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Prediction of California Bearing Ratio Values from Gradation and Plasticity Features of Red Gravel Soils

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Abstract: Estimation of California bearing Ratio values are important for civil engineers to quickly assess the behavior of soils used in the civil engineering infrastructure projects (Roads/Pavements).California bearing ratio test is usual to know the shear strength i.e. Penetration Resistance of component layers such as pavements such as sub-grade, sub-base and base course materials. In the present investigation 40 gravel soil samples are used to predict California bearing ratio values from index properties such as gradation, plasticity characteristics. 8 No of correlation equations are prepared by performing tests on gravel soils. Increasing the number of parameters in the given regression analysis high R^2 values are obtained and efficiency in prediction of California bearing ratio values are also increasing.

Key word: California bearing Ratio, Regression analysis, Correlation.

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I. INTRODUCTION:

The durability of pavement depends on the quality of the materials used in the construction of the component layers of a pavement. The quality can be assessed by strength in terms California bearing ratio value of that materials. Therefore California bearing ratio test is a popular test which can determined by performing in the laboratory which is laborious and time consuming. Increasing the size of the project increases the quantum of California bearing ratio tests which are increasing at regular intervals. Therefore it is required to quick assessment of California bearing ratio values. Hence the need of prediction of California bearing ratio values are essential.

Many researchers have made attempts to develop correlation for the prediction of California bearing ratio values. Black (1962) developed approximated method to predict California bearing ratio values based on the plasticity index.

Agarwal (1970) established correlation between California bearing ratio values and index properties. Yildirim (2011) proposed California Bearing Ratio values in terms OMC MDD ,liquid limit and Plastic limit .NCHRP (2001) proposed the California Bearing Ratio in terms of D_{60} of soils in the present investigation an attempt is made to develop correlation equations to predict California Bearing Ratio values based on test results of gradation and plasticity characteristics of Red gravel soils.

1. Agarwal and Ghanekar (1970):
California Bearing Ratio= 2-16 log (OMC) + 0.07 (LL)
2. Vinod, Reena and Cletus (2008)
California Bearing Ratio= -0.889 (W_{LM}) + 45.616 R^2=0.98
3. Patel and Desai (2010)
(California Bearing Ratio)$_S$= 43.907 – 0.093 (PI) – 18.78 (MDD) - 0.3081 (OMC)
4. The National co-operative highway research program (NCHRP) (2003) [3]
California Bearing Ratio= 75/ 1+0.728(WPI)
5. Yildirim and Gunaydin (2011)
California Bearing Ratio= 0.62 OMC + 58.9 MDD+ 0.11 LL + 0.53 PL – 126.18, R^2=0.63
California Bearing Ratio=0.22 G+0.045S+4.74MDD+0.122 OMC R^2=0.88
6. A.A. Bello (2012):
California Bearing Ratio= 13.56 + 1.04 (PL)
California Bearing Ratio= 28.87 + 0.22 (LL)
California Bearing Ratio= -70.22 + 50.28 (MDD)
Following correlation for California Bearing Ratio un- soaked value with index properties of lateritic soils:

California Bearing Ratio = 65.31 + 0.8 (PL)
California Bearing Ratio = 83.19+ 0.031 (LL)
California Bearing Ratio = 65.88+ 8.66(MDD)
7. Rama Subba Rao G.V and Siva Sankar G (2013)
$(\text{California Bearing Ratio})_S$=0.064 F+0.082 S+0.033 G-0.069 LL+0.157(PL)-1.810MDD-0.061 OMC, R^2=0.96.

II. MATERIALS (EXPERIMENTATION):

To study the inter-relationship 40 red gravel soil samples were collected from different regions of north coasted districts of AP and tests like grain size distribution (Dry and Wet analysis) (IS 2720 part 4), Plasticity characteristics (W_L, W_P,& I_P)soaked California bearing ratio tests have been conducted and the results are as shown in the table 1.

Table 1: Geotechnical Characteristics of Red Gravel soils:

Properties → Location ↓	G (%)	S (%)	F (%)	Silt (%)	Clay (%)	W_L (%)	W_P (%)	I_P (%)	OMC (%)	MDD (g/cc)	IS
Etcherla	53	31	16	12	4	26	19	7	8.8	2.12	GC
Narasannapeta	38	32	30	20	10	38	21	17	11.0	2.05	GC
Pathapatnam	48	39	23	16	7	26	18	8	8.8	2.10	GC
Tekkali	38	30	32	22	10	30	20	10	10.5	2.07	GC
Vizag (APSEB)	54	28	18	12	6	28	19	9	9.0	2.08	GC
Dassannapeta	50	29	26	12	9	40	21	19	11.2	2.05	GC
Bhogapuram	46	30	24	16	8	30	20	10	10.0	2.07	GC
Pydibhimavaram	38	34	28	20	8	27	18	9	10.0	2.08	GC
Yendada	42	25	33	20	13	35	20	15	10.5	2.06	GC
Duvvada	56	26	18	10	8	40	22	18	11.0	2.07	GC
Seethammadhara	67	14	19	12	7	30	20	10	10.0	2.12	GC
Autonagar	52	30	18	12	6	28	19	9	8.5	2.11	GC
MMTC	56	28	16	10	6	26	18	8	8.6	2.12	GC
Madhurawada	60	26	14	10	4	25	18	7	8.2	2.13	GC
Lankelapalem	40	32	28	18	10	27	19	8	9.3	2.06	GC
Parawada	46	30	24	16	8	26	18	8	9.0	2.07	GC

G – Gravel, S – Sand, F- Fines.

