International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 8 Issue 6 Ser. 1 ǁ 2020 ǁ PP. 44-50

CBR and Its Regression Model on Time Dependent Field

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***ABSTRACT**: In the present paper a series of California Bearing Ratio (CBR) tests has been performed in both soaked and unsoaked condition on field samples collected from road subgrade. Four rural roads in West Bengal, India have been considered for collection of field CBR sample. From the experimental data it is found that with time the values of CBR in soaked and unsoaked condition increases irrespective of types of road subgrade. Based on the present experimental data a nonlinear power model has been developed to predict field soaked CBR value with time (CBR_{fst}), in terms of field soaked CBR value at 0 days (CBR_{fs0}) and time 't'.*

***Key words:** Field CBR, Time, Soaked, Unsoaked, Regression analysis, Subgrade, Rural road.*

I. INTRODUCTION

Nowadays one of the important parameter for evaluation of performance of any types of roads such as rural roads, highways is field CBR. Most of the designer design the road based on soaked CBR value but after construction of roads these CBR value may not remain same rather increases due to simultaneous effect of consolidation and compaction of subgrade soil. The post construction subgrade CBR value is necessary in case of stabilization of soft subgrade soil with Limited Life Geotextiles (LLG) such as jute geotextile, geotextile made of coir, kenaf etc. Sarsby [1] reported that LLG as reinforcing fabrics that are working for a limited time in many civil engineering applications such as roads, and embankment etc..Pandit et al. [2] also evaluated the the use of jute and coir in pavement system. Basu et al. [3] found the considerable increase in field CBR value after 18 month of construction of unpaved rural road reinforced with jute synthetic blended geotextile. Choudhury and Sanyal [4] suggested that JGT last for a limited period of time but its effect on enhancing performance for soil property continues for longer time. Choudhury and Sanyal [4] also further reported that in 18 months CBR can enhance about 1.5 to 3.0 times. Khan et al. [5] conducted field investigation on five numbers of JGT reinforced rural road section and observed that the subgrade CBR value has been increased with passage of time. Khan et al. [5] also reported that the load carrying capacity of the road sections increase from 1.5 to 7 times over a range of time. Sanyal [6] reported that for JGT reinforced rural road within 7 to 12 month subgrade CBR value has been increased by 1.5 times. From the above literatures it has been clearly observed that the subgrade CBR value is increasing with time. A numbers of researchers also [7-10] have been studied on laboratory CBR in both soaked and unsoaked condition in the remoulded soil sample to correlate the CBR value with other soil properties only. But detail study on field CBR of road subgrade with respect to time is scarce. In the present investigation an attempt has been made to study the effect of time on subgrade CBR value in both soaked and unsoaked condition. An attempt also has been made to develop a regression model to estimate the time dependent field soaked CBR (CBR_{fst}) of subgrade soil based on the initial field soaked CBR (CBR_{fs0}) value of subgrade soil.

II. SELCTION OF RURAL ROAD

Based on the importance to study the subgrade CBR value with time four JGT reinforced rural road section has been considered and regularly field CBR samples has been collected. Four rural roads such as Kanksa to Bati (8.10 km) , Nihinananagar to Hazratpur (7.90 km), Udal to Chakrabramha (4.75 km) and Bagdimarimulo Barada to Damkal Kheya Ghat (8.70 km) in the west Bengal, India have been selected for the present investigation. The above roads may be designated as (JKB) (JNH) (JUC), (JBD) for Kanksa to Bati, Nihinananagar to Hazratpur, Udal to Chakrabramha and Bagdimarimulo Barada to Damkal Kheya Ghat respectively.

