Quick Prediction of Surat Region Expansive Soils Parameter Based on Swelling Characteristics

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Abstract*: In India large surface deposits are covered by Expansive soil. Surat city situated in South Gujarat region of India is covered with the expansive soil. Civil engineering structure constructed on such soils experience damage due to uneven movement caused by swelling and shrinkage process of the soil. Hence swelling characteristics are more important in case of expansive soil. Identification and classification of the soil for Surat region has been carried out. The swelling pressure test taking the more time to find out the pressure exerted due to swell. Past empirical correlation for the swelling pressure and free swell index with index properties developed by the researchers are not the accurate solution for the Surat region. Hence, new correlations of swelling pressure and free swell index have been carried out for the Surat region by statistical analysis using linear regression analysis method. New correlations are proposed for prediction of swelling pressure and free swell index using basic index and plasticity characteristics in different combinations for this region. These correlations may use for quick analysis of free swell index and from that swelling pressure using this basic properties.

***Keywords:* Empirical corrélations, Free swell index, Regression analysis, Swelling pressure.**

I. INTRODUCTION

Surat is "THE GREEN CITY" located at west side in India in the state of Gujarat. Deep black coastal alluvial predominant in Surat city. Various types of civil engineering activities taking place on the expansive soil deposits. Expansive soil which have tendency to undergo volume change due to change in water content with seasonal variation. Due to the peculiar behavior of the expansive soils the structure constructed on them shows heavy sign of damage like cracking, sliding, heaving and the expenditure on annual repair and maintenance of such building and structure. Expansive soil owes this property due to presence of clay mineral known as montmorillonite. Soils which contain smectite minerals such as montmorillonite are capable of absorbing great amount of water and expand. . Expansive soils also shrink when they dry out. Fissures in the soil can also develop. These fissures help water to penetrate to deeper layers when water is present. This produces a cycle of shrinkage and swelling that causes the soil to undergo great amount of volume changes. These clays are available worldwide and are a continual source of concern causing substantial distress.

In ordinary soils, where settlement or shear strength is important in the design of foundation, in expansive soils, heave or swelling pressure becomes important. Its, Therefore becomes necessary to identify expansive soil by simple classification tests before determining their potential for swell in order to estimate the magnitude of heave.

II. IDENTIFICATION AND CHARECTERISTICS

The entire region of Surat is divided mainly in seven zones by the region within Surat Corporation Boundary. "Work from whole to part" principal is applied in this work. The soil in most of the zones are stratified alluvial deposits under the alternate floods and tides.The city is subjected to frequent floods. The laboratory results of 14 soil samples of different zones are studied. The depth of soil studied is about 1.5 m. The figure 1 shows the different locations from where the soil samples have been collected, the dots shows the location of the collected soil samples.

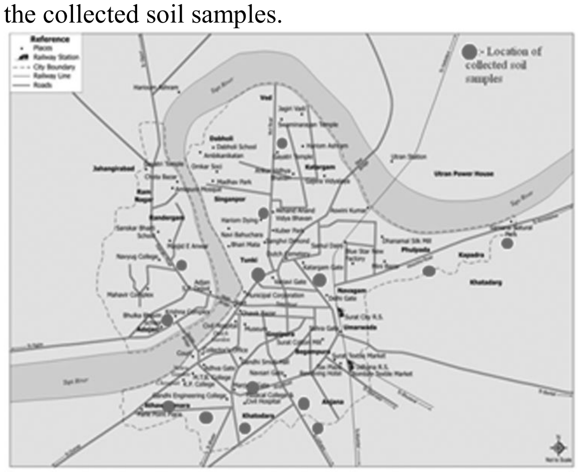

Fig. 1. Location of collected sample in Surat

As a convenience for comparing a variety of soils, Dakshanamurthy V. and Raman V. give a plasticity chart shown in figure 2. According to chart, soil is identified as high swelling and high plastic soil.

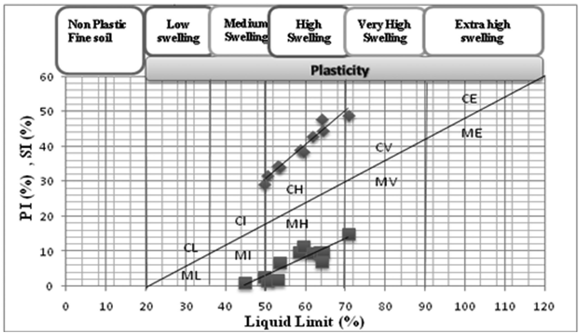

Fig. 2. A-line chart

From the chart, for the Surat region high plastic clay and high swelling silt are available at the 1.5 to 2 m depth. Test shows the low value of swelling pressure which indicates the moderately swelling soil. This is due to clay and silt particles present in the soil. The average ranges of soil properties are shown for expansive soil of studied area as shown in Table I.

