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RELATIONSHIP BETWEEN FIELD CBR AND DYNAMIC DEFLECTION MODULUS FOR BC SOIL

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ABSTRACT

Light Weight Deflectometer (LWD) simulates the effect on subgrade caused due to constant dynamic load. In our study, we tried to relate dynamic deflection modulus with Field California Bearing Ratio (FCBR). The FCBR test was used to determine CBR on the field to counter practical problems associated with Lab CBR. These tests were performed at 26 testing points, with a distance of around 2.5m between two test points. The test results showed that there is a strong linear correlation between FCBR and Dynamic Deflection Modulus (E_{vd}) for black cotton soil in saturated condition. By using LWD instead of FCBR would result in better quality control, significant cost and time saving.

Key words: Dynamic Deflection Modulus, CBR, Regression, Black Cotton Soil, Saturation

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1. INTRODUCTION

Subgrade is the most important component of a pavement for its proper and effective functioning. The subgrade should be strong enough to support the layers above it. In order for a road to accomplish its purpose, even during adverse factors such as increased traffic, overloading of vehicles, Climate changes, Improper materials etc. it is very important that the subgrade must be built appropriately. Thus, the subgrade properties must be accurately evaluated to counter these. To quantify the quality of the subgrade, engineers have been using California Bearing Ratio (CBR) and Modulus of Subgrade Reaction (k).

The instruments used to measure these are the lab CBR test, plate load test, FCBR etc. These instruments, though appropriate for the evaluation of subgrade, are very bulky, and time-consuming. They also require large equipment for reaction loading. Since it takes the time to obtain results from these experiments, it becomes difficult to make decisions in cases which need quick action. There are instruments to counter this problem, one such being the Light Weight Deflectometer which is being widely used to evaluate subgrade stiffness and compaction.

Recently, Jong Ryeol Kim et. al (2007), studied the relationship between the portable Falling Weight Deflectometer and plate bearing load test. They stated that there existed a reasonable linear relationship between the dynamic deflection modulus (E_{vd}) and the modulus of Subgrade reaction (k). Fleming (2000) compared the dynamic deflection modulus obtained by the conventional falling weight deflectometer and other equipments. Moshe and Yair (2001) reported the relationship between in-situ CBR test for subgrades, subbases, and base courses and the dynamic deflection modulus using a Light Drop-Weight tester (LDW).

This study focused on evaluating and assessing the possibility of a relationship between the E_{vd} the dynamic deflection modulus obtained by the LWD and the CBR value obtained by the Field CBR test for black cotton soil.