Table 1 Engineering properties of subgrade soil of four different roads

Engineering Properties	Property value			
	JNH	JUC	JKB	JBD
Sand Content(%)	2.00	14.00	4.00	5.00
Silt Content (%)	70.00	50.00	72.00	67.00
Clay Content (%)	28.00	36.00	24.00	28.00

D50 (mm)	0.0056	0.015	0.0064	0.0078
Specific Gravity	2.687	2.674	2.685	2.650
Liquid Limit (%)	48.00	55.50	47.50	43.00
Plastic Limit (%)	17.72	23.18	28.19	20.00
Plasticity Index (%)	30.28	32.32	19.31	23.00
OMC (%)	19.75	16.02	18.46	18.02
MDD(kN/m^3)	16.55	16.50	16.41	16.76
Permeability (m/sec)	3.76×10^{-07}	3.10×10^{-08}	3.85×10^{-08}	3.28×10^{-07}
Classification based on	CL	CH	ML	CL

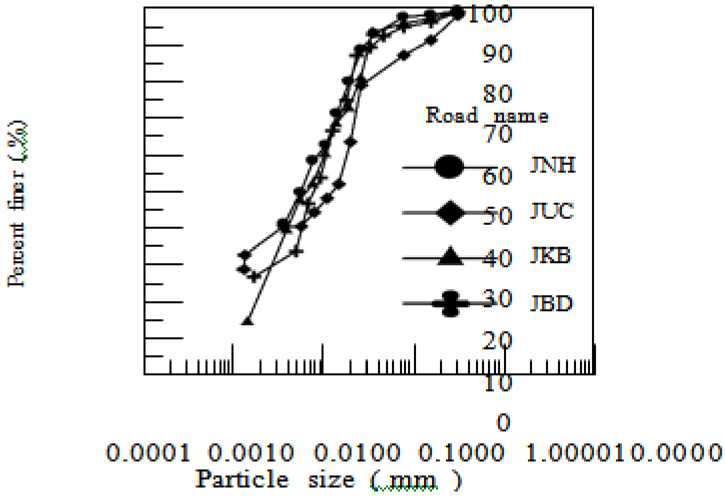


Figure1 Grain size distribution curve for subgrade soil for four different

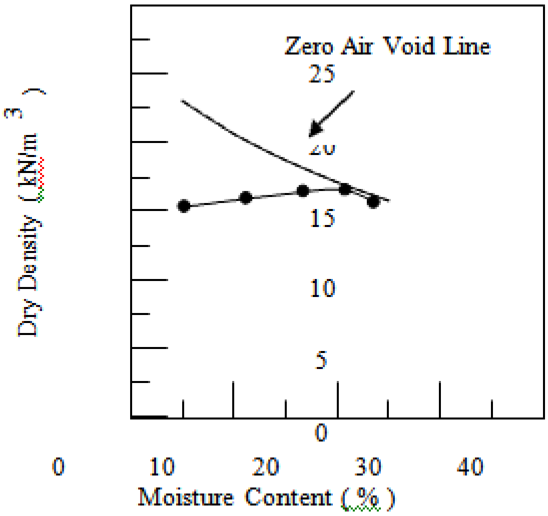
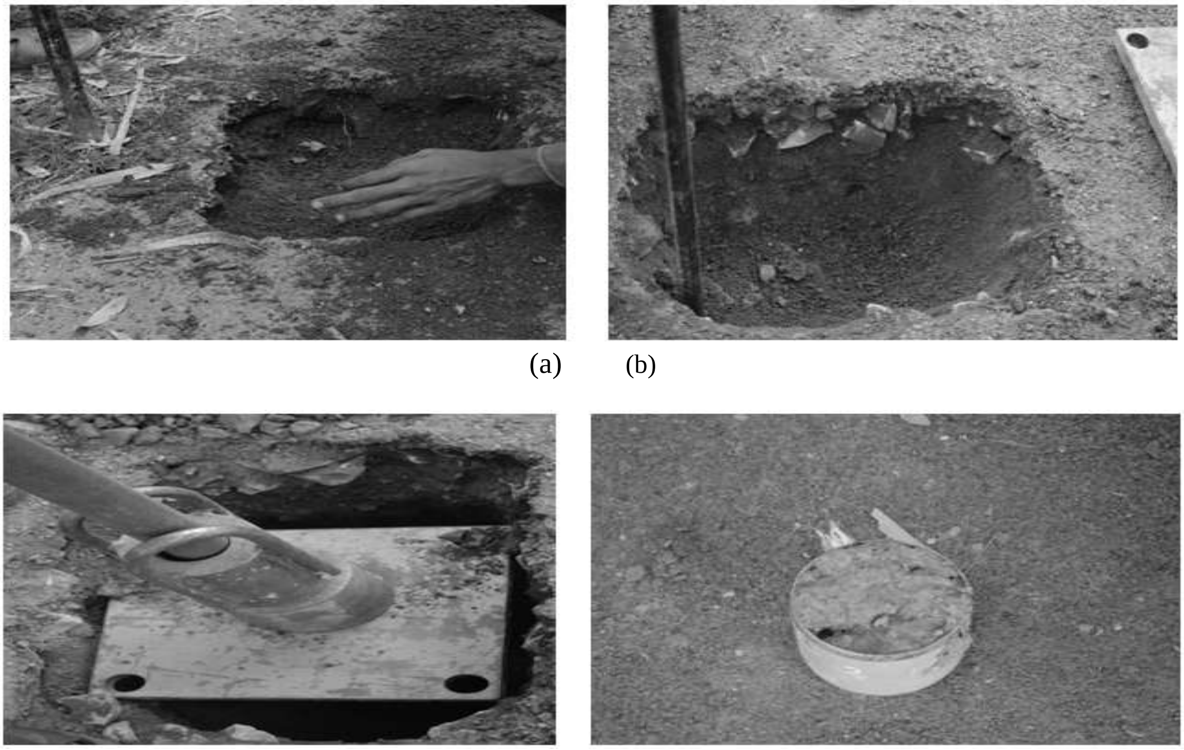