TABLE I
CHARACTERISTICS OF EXPANSIVE SOILS FOR STUDY AREA

Property	Range
Field Moisture Content (%)	10 - 35
Field Dry Density (gm/cc)	1.15 - 1.65
Liquid Limit (%)	40 - 70
Plastic Limit (%)	18 - 25
Plasticity Index	25 - 50
Shrinkage Limit (%)	8 - 20
Shrinkage Index	0 - 15
Free Swell Index	40 - 80
Swelling Pressure (kg/cm^2)	0.065 - 0.258

Most of the ranges of expansive soil properties given by Prof. Katti are matched with performed properties for Surat city. So on that basis soil of Surat city is concluded as an expansive.

III. STATISTICAL SUMMARY OF NEW CORRELATIONS FOR FREE SWELL INDEX

In Multiple regressions analysis, the relationship between a single dependent variable and *two or more* independent variables are studied using regression forecasting software as shown in figure 3.

Measures of Effectiveness from software:

R Square

R^2, the coefficient of multiple determinations represents the strength of the relationship between the dependent and independent variables.

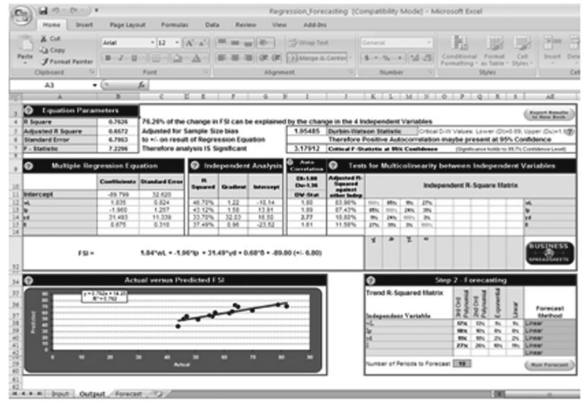

Fig. 3. Regression analysis

Adjusted R

In a multiple linear regression model, adjusted R square measures the proportion of the variation in the dependent variable accounted for by the explanatory variables. Unlike R square, adjusted R square allows for the degrees of freedom associated with the sums of the squares. Therefore, even though the residual sum of squares decreases or remains the same as new explanatory variables are added, the residual variance does not. For this reason, adjusted R square is generally considered to be a more accurate goodness-of-fit measure than R square.

Points to note when using adjusted R square: If adjusted R square is significantly lower than R square, this normally means that some explanatory variable(s) are missing. Without them, the variation in the dependent variable is not fully measured.

Standard error

The standard error of a method of measurement is the standard deviation of the sampling distribution associated with the estimation method.

F Statistic

Also known as F provides an indication of the lack of fit of the data to the estimated values of the regression. The F statistic can test the null hypothesis that no connection exists between the dependent variable and all or some of the independent variables.

Correlation for Free Swell Index with basic soil properties:

Test datasets of free swell index with liquid limit, plasticity index, dry density and % clay of soils is used for study area.

$$F.S.I. = 1.84 w_L - 1.96 I_P + 31.49 \gamma_d + 0.68\,\delta - 89.80\ (+/- 6.80)$$

$R^2 = 0.7626$

Where, FSI : Free Swell Index

w_L: Liquid Limit

I_p : Plasticity Index

γ_d : Field Dry Density

δ : Soil Passing Through 75 μ

R^2 : Correlation coefficient

Correlation using these test results for free swell index is derived with higher value of correlation coefficient (R^2). These results show high coefficients of multiple determinations which confirm the existence of strong correlations between the FSI and the soil properties.

R square: 0.7626
Adjusted R square: 0.6572
Standard Error: 6.7953
F-Statistic: 7.2296

The graph below shows comparison between actual FSI obtained from test results and predicted FSI obtained from regression analysis. Comparison shows satisfactory results for test readings therefore it can be used for prediction of FSI from easily determined soil properties. The data trends in the figure indicate that there is a good agreement between the measured and predicted FSI.

