Correlations between Relative Density and Compaction Test Parameters-Part-b

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***Abstract*: Being the oldest construction and probably engineering material soil is one of the most complex field since civil engineering. Soil is naturally occurring, un-cemented or un-aggregated deposits of minerals so it is difficult to maintain its properties while bringing representative sample in laboratory for testing. Also the testing methods in soil engineering are mostly of empirical nature and as a result, the properties of soil are highly variable and cannot be estimated so accurately. So the project involve developing a suitable correlation between different parameters (these parameters help us in using various equations) by using SLR and MLR. For this purpose we used non cohesive sandy soil (c=0) from different places of Sindh, and performed different physical and mechanical tests on that soil for determining its condition such as, sieve analysis for determining (coefficient of uniformity, coefficient of curvature), specific gravity, water content, relative density, standard proctor, modified proctor, sand equivalent etc. From this research it is concluded that equations we made by comparing these results can be utilized on (A-3) Soil with confidence. Equations developed by using MLR are more reliable than SLR.**

Keywords: Single Linear Regression, Multiple Linear Regression, Relative Density, Sand Equivalent, etc.

I. INTRODUCTION

Soil which is oldest of the engineering materials is also one of the most complex. Just like other construction materials soils has its own scientific analysis with regards to its abilities on dealing with forces. Being the oldest construction and probably engineering material soil is one of the most complex fields in civil engineering i.e. the uncertainty in soil analysis and design is higher. As the soils are covering large portion of earth's crust naturally occurring materials, thus Soils are highly variable and complex materials, possessing different engineering properties that may be very difficult to find the uncertainty in the analysis and design of soil is much greater because of its natural origin and heterogeneity. Also the testing method sin soil engineering are mostly of empirical nature and as a result, the properties of soil are highly variable and cannot be estimated so accurately. Therefore, many researchers all over the world have been trying to develop relationships between different soil properties in order to easily estimate their values under different conditions. Soil particle size and consistency tests are relatively simple and quick to perform, and are considered as inexpensive.

However, the more advanced tests such as relative density and soil compaction test require greater skills and are time-consuming. It would be quite helpful if there are certain correlations between these tests which can be used to estimate one property from the other through suitable equations. Soil classification tests, such as sieve analysis for sand soil, are relatively quick and easy to perform and are considered to be not expensive. However; the tests required for the determination of compaction parameter are relatively expensive and need some testing time. The availability of correlations between the tests results would reduce the effort and cost by guessing with confidence any compaction properties. In this research, different tests were carried out such that sieve analysis, specific gravity, standard and modified proctor compaction tests. Also minimum and maximum void ratio, were tested using Egyptian specification. The test results are used to evaluate the different soil properties required for investigation of possible correlations between them. The relationships between tested minimum and maximum void ratio, tested minimum void ratio and coefficient of uniformity, and tested and calculated minimum void ratio were studied. Then correlation between degree of compaction, RC and relative density then, relationship between coefficient of uniformity and maximum dry density tested by using standard proctor test sand calculated using relative density .The aim of this research is to develop correlations between relative density and compaction test parameters of soil.

II. LITERATUREREVIEW

In this study correlations between physical and mechanical properties of the different non-cohesive sample (sandy soil) were predicted. The mineralogy or condition of soil affects these relationships. These relationships are determined by performing different physical and chemical tests on different sandy samples. The availability of correlation between different parameters would reduce effort and cost and create confidence in estimating the compaction properties [3]. Efforts were made to create a correlation between standard and modified proctor test results. The results of this analysis prove that variation between predicted values of maximum dry density is ±4%, and that of way optimum moisture content (modified) is ±2. Also, the results show that maximum dry density increases with increase in fine content up to 35% and above this limit the density decreases. The optimum moisture was found to decrease with the content of fines in the soil. [4] This study suggests that when the sand is used as a fill or foundation material its particle size and shape is an important factor. In this research different granular soils were for their relative densities and also the direct shear tests were performed no these soils to develop correlations between the results obtained from both the tests. [5] This study suggests that the settlement of cohesion less soil is dependent on its in-situ density. To determine the relationships between them, different tests were performed and suitable empirical correlations were developed. [6]In this study, it was concluded that the behavior of every type of foundation depended on engineering properties of the underlying soil. The proper compaction ensures the reliability and safety of carrying loads. [7] The effects of gradation, percentage and plasticity of fines, and moisture on vibratory and impact compaction of granular soils were investigated by adding measured percentages of low plasticity (ml) and medium plasticity (cl) fines to a poorly graded (sp) and nearly well graded (sw-sp) sand. Results indicated that more fines can be added to uniform sand and that uniform sand densifies by vibration more effectively than well graded sand[8] All tests were carried out in order to investigate possible correlation so compaction parameters. The geotechnical requirements are very important for the designers to define the efficient foundation to be chosen for any construction for suitable type of soil [9] Maximum and minimum density tests, conducted on a variety of sands, show that the minimum and maximum void-ratio limits are controlled primarily by particle shape, particle size range, and variances in the gradational- curve shape, and that the effect of particle size is negligible more fines can be added to uniform sand and that uniform sand densifies by vibration more effectively than well graded sand. The dilatancy of silty sand based on relative compaction is evaluated. [10].The analysis of all geotechnical problems such as transmission structure foundation design, require the adoption of a soil behavioral model that must include all relevant soil properties. These soil properties are not known in advance and require a design engineer to either measure or estimate Properties using correlations [11]. Degree of compaction in terms of relative density, as compared to percent of maximum density, requires using different standards for both the level of compaction required and the limits within which compaction would be considered acceptable [12]. when cone penetration resistance is replaced by relative density, performance is comparable for tests conducted in the two sands at the same relative density. [13].