Figure 2 Typical dry densities versus moisture content curve for subgrade soil of JNH road

III. ENGINEERING PROPERTIES OF SUBGRADE SOIL

Engineering properties of the subgrade soil of four roads has been determined in the geotechnical laboratory of Civil Engineering Department, IIEST, Shibpur, India. Figure1 shows the plots of grain size distribution curve for four different roads. Table 1 presents the engineering properties of subgrade soil at the time of construction for four different roads. In accordance with ASTM 2487 [11] the subgrade soil of the above roads (JKB), (JNH), (JUC), and (JBD) may be classified as ML, CL, CH, and CL respectively. Figure 2 shows the typical dry density versus moisture content curve for subgrade soil of JNH road. The values of MDD and OMC of the respective roads are presented in the Table1.



(a) (b)

(c) (d)

Figure 3 Photo plates during collection of CBR sample of JBD road. (a) Marking for the excavation of pit; (b) Excavation is in progress; (c) Penetration of CBR mould into subgrade soil with the help of Hammer and plate; (d) CBR sample from field (before dressing).

Table 2 Schedule for the collection of field CBR sample

Sl. No.	Name of the Road	Schedule for the collection of field CBR sample				
		1st Monitoring	2nd Monitoring	3rd Monitoring	4th Monitoring	5th Monitoring
1	JNH	March 2013	Nov. 2013	April 2014	Sep. 2014	Feb. 2015
2	JUC	March 2013	Nov. 2013	April 2014	Sep. 2014	Feb. 2015
3	JKB	Dec. 2013	April 2014	Sep. 2014	Feb. 2015	June 2015
4	JBD	Dec. 2013	April 2014	Sep. 2014	Feb. 2015	June 2015

IV. COLLECTION OF CBR SAMPLE FROM ROAD SUBGRADE

After construction of the roads, field CBR samples has been collected for each road at the interval of 3 month to 9 month subjected to availability of the proper logistic and permission of the concern road authority. Monitoring schedule adopted in this work has been presented in Table 2. Sample for CBR tests has been collected by using field CBR mould of 150 mm diameter and 125 mm long with sharp edge. Before collecting the sample from the road subgrade, a pit of size 400 mm × 400 mm in cross section has been marked and excavated up to the subgrade soil and cleaned thoroughly.CBR mould has been kept on the subgrade soil. A steel plate of 300 mm × 300 mm is placed followed by a collar on the top of the CBR mould and the mould is then allowed to penetrate into the subgrade soil with the help of a hammer. After penetration of the mould with desire depth in to subgrade soil, the mould is removed by under digging the surrounding soil. The CBR mould is kept into the air tight polyethylene bag so that the field moisture content has been preserved and immediately sent to the laboratory for CBR test. The in situ CBR sample collection for the road JBD during October, 2014 is shown stepwise in Fig.3 (a-d). CBR tests in the laboratory have been performed in accordance with IS 2720 (part 16) [12] for both soaked and unsoaked condition.