2. MECHANISM OF LIGHT WEIGHT DEFLECTOMETER

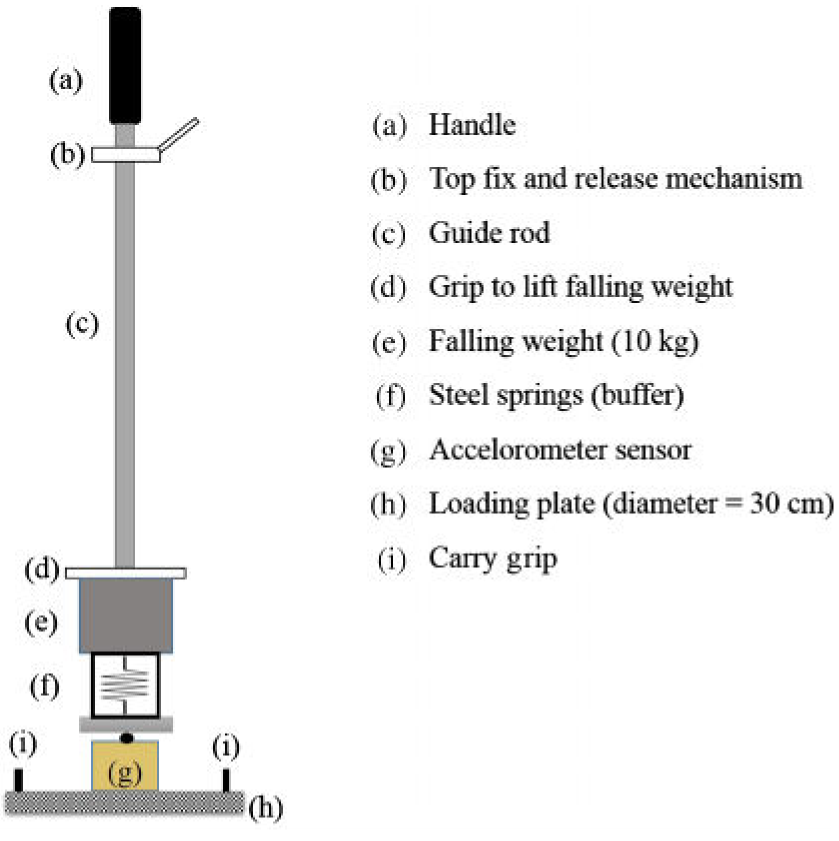

Figure 1 Light Weight Deflectometer

The mechanism of an LWD can be explained by making two assumptions, 1.) The subgrade is a uniform elastic body, 2.) The pressure applied by the falling weight is uniform. The deflection of the subgrade is measured by the accelerometer sensor installed at the bottom of the LWD. The impact force is the product of falling weight and the height of fall. The uniform pressure can be calculated by taking the division of the falling load with the contact area. Mathematically this is represented as:

$P = W * H * g$ (1)

$P = 7.07$ KN

$q = P/A$ (2)

$q = 100$ KN/m^2

For the Weight (W) 10 kg and the Height of fall (H) 72 cm the Impact force can be calculated to be 7.07 KN, while the contact diameter considered to be 30 cm, the uniform pressure (q) can be calculated to 100 KN/m^2. The dynamic deflection of the subgrade is determined by considering that the subgrade is a semi-infinite elastic body and the loading is uniform over a circular area. This can be mathematically calculated as:

$E_{vd} = 2*(1-v^2)*q*A / d$ (3)

Where E_{vd} is the Dynamic deflection modulus,

d is the vertical deflection,

v is the poisons ratio of soil.

3. METHODOLOGY

Figure 1 depicts an LWD. It shows the basic components of an LWD, weight, sensor, guide rod, springs, loading plate, and fixing mechanism. The weight of 10 kg is first fixed at the top i.e. release and fix mechanism. The weight is allowed to free fall through the guide rod, 72cm long. A total of 6 drops were taken. The first three drops are considered as pre-loading drops, which help in proper contact with the subgrade. It must be taken care that a single drop has only one impact and is caught on the recoil. The next three drops were recorded for deflection, which was very close. The average of the above three drops was taken to determine the vertical deflection. The s/v ratio is a measure of the degree of compaction of the subgrade while the dynamic deflection modulus (E_{vd}) is the ratio of a pressure of 0.1MN/m^2 during the designed load time of 18ms with the deflection. The s/v ratio and the E_{vd} value are also determined by the LWD through an inbuilt computer program. The test was conducted over typical road sites, with saturated subgrade having Black Cotton Soil. A total of 26 readings were taken over this patch, at a distance of approximately 2.5m from each other to eliminate the possibility of any effect of the readings taken at any previous interval.