III. MATERIALS &METHODS

A. Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. The composition of sand varies, depending on the local rock source sand conditions, but the most common constituent of sand is silica (silicon dioxide, or SiO_2),usually in the form of quartz.

Fig: 1 Sandy Sample Used In Research

Fig: 2 Sand Used In Research

Table 1: location of samples collected for laboratory tests

Sample	Location
SAMPLE 1	Baz site 1
SAMPLE 2	Niazbazkando
SAMPLE 3	Niazkhosodika
SAMPLE 4	Niazdika
SAMPLE 5	Niazdika open
SAMPLE 6	Al -Manzar Sand

SAMPLE7	Mulakatyar Sand
SAMPLE8	Nooriabad Karachi
SAMPLE9	Nooriabadkarachi
SAMPLE 10	NooriabadKarachi

B. Methodology

In total, ten Samples of sandy soil were collected from different regions of Sindh whose (c=0) were tested in laboratory. The aim of this research is to introduce a co-relation between relative density and Compaction test parameters by performing different physical and mechanical test to develop an equation so, that we can directly use that equation in field. Bringing representative soil to the laboratory and performing different test on the sample is very much time consuming and costly. The sample which is bought to the laboratory propose d sample of proposed site. Thus it becomes cumber some to evaluate actual test results. So all the tests were carried out in order to investigate the possible correlations of compaction parameters.

Table 2: Various Codes & Standard followed in Laboratory Testing

PROPERTY	•CODES/STANDARD
Natural Moisture Content	•AASHTO T 265, ASTM D2216.
Classification	•AASHTO T87,88.ASTM D 421,422,2217
Sand Equivalent	•AASHTO T176.ASTMD-2416-02.
Specific gravity	• AASHTO T100.ASTM D 854-92,70
Relative density	•AASHTO T8990.ASTMC-128-15.
Dry Density (maximum)	•AASHTO T 180,ASTMD-1557
OMC	•AASHTO-T 265, ASTM D2216.

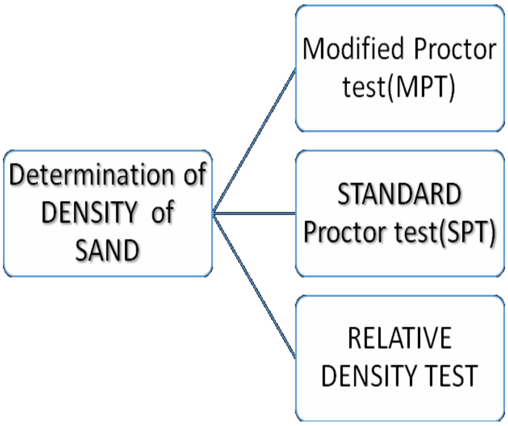

Fig 3: test performed with addition for density determination

IV. RESULTS

A. Soil Classification:

According to AASHTO classification, if the soil sample passing from #200 sieve is greater than 35% then the material is said to be "Silt-clay material" and if the percentage passing is less than 35 then soil is said to be "Granular material" in nature.

Table 2: Group of soil

Plastic limit	%fines	Group
Non plastic	8.43	A-3
Non plastic	7.85	A-3
Non plastic	3.65	A-3
Non plastic	6.04	A-3
Non plastic	5.2	A-3
Non plastic	3.3	A-3
Non plastic	9.04	A-3

Non plastic	6.64	A-3
Non plastic	8.22	A-3
Non plastic	8.05	A-3

Modified Proctor Test (MPT):

We performed both standard and modified proctor curve of some samples are shown, from the shape of curve it is concluded that proctor test is reliable for the soils used in this research.

