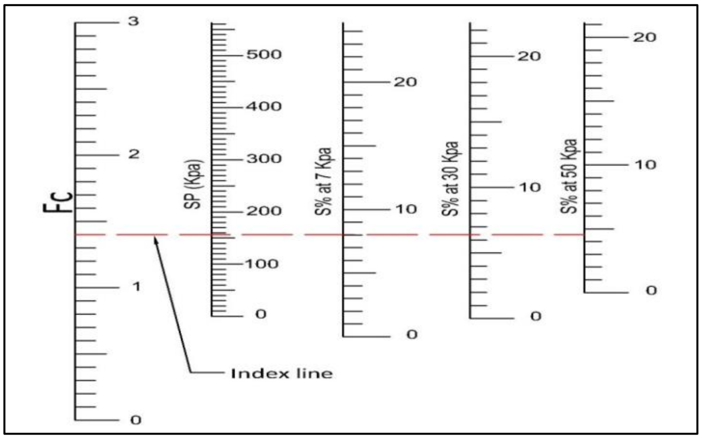

Fig. 14. Nomograph of swelling properties

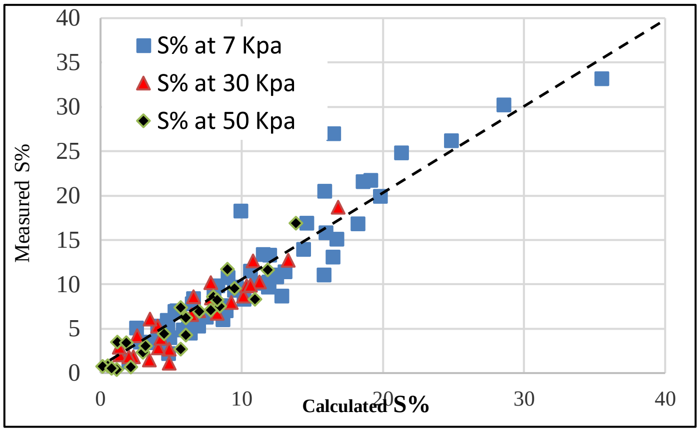

Fig. 15. Comparison between measured and predicted S% of the present study and some previous studies

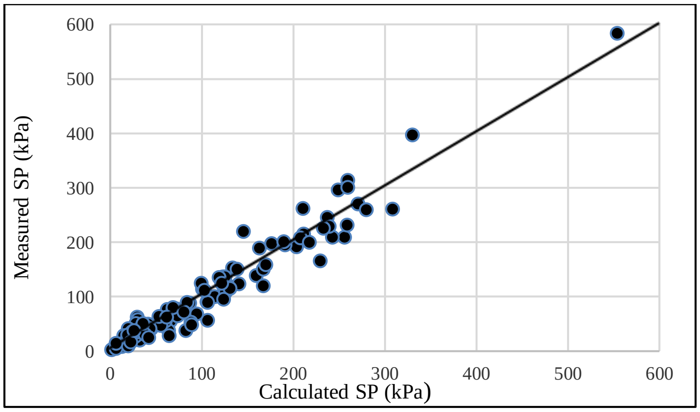

Fig. 16. Comparison between measured and predicted SP of the present study and some previous studies.

8. CONCLUSION

The paper methodology is experimental work conducted on different expansive soils samples taken from different regions in Sudan. The basic properties of the soil samples were measured. The three soils have high plasticity, so they were classified as highly expansive soils.

The XRD test showed that the three soils contain montmorillonite mineral. The test result showed that soil **S1** has the highest montmorillonite than the other two soils. Therefore S1 is considered as the most expansive soil compared with the other soils.

The swelling characteristics of the three soils were measured. The three soils were classified as high potential soils.

The developed consistency factor can be used to correlate the basic properties of the soil with the swelling properties. The consistency factor is a combination of the moisture content, dry density, void ratio, liquid limit and plasticity index. These parameters are combined in a way reflecting the influence of each of them on the soil property. The swelling properties were measured for 83 soil samples compacted at different moisture content and different dry densities.

A very good linear relationship was developed between the consistency factor and the swelling properties. The correlation developed was verified by using the data of this study and the data reported by some previous researchers.

The Nomograph is matching soil properties, which make it easy and simple to estimate the soil properties instantly. Predicted soil properties in this study were plotted on Nomograph in different scales and that makes it directly in lines to match properties together. From the regression analysis, the linearity index (R^2) was found to be in the range 0.85 to 0.98 which indicated very good linear relationship.

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Table 2. The swelling measured values of the three soils under different placement conditions

Soil	**m.c (%)**	**Υ_d (gm/cm^3)**	**e**	**CI**	**F_c**	**S% @**	**S% @**	**S% @**	SP(**kPa)**
S1	14.8	1.257	1.2	1.4	1.5	9.4	6.7	4.3	*
	14.8	1.400	0.9	1.4	2.0	13.9	12.7	11.6	261
	15.1	1.135	1.4	1.4	1.1	5.0	2.7	0.7	57
	19.5	1.394	0.9	1.3	1.9	*	*	*	270
	20.0	1.279	1.1	1.3	1.4	10.8	10.2	*	198
	20.2	1.106	1.5	1.2	0.9	2.2	1.5	1.5	77
	24.2	1.163	1.3	1.2	1.0	7.1	5.3	3.5	89
	24.5	1.417	0.9	1.2	1.8	*	*	*	209
	24.9	1.234	1.2	1.2	1.2	*	*	*	136
	25.0	1.425	0.9	1.1	1.8	11.0	10.3	9.6	313
	28.2	1.440	0.9	1.1	1.8	13.3	12.7	11.7	296
	29.7	1.136	1.4	1.0	0.9	5.0	4.2	*	*
	28.2	1.440	0.9	1.0	1.8	3.5	1.9	0.4	296
S2	14.7	1.195	1.3	1.4	1.3	*	*	*	56
	15.0	1.357	1.0	1.4	1.8	9.7	8.4	7.0	*
	19.7	1.364	1.0	1.2	1.7	9.9	8.6	7.4	166
	19.8	1.201	1.3	1.2	1.2	3.5	2.1	0.8	62
	19.8	1.431	0.9	1.2	2.0	*	8.0	7.5	397
	24.5	1.417	0.9	1.1	1.8	7.6	7.0	6.2	209
	24.9	1.339	1.0	1.1	1.5	*	2.9	2.4	152
	29.5	1.314	1.1	1.0	1.3	3.4	1.9	0.6	59
	29.5	1.391	1.0	1.0	1.5	4.9	3.9	3.1	124
S3	14.9	1.529	0.8	1.2	2.2	21.7	18.7	16.9	232
	15.1	1.274	1.2	1.2	1.2	9.1	6.6	4.4	91
	15.1	1.379	1.0	1.2	1.6	10.3	8.7	7.1	138
	19.3	1.407	1.0	1.1	1.6	11.1	9.8	8.6	189
	19.7	1.525	0.8	1.1	2.0	*	*	*	245
	20.0	1.246	1.2	1.1	1.1	4.5	1.1	*	38
	23.9	1.216	1.3	1.1	1.0	*	6.1	3.4	76
	24.4	1.513	0.9	1.1	1.9	*	*	8.3	262
	24.5	1.443	0.9	1.1	1.6	10.9	9.9	8.3	150
	29.6	1.393	1	1.0	1.4	*	*	2.7	117
	30.1	1.156	1.4	1.0	0.8	5.1	2.9	0.8	57

* The tests were not performed due to technical difficulties.