The Field CBR test was done by using a conventional Field CBR apparatus,

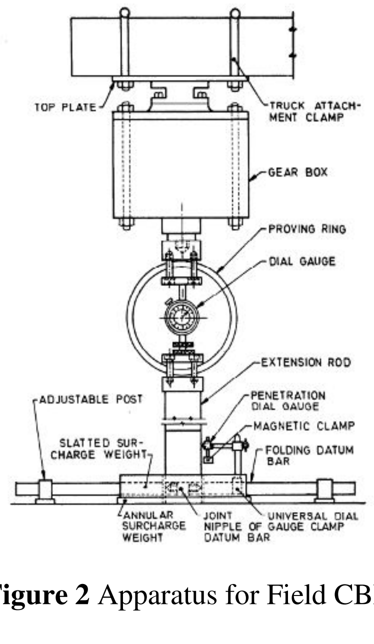

Figure 2 Apparatus for Field CBR

Figure 2 depicts a Field CBR apparatus. The top plate is clamped to truck to provide reaction loading so as to stop the apparatus from getting lifted by the upward reaction. The gear box is used to provide loading to the apparatus at the desired rate of deflection of 2.5mm/min. The Proving ring and the dial gauge are used to measure the load applied and deflection respectively. A surcharge loading of 5 kg is applied at the bottom by an annular ring with a central hole so that a plunger of 50mm can pass through. Also, the spirit level is used to maintain the horizontality of the apparatus. Also, care should be taken that the plunger is at the right angle to the ground rather than being inclined. The reading must be taken only at the places where the soil is of uniform nature and does not have gravel or stones.

The subgrade showed slight variations across its surface. It was saturated throughout by running water across the surface for two days.

Table 1 Index properties of Subgrade Soil

Soil Type	Plasticity Index	Specific Gravity	Water Content (%)	Optimum Moisture Content (%)	Dry Density (KN/m^3)
ML	9.734%	2.66	38%	24%	15.60

Out of the total 26 readings, 5 results were kept out of the relation making the process so as to test the relationship. These results were tested after the model making process.

4. DATA ANALYSIS

The established Field CBR test was done at the same locations as that of an LWD with the same moisture content for which the readings are shown in below table 2, so as to study and establish a relationship between the Field CBR and the E_{vd}.

Table 2 LWD and Field CBR readings for each station

Station No.	LWD Deflection (mm)	S/v	Evd (MN/m^2)	CBR
1	1.668	4.368	13.49	63.7086245
2	5.39	7.470	4.17	15.92715613
3	5.287	7.282	4.26	21.23620817
4	4.909	7.195	4.58	27.20889172
5	4.973	7.026	4.52	9.290841073
6	5.068	7.012	4.44	11.94536709
7	1.056	3.872	15.00	70.542356
8	2.325	4.909	11.69	52.36456859
9	2.856	5.342	10.31	45.6598746
10	3.865	6.166	7.69	31.35794659
11	4.268	6.495	6.64	31.365984
12	4.384	6.676	5.13	23.89073419
13	5.126	7.196	4.41	16.3648895
14	3.956	6.24	7.45	35.644579
15	4.456	6.649	6.15	25.32467893
16	3.198	5.621	9.42	45.2356489
17	2.031	4.669	12.46	56.32455699
18	4.569	6.741	5.86	24.62368
19	5.644	7.619	3.06	10.34765
20	5.365	7.391	3.79	13.9564123
21	4.658	6.814	5.63	22.5978

It was found that at points 1 and 7 the CBR value was very high and the E_{vd} values were also relatively high. It must be noted that at these places, the compaction was also relatively better and the LWD deflection was low. It appears from these values that the subgrade was relatively weak. It was found that as the deflection value increases, the E_{vd} decreases and so the CBR decreases. The average deflection of the subgrade was found to be 4.05 mm which may be attributed to the high inflow of water. The following graph shows the deflection at each station throughout.