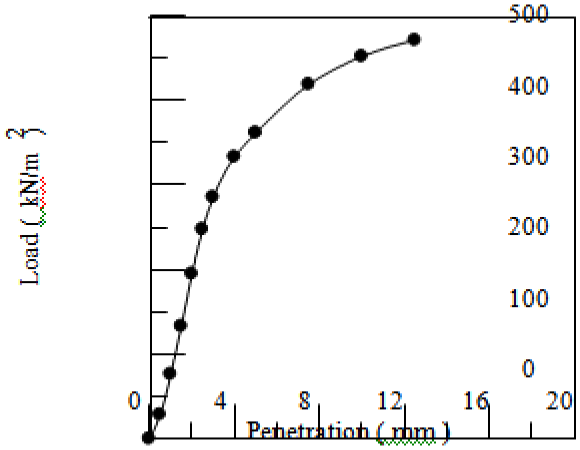


Figure 4 Typical load versus penetration curve for subgrade soil of JBD roads (September,2014)

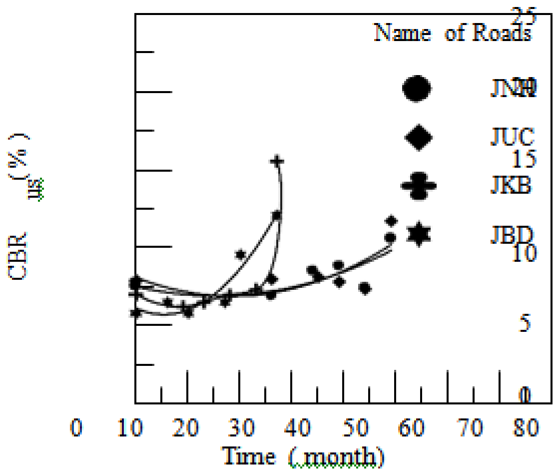


Figure 5 CBR_{US} versus time curve for different roads

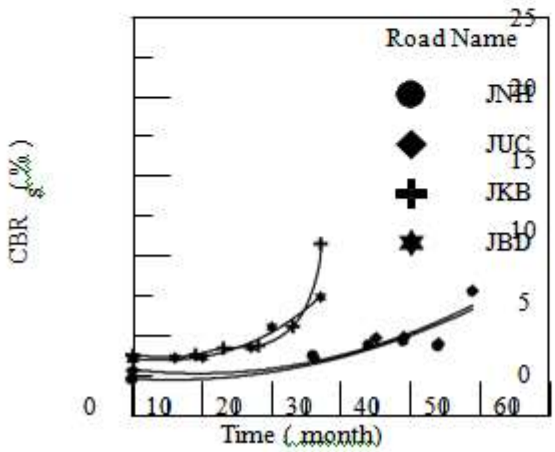


Figure 6 CBR_S versus time curve for different roads

V. RESULTS AND DISCUSSION

Figure 4 shows the typical load versus penetration curve for subgrade soil of JBD road (sample collected on November, 2014). Figures (5-6) shows the plots of CBR_{us} versus time and CBR_s versus time curve respectively. From both the curves it has been found that with time the CBR value increases. It is may be due to that after construction of roads, the subgrade soils are consolidated with load coming from surcharge above subgrade soil and the same time the subgrade soils compacted due traffic loads as a results of higher CBR. Basu et al. [3] also reported the similar types of results.