III. PARAMETRIC ANALYSIS OF RED GRAVEL:

The following identifications are made from the test results of gravel soils.

- Increasing the percentage of greater than 4.75 mm (Gravel) sizes increases the California Bearing Ratio values, whereas increasing 4.75 mm – 0.075 mm (sand) particles decreases California Bearing Ratio values.
- Inclusion of the percentage of fines decreases California Bearing Ratio values.
- Increasing the high percentage of fines increasing plasticity index values there by reducing California bearing ratio under soaked condition.
- High quantities of fines increase the deformability conditions there by decreasing the shear strength and penetration resistance.
- Some of the red gravel soil in this region exhibited high densities and high California bearing ratio values are due to occupation of wide range of particles with less plasticity characteristics. This phenomena offer more shear resistance against penetration due to inter locking of particles.

- Low California Bearing Ratio values are due to softening of gravel soils under soaking. Due to presence of high percentage of fines which offers less shear resistance against penetration.
- Domination of uniformly graded particles decreases dry density and California bearing ratio values.

IV. CORRELATION:

Based on the test data like grain size distribution i.e. (Gravel, Sand, Fine particles), their range in terms of gradation coefficients such as coefficient of uniformity(C_u) and coefficient of curvature (Cc), with respect to soaked California bearing ratio values, various relationships are established. It is further included Liquid Limit and plasticity index and correlated with California Bearing Ratio values. Correlation models have generated by choosing California bearing ratio as dependent variable and gradation characteristics. Plasticity characteristics as independent variables using excel Microsoft analysis. Simple linear regression analysis (SLRA), multiple linear regression analysis (MLRA) have been done and the following correlation equation are identified with R^2 values.

Table 2: Correlation equations of California bearing ratio

S.NO	Variable	Equation	R^2
1	f(G ,S, F)	CBR= 0.633(G)+0.42(S)+0.066(F)-16.74	0.421
2	f(G,S,F,D_{60})	CBR = 0.5(G)+0.43(S)+0.04(F)+0.2(D_{60})-12.25	0.428
3	f(G,S,F,D_{60},C_U)	CBR = 0.42(G)+0.349(S)+0.216(F)+0.287(D_{60})-0.00098(C_U)-8.48	0.5
4	f(G,S,F,W_L)	CBR = 0.454(G)+0.198(S)+0.0955(F)-0.72(W_L)+19.5	0.784
5	f(G,S,F,W_L,I_P)	CBR= 0.455(G)+0.199(S)+0.096(F)-0.709(W_L)-0.0179(I_P)+19.19	0.784
6	f(G,S,F,D_{60},W_L)	CBR= 0.313(G)+0.214(S)+0.069(F)+0.216(D_{60})-0.72(W_L)+24.33	0.791
7	f (G,S,F,D_{60},C_U,W_L,I_P)	CBR= 0.295(G)+0.195(S)+0.116(F)+0.238(D_{60})-0.00028(C_U)-0.76(W_L)+0.087(I_P)+25.28	0.797
8	f (G,S,F,D_{60},C_U,I_P)	CBR= 0.329(G)+0.24(S)+0.136(F)+0.25(D_{60})-0.00022(C_U)-0.86(I_P)+8.72	0.79

The strength, effectiveness of these correlations can be represented by their R^2 values by performing multiple regression analysis. From the correlation it is identified that grain size distribution (G,S,F) has considerable influence on California bearing ratio values with R^2 values as 0.638 whereas grain size distribution with gradation parameters(C_u, C_c) which representing range of particles further improved correlation coefficient (R^2) to 0.683.

It is also noted that inclusion of plasticity index with grain size distribution and gradation characteristics of rose to correlation coefficient (R^2) to 0.863. Inclusion of plasticity characteristics (I_p) has high influence on California Bearing Ratio values. Inclusion of more number of effective parameters improves the predicted California bearing ratio values with high correlation coefficient. It is further identified that involvement of more independent variables in the correlation analysis made more accurate in estimation of California bearing Ratio values. Hence the predictive equations are simple and can be effectively used in estimation of California bearing ratio values of red gravel soils with high accuracy.

V. CONCLUSION:

Red gravel soils with wide range of particles and low percentage of fines exhibited high dry densities and high soaked California bearing ratio values.

The models developed using MLRA with gradation characteristics (G, S, F, D_{60}, C_u) have shown relatively with high R^2 values.

Inclusion of plasticity characteristics showing the highest R^2 value of 0.8.

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