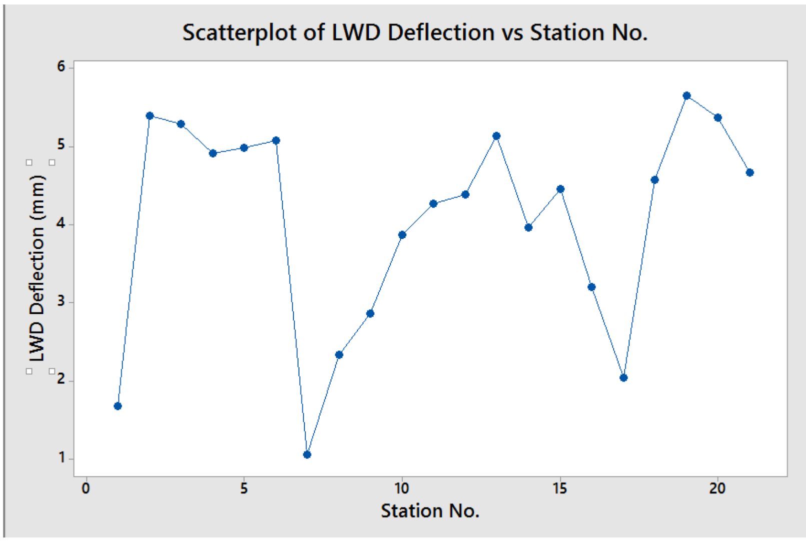

Figure 3 Deflection for each station

The following figure displays the relationship between the Field CBR and the E_{vd} values at various points obtained throughout the study. It was found that the relationship was linear with the R^2 value as 96.05% for this type of soil with the subgrade being in saturated condition, soaked for 2 days throughout. This explains that the relation between CBR and E_{vd} is a reasonable story.

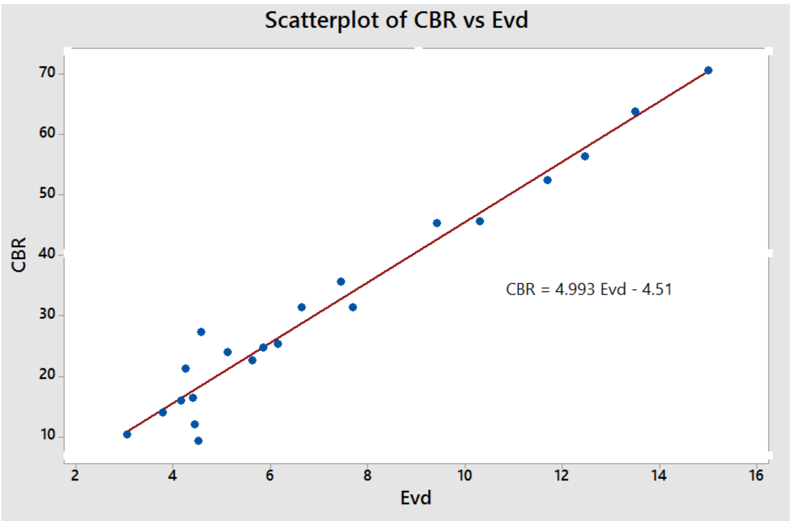

Figure 4 Graphical relationship between Field CBR & E_{vd}

The relationship obtained for the study was

$CBR = 4.993\ E_{vd} - 4.51\ (R^2 = 96.05\%)$ (4)

The relationship obtained was required to be tested, so as described above the 5 readings kept for testing is as given below, along with the calculated Field CBR for Black cotton soil in the saturated condition.

Table 3 Comparison of CBR obtained and calculated from derived equation

Station No.	LWD Deflection(mm)	S/v	Evd (MN/m^2)	CBR Actual	CBR Calculated
22	4.569	6.741	5.86	24.32546	24.62140266
23	3.365	5.758	8.99	40.56452	40.64895193
24	3.456	5.834	8.75	39.65412	39.41094356
25	3.856	6.159	7.71	33.32146	34.11280019
26	5.654	7.627	3.04	12.32564	10.17797163

The graph plotted between CBR actual V/S E_{vd} and CBR calculated V/S E_{vd} are shown below. The graph between Actual CBR V/S Calculated CBR was plotted. It gave the equation between these as

CBR Actual=2.23+0.9335*CBR Calculated. (5)

The results show that there is negligible difference in both the CBR obtained and CBR calculated as the R-square value is 99.70%.