VI. NUMERICAL MODEL FOR CBRFST

To get the idea of the field CBR value with time and at the same time design of rural load with limited life geotextile it is necessary to develop a mathematical model for field CBR value on soaked condition. Based on the nature of present experimental data and also by examining the scatter plot matrix, a nonlinear power model has been chosen as follows:

$$\widehat{CBR_{fst}} = CBR_{fs0}{}^{\beta 0} \times \beta_1^t \quad (1)$$

Based on the 20 numbers of data point obtained from present investigation and by using multiple regression analysis the above equation may be written as:

$$\widehat{CBR_{fst}} = CBR_{fs0}{}^{0.935255} \times (1.00069)^t \quad (2)$$

Where,

$\widehat{CBR_{fst}}$= predicted field soaked CBR value with time (%),

CBR_{fso}= field soaked CBR value (%)at 0days,

t = time in days.

To know the efficiency of the model the values of estimated standard error (E_s) and coefficient of determination (R^2) of the model in eqn. (2) are 0.062 % and 0.991 respectively. The significance of the partial regression coefficient and regression coefficients as a whole of the eqn. (2) has been tested by using $t_{statistics}$ and $F_{statistics}$ respectively. Table 3 presents the values of $t_{statistics}$ and $F_{statistics}$. From Table 3 it is found that all the variables of the eqn. (2) have significant contribution to the equation. Figure 7 shows the plots of predicted CBR_{fst} versus observed CBR_{fst} curve. From the Figure 7, it is found that predicted CBR_{fst} in both types using the data used in developing the model and also data not used in developing the modelis within ±25 % error. The above model has been very much applicable within the range of CBR_{fs0} of 2.2 to 3.8, and t within 1470 days. Beyond the limits of the data the above model may be verified with one set of additional data. The above model is very much comfortable to use for the field engineers because one has to used CBR_{fs0} to predict the CBR_{fst}, the CBR_{fs0} can be obtained during construction (0 days of construction), which consider the behavior of pavement subgrade at 0 days.

Table 3 Values of t-statistics and F-statistics for different parameter of Eqn.2

Parameters	**Coefficient of the parameter**	**Standard error**	**$t_{statistics}$**	**$t_{critical}$= $t_{(0.975,18)}$**	**$F_{statistics}$**	**$F_{critical}$= $t_{(0.975,2,18)}$**
CBR_{fs0}	□0=0.935255	0.04226300	+22.13	2.101	1103.73	3.55
t	Log□1=0.000301	0.00000248	+12.13			

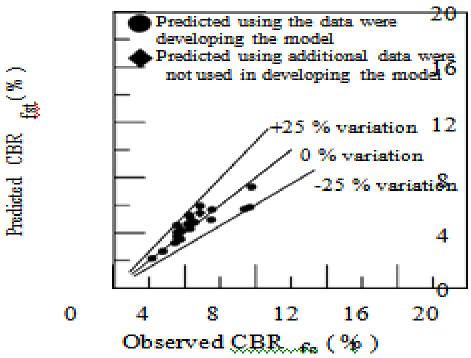


Figure 7 Predicted CBRfst versus observed CBRfst curve

VII. CONCLUSION

Based on the results and discussions made in the present investigation and also numerical model the following conclusions may be drawn:

With time the values of field CBR in both soaked and unsoaked condition increases irrespective of types of subgrde soil.

A nonlinear power model has been developed using multiple regression analysis to predict the CBRfst in terms of CBRfs0 and t

The regression model presented in the present paper is based on the experimental data within the range of CBR_{fs0} 2.2 to 3.8, and t within 0 to 1470 days. Beyond the limits of the data the above model may be verified with one set of an additional data.

This model may be useful in the field of transportation engineer to design and performance evaluation of any types of rural roads (rural roads reinforced with limited life geotextiles and rural roads without reinforcement).

ACKNOWLEDGEMENTS

Authors express their sincere gratitude to the officials of National Jute Board (NJB), Kolkata, India for their cooperation to collect the field CBR samples. Authors also like to express their heartfelt thankfulness to WBSRDA and staffs of Geotechnical Laboratory, IIEST, Shibpur for their help during collection of field sample and testing in the laboratory.

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