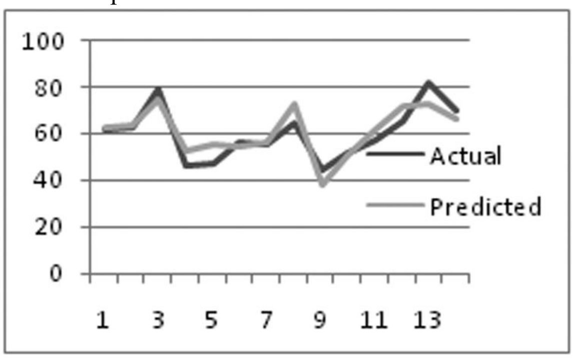

Fig. 4. Comparison between Actual & predicted FSI

IV. STATISTICAL SUMMARY OF NEW CORRELATIONS FOR SWELLING PRESSURE

The detail statistical analyses of soil index properties and swelling pressure of expansive soil of study area are carried out using various datasets. A dataset containing index and swelling pressure are used to conduct a statistical study to determine suitable correlations for estimating swelling pressure. The analysis was carried out by two method of regression analysis such as by solving matrices AX = B and by using software SPSS 13. data editor. This statistical analysis was carried out in order to obtain the most suitable and practically applicable relationships by comparing results of both methods. The statistical parameters such as unstanderdized and standardized coefficient, mean, standard deviation and analysis of variation (ANOVA) are presented in Table 2, 3 and 4 for different soil properties. The laboratory test results for soil characteristics of zones of Surat are carried out. Using these laboratory results new correlations are derived for swelling pressure of soil. These correlations and correlation coefficient are shown below.

Unstandardized coefficients show absolute change of dependent variable weight if dependent variable size changes one unit. The beta coefficients are the standardized regression coefficients. Their relative absolute magnitudes reflect their relative importance in predicting weight. The t value provides a test of the hypothesis that the associated parameter is zero against the alternative hypothesis that it is non-zero.

TABLE II
COEFFICIENT BY SPSS 13

Model	Unstandardized coefficients		Standardized coefficients	t	sig
	B	Std. Error	Beta		
1 Const.	-0.296	.015		-19.276	.000
W_L	.008	.000	.994	29.633	.000
2 Const.	-.284	.041		-6.843	.000
W_L	.007	.002	.917	3.754	.005
I_P	.001	.002	.078	.318	.758
3 Const.	-.295	.075		-3.908	.004
W_L	.008	.003	.969	2.539	.035
I_P	.0003	.002	.043	.132	.898
Is	.0002	.001	-.019	-.183	.859
4 Const.	-.276	.131		-2.106	.073
W_L	.007	.004	.921	1.906	.098
I_P	.00048	.003	.064	.177	.864
Is	.00015	.002	-.011	-.097	.925
FMC	.00018	.001	-.021	-.184	.859
5 Const.	-.316	.121		-2.624	.039
W_L	.008	.003	.969	2.222	.068
I_P	.002	.003	.225	.660	.534
Is	-.0003	.001	-.023	-.219	.834
FMC	.0002	.001	.025	.229	.827
FSI	-.001	.000	-.168	-1.621	.156

TABLE III
MODEL SUMMARY BY SPSS 13.

Model	R	R Square	Adjusted R Square	Std. Error of the
1	.994(a)	.989	.988	.006653
2	.994(b)	.989	.986	.006974
3	.994(c)	.989	.985	.007381
4	.994(d)	.989	.983	.007872

R Square is influenced by the number of independent variables. The measure R is the *positive multiple correlation coefficient*. The measure *R Square,* usually written as R^2, is the square of R and represents the proportion of variation in the response variable explained by the regression model. It takes a value between 0 and 1. Note that although a high value of R^2 may be seen as evidence of a good fit,

TABLE IV
ANOVA FROM SPSS 13.

Model	Sum of Square	df	Mean Square	F	Sig.
Regression	.039	1	.039	878.130	.000
Residual	.000	10	.000		
Total	.039	11			
Regression	.039	2	.019	399.645	.000
Residual	.000	9	.000		
Total	.039	11			
Regression	.039	3	.013	237.828	.000
Residual	.000	8	.000		
Total	.039	11			
Regression	.039	4	.010	156.837	.000
Residual	.000	7	.000		
Total	.039	11			
Regression	.039	5	.008	155.167	.000
Residual	.000	6	.000		
Total	.039	11			

df = degree of freedom

ANOVA tells us how these independent variables interact with each other and what effect these interaction have on the dependent variable.