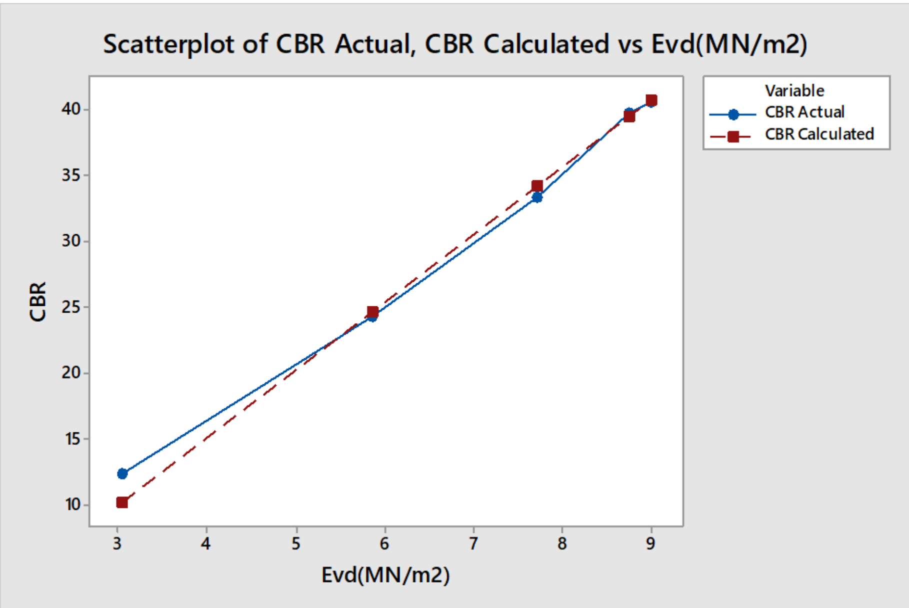

Figure 5 Comparison of Actual CBR and Calculated CBR

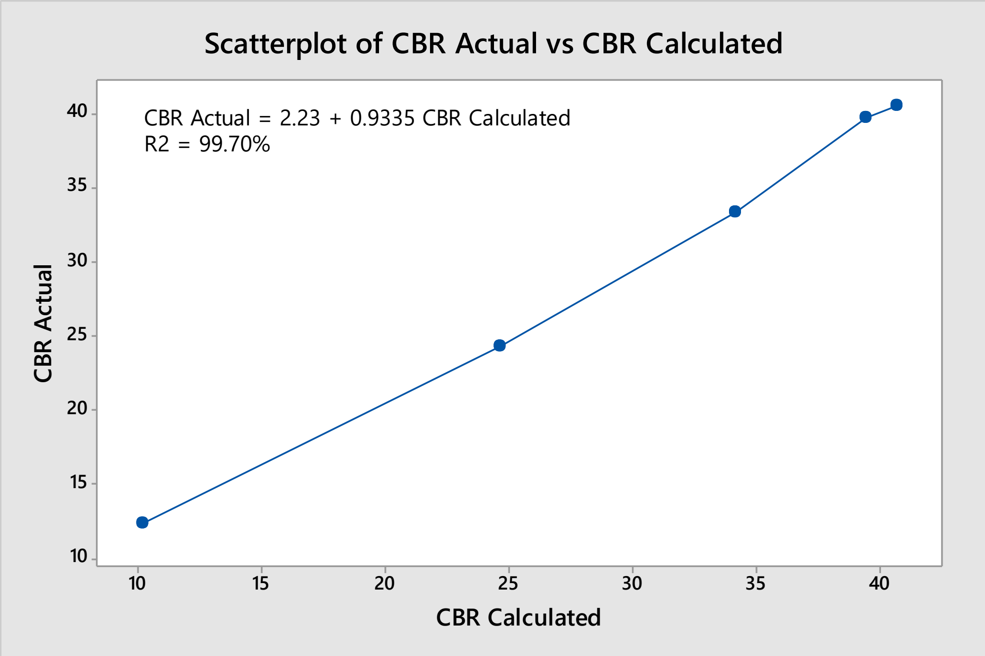

Figure 6 Graph between Actual CBR and Calculated CBR

5. RESULT AND CONCLUSION

This paper studies the relationship between Field CBR and Dynamic deflection modulus for black cotton soil. The soil was in saturated condition. From the results, the equation FCBR= $4.993E_{vd}$-4.51 was developed with R^2 value of 96.05%. This equation was tested for 20% of the readings taken for relationship building and it was found that the results were strongly correlated. The R^2 value of the relationship between Actual CBR and Calculated CBR was 99.70%.

The Study was mainly focused on black cotton soil since its prevalence in the region. Since this study was done only on black cotton soil, it leaves a scope for the study to be done on other types of soil. The soil was in saturated condition so someone may take upon to determine the relationship for the soils in field moisture condition.

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