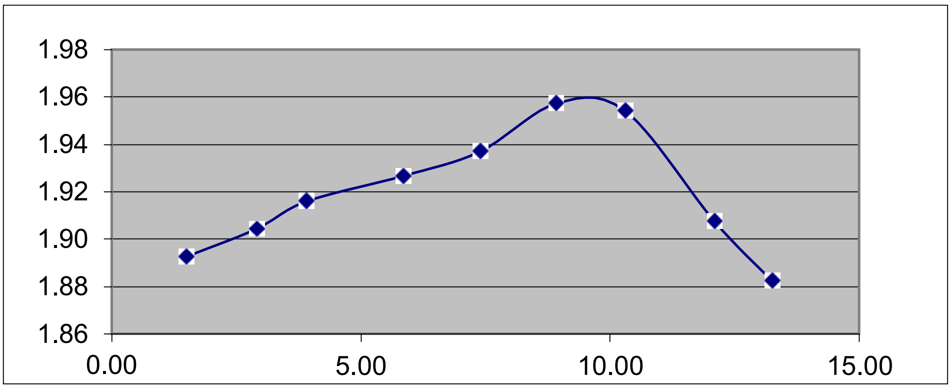

Fig 3: Some of the sample of proctor graph

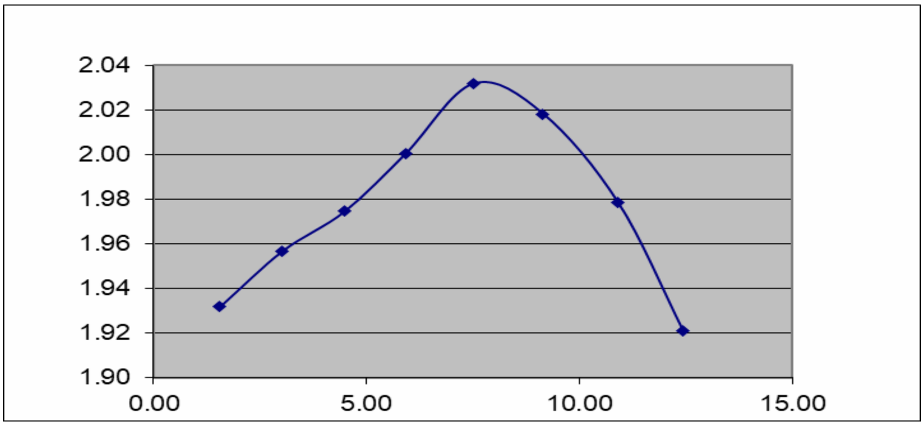

Table 3: final table used for correlation

Sample	**Tested**		**Grain size Distribution**			**Tested**	**Standard Proctor**		**Modified Proctor**		**Relative density test(gm/cm3)**	
No	e_{max}	e_{min}	**cu**	**Cc**	**%fines**	**Gs**	$\gamma_{d\,(max)}$	**O.M.C %**	$\gamma_{d\,(max)}$	**O.M.C %**	$\gamma_{d\,(max)}$	$\gamma_{d\,(min)}$
1	*0.88*	*0.479*	4.118	0.915	8.43	2.63	2.03	7.22	1.96	9.89	2.070	1.825
2	0.889	0.48	4.118	1.150	7.85	2.65	2.03	7.51	1.96	8.92	2.080	1.750
3	0.884	0.467	10	0.400	3.65	2.66	2.17	8.38	2.02	9.54	2.07	1.885
4	0.84	0.475	5.556	0.889	6.04	2.64	2.07	8.48	1.96	10.32	2.15	1.39
5	0.87	0.467	9.459	0.095	5.2	2.65	2.19	7.25	2.08	9.8	1.740	1.90
6	0.85	0.47	7.859	1.061	3.3	2.64	2.16	7.52	2.02	11.99	2.250	1.71
7	*0.92*	*0.49*	2.0	4.302	9.04	2.64	1.89	11.28	1.92	14.8	2.035	1.780
8	0.93	0.463	13.33	11.008	6.64	2.65	2.29	8.37	2.19	9.38	2.16	1.520
9	0.85	0.468	8.889	0.868	8.22	2.67	2.24	8.09	2.18	9.1	1.83	1.790

10	0.926	0.484	3.125	1.531	8.05	2.65	1.96	9.68	1.91	11.25	2.14	1.70

Single Linear Regression Equations

In simple linear regression, we predict scores on one variable from the scores on a second variable. The variable we are predicting is called the criterion variable and is referred to as Y. The variable we are basing our predictions on is called the predictor variable and is referred to as X.

Multiple Linear Regression Equations

It is most common form of linear regression analysis as a Predictive analysis, the multiple line regression is used to explain the relationship between one continuous dependent variable from two or more independent variable.

Note: we have developed many single linear and multiple linear regression equations but here we show only few equations whose (R2 IS greater than 85%) means which are very reliable.