From the above analysis, the more accurate correlations are,

$$p_s = 0.0008 - 0.00553(w_L) + 0.012326(I_P)$$

$R^2 = 0.931$

$$p_s = 0.000314 - 0.00387(w_L) + 0.009067(I_P) + 0.004062(I_S)$$

$R^2 = 0.967$

$$p_s = 0.00032 - 0.00429(w_L) + 0.010626(I_P) + 0.004126(I_S) - 0.00061\ (FSI)$$

$R^2 = 0.972$

$$p_s = -0.276 + 0.007(w_L) + 0.0005(I_P) - 0.00015(I_S) + 0.00018(FMC)$$

$R^2 = 0.974$

$$p_s = 0.00015 - 0.00078(w_L) + 0.00642(I_P) + 0.00242(I_S) - 0.00176(FMC) - 0.00042(FSI)$$

$R^2 = 0.983$

where,
p_s = Swelling pressure in Kg/cm^2
w_L = Liquid limit(%)
Ip = Plasticity Index
Is = Shrinkage Index
FMC = Field moisture content(gm/cc)
FSI = Free swell index
R^2 = Correlation coefficient

Swelling Pressure from Liquid Limit, Shrinkage Index, Plasticity Index, FMC, FSI of Soils:

Test datasets of swelling pressure with liquid limit, shrinkage index, plasticity index, FMC, FSI of soils is used for study area. Correlation using these test results for swelling pressure is derived with higher value of correlation coefficient (R^2).

$$p_s = 0.00015 - 0.00078(w_L) + 0.00642(I_P) + 0.00242(I_S) - 0.00176(FMC) - 0.00042(FSI)$$

$R^2 = 0.983$

Comparison of predicted and measured values of swelling pressure is shown in Fig 6.

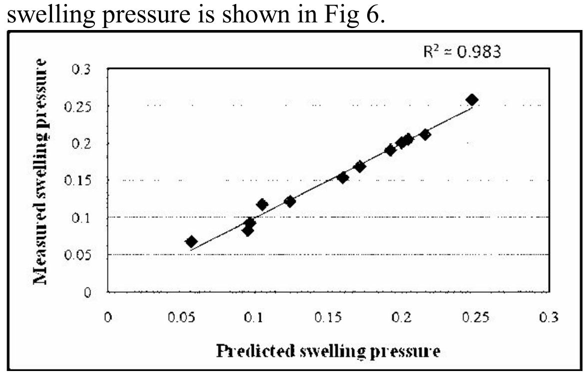

Fig. 6. Comparisons of measured and predicted value.

And the correlation coefficients of swelling pressure with individual properties are,

Liquid Limit (w_L) = 0.993862
Plasticity Index (Ip) = 0.98561
Shrinkage Index (Is) = 0.880235
Field Moisture Content (FMC) = 0.92775
Free Swell Index (FSI) = 0.894183

The above relation can be used to determine swelling pressure values with the help of basic soil properties, which can be easily found out in laboratory. Also the consistency of the correlated soil properties with swelling pressure is verified with correlation coefficient. The degree of correlation of liquid limit, plasticity index with swelling pressure is maximum and very near to 1. Correlation coefficient of shrinkage index, field moisture content and free swell index with swelling pressure is also high.

V. CONCLUSION

Expansive soil for the Surat region were identified as moderately swelling black alluvial deposited containing high plastic clay and high swelling silt particle available at 1.5 to 2 m depth of study area. A dataset also containing basic soil properties and swelling pressure are used to conduct statistical study to verify suitable correlations for estimating free swell index and swelling pressure of expansive soil for alluvial deposits. The statistical analysis was carried out in order to obtain the most accurate and suitable relationship. The liquid limit, plasticity index, dry density and soil passing 75 μ are correlated with free swell index excellently. The liquid limit, plasticity index, shrinkage index, field moisture content and free swell index are correlated with swelling pressure excellently and have a considerable impact on predicting swelling pressure value. If any research organization needs to examine the nature of soil and its properties in this region, it can use this result. Also the equation of free swell index and swelling pressure connecting different soil properties will be applicable to this region in future, unless there is extensive change in geological formation of the strata.

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