GRAPHN RELATION	POLYNOMIAL EQUATION	LINEAR EQUATION
E max vs cu	E max=+0.005(cu)2-0.025(cu)+0 .830 $R^2 = 0.975$	e(max) = - 0.016ln(Cu) + 0.8105 $R^2 = 0.9662$
ʋd mini vs %finer	ʋd min= - 0.004(%FINER)3 + 0.066(%FINER)2 - 0.291(%FINER) + 2.163 $R^2 = 0.941$	ʋd mini= - 0.0622%FINER + 1.9744 $R^2 = 0.9$
ʋd min vsʋd max(ID)	ʋd min= - 2.108(ʋd max I?)3+ 12.81(ʋd max ID)2 - 24.58(ʋd max ID) + 16.47 $R^2 = 0.989$	ʋdmin=1.23 ʋdmax (ID) - 0.7593 $R^2 = 0.9879$
ʋd max VS %FINER	ʋd max= - 0.003(%FINER)2 - 0.012(%FINER) + 2.141 $R^2 = 0.909$	ʋd max (ID) = - 0.0498%finer + 2.2195 $R^2 = 0.8845$

Some reliable multiple linear regression equations:

[1] %finer = -0.51141Cu + 2.791250907Cc + 20.89321429SG - 49.87403079
R^2= 0.604815

[2]Cu = -67.422 e (max)-120.947 e (mini)- 5.67792SG + 130.1798
R^2= 0.994069

[3] %FINER = -581.381e (max) + 643.6377e (mini) + 29.69709SG+ 77.4978
R^2= 0.921247

[4]e(max) = 0.934553 e(mini) + 0.058599SG + 0.189361
R^2= 0.859891

[5] e(max) = 1.266633 e(mini)- 0.00164%FINER + 0.189382

(R^{2}= 0.942803)

[6] e(max) -0.58225 e(mini)- 0.00793Cu + 1.102074

R^{2}= 0.952473

[7] Sand equivalent = 0.688908Cu - 4.83098Cc + 0.473279 I? + 50.13317

R^{2}= 0.95287

[8] Sand equivalent = -12.9534 e (max)-112.287 e(mini) + 0.60689 I? + 104.4119

R^{2}= 0.895783

[9] Sand equivalent = 0.660814Cu + 0.660814 I? + 36.37227

R^{2}= 0.902192

[10]%FINER = 3.836409 ãd max (I?)-17.5624 ãd mini (I?)+ 26.576

R^{2}= 0.900536

[11] e(max) = 1.052269e(mini) - 0.00744Cc + 0.291587

R^{2}= 0.883688

V. CONCLUSIONS

In this research work co-relation were established by conducting different physical and mechanical laboratical test son sandy soil. The Associations have been established between variable characteristics such as Relative density, Coefficient of uniformity, Specific gravity, Coefficient of curvature, Maximum & minimum void ratio, Sand equivalent, porosity, Degree of saturation. Different associations between dissimilar parameters were developed by applying single and multiple linear regression. It is perceived that equations generated from (MLR) are more consistent than (SLR).Some consistent equations whose R2 >90% are given below.

- From this study the following conclusions were obtained.
  Different correlations between different parameters were developed by utilizing single linear regression and multiple linear regression
- ItisobservedthatequationsdevelopedfromMLRaremorereliablethanSLR.
- SomeofthereliableequationswithvalueofR²>0.90

(1)Cu = - 67.422 e (max)-120.947 e(mini)- 5.67792SG +130.1798

R^2 =0.994069

(2) n =0.002 γsat-0.014 γd max(I_D)-0.004 (I_D)+0.205

R^2=0.977

(3)Sand equivalent=0.688908Cu-4.83098Cc+0.473279 I_D+50.13317

R^2 =0.9528

(4)e(max)=-0.58225e(mini)-0.00793Cu+1.102074

R^2 =0.952473

(5) υd min = - 2.108 υd max I?)3+12.81 υd max I?)2-

R^2 = 0.989

24.58 υd max I?)+16.47

(6 υd max = 2135(SG) 3 -16700(SG)2 + 43533(SG) - 37817

$R^2 = 0.952$

(7) e (max) = 7.455 υd max ID) 3 - 43.40 υd max ID)2 + 83.96 υd max ID) - 53.

$R^2 = 0.959$

(8) n =0.001 γsat+0.003 γd max(Iᴅ)+0.295e(max)-6.65Cu +0.199

R2=0.975

(9) n=0.003γdmax(Iᴅ)+0.0002%FINER+0.287e(max)+7.59Cu+0.2065

R2= 0.976

VI. RECOMMENDATIONS

These equations are recommended for non-plastic soil (c=0) belongs to A-3 group. These equations can be utilized in industry for time saving.

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