Journal of Modern Science and Technology
Vol. 6. No. 2. June 2018 Issue. Pp.1-9

Relationship between CBR and Soil Index Properties of Bangladesh Soil Samples

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*California Bearing Ratio (CBR) value is an important soil parameter in the design of flexible Pavement as it is considered as the strength measuring parameter.Determination of CBR is a very complex and time consuming. Here a simplified method based on liquid limit, plastic limit, plasticity index, optimum moisture content and maximum dry density of the soil are used to estimate the CBR value. Five soil samples were collected from Mirpur, Gazipur, Noakhali, Hatirpool and Nawabganj are used to estimate soil properties. Finally a regression analysis is made by using SPSS 16.0 software based on Correlation coefficient to predict the unsoaked CBR value and predicted values are compared with the actual CBR value.*The co-efficient of determination R varies from 0.86 to 0.99 for CBR with Plastic limit and 0.06 to 0.2 for MDD. Thus it can be stated that unsoaked CBR value has a very good linear relationship with PL and a very poor linear relationship with MDD.

Keywords: Regression, liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, unsoaked CBR value, SPSS.

Field of Research: Civil and Geotechnical Engineering

1. Introduction

Roads have a very significant contribution to economic development and growth as well as bring crucial social benefits. In our country, most of the highway system consists of flexible pavement. The load from the pavement surface ultimately goes through the different layer of pavements such as sub-base, sub-grade layer. So the suitability must be checked before the pavement design. California Bearing Ratio (CBR) is a commonly used indirect method to assess the stiffness modulus and shear strength of sub grade in pavement design (John et al. 2017).

The thickness of pavement layer depends on the CBR value. For high CBR value the thickness of maybe lower and for lower CBR the thickness must be greater(Bassey et al. 2017). But the CBR test is very complex, time consuming and required comparatively large amount of sample. To overcome this problem a correlation can be developed between CBR and other soil index properties. These tests are much economical and more rapid than CBR test (Korde &Yadav, 2015).

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In the present study unsoaked CBR is correlated using simple correlation with the properties of soil like liquid limit, plastic limit, and plasticity index, optimum moisture content (OMC), maximum dry density (MDD) as well as finally a numerical equation is developed to predict CBR by using SPSS 16.0 software.

The paper is organized under five sections. The first section deals with the introduction. Section two deals with the published literature. Sample collection and methodology are conducted in section three. In forth section data analysis and correlation are shown. And the section five highlights the conclusion and recommendation.

2. Literature Review

Some correlations do exist to estimate CBR of a soil, based on soil classification, other index property values, and/or physical property measurement of soil. Aggarwal & Ghanekar(1970) performed their analysis of fine grained soils over 48 samples found in India; on the basis of their analysis they had tried to develop a correlation between CBR values and Liquid Limit, Plastic Limit/Plasticity Index. However, their analysis failed to determine any strong correlation between them. Instead a much better correlation was found when they included the liquid limit and optimum moisture content (OMC). The significant results notified can be described below:

$$CBR = 2\text{-}\log(\text{Optimum Moisture Content}) + 0.07^{*}(\text{Liquid Limit}).$$

Venkatasubramanian et al.(2011) proposed a technique to correlate CBR values with the soil parameters of various types of soils taken from the three different districts of Tamil-Naidu. A relation was developed with the help of Artificial Neural Network System (ANN) and Multiple Regression Analysis (MLR).

Korde & Ydadav (2015) proposed a correlation to determine the CBR value of some soils collected from different parts of Jabalpur city based on index properties like liquid limit (LL), plastic limit (PL), plasticity index (PI) and compaction characteristics i.e. optimum moisture content (OMC) and maximum dry density (MDD). Their developed equation is given below;

$$CBR = -0.258 - (0.014*LL) - (0.015*PI) + (0.011*OMC) + (2.100*MDD)$$

Patel & Desai (2010) had proposed a correlation between plasticity index, maximum drydensity and optimum moisture content. The proposed equation is,

$$CBR = 43.907 - 0.093*PI - 18.78*MDD - 0.3081*OMC$$

3. Methodology

3.1Soil Sample

The soil samples used in this study were collected from five different locationsin Bangladesh. Soil samples were collected from the surface, using the method of disturbing sample.

3.2 Index Properties

Index properties such as specific gravity, atterbergtest, i.e. liquid limit, plastic limit and plasticity index and shrinkage limit were investigated. AASHTO or ASTM method was used for this test.

3.3 Compaction Test

The standard proctor described by AASHO was used to determine the compaction characteristics of soil. The standard proctor were utilized 3 layers, applying 25 blows each of a 5.5lb hammer falling from a height of 1 ft using 1/30 ft^3mold.

3.4 California Bearing Ratio Test

The California bearing ratio (CBR) test carried out in this study to measurethe strength characteristic of soil. Unsoaked CBR value was used by using standard proctor method. The CBR value was calculated for 10, 25 and 56 blows.

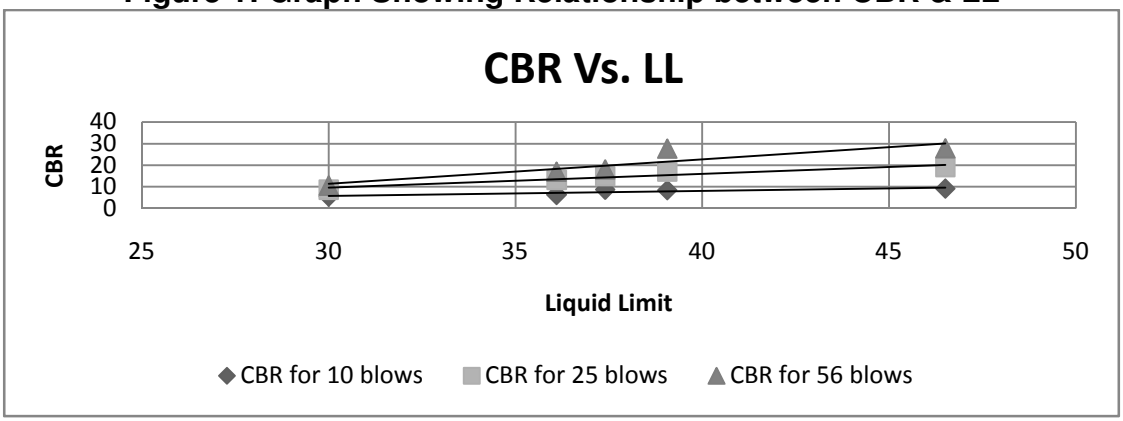
3.5 SPSS Software

To establish a relationship between CBR and soil index properties, multiple linear regression analysis was developed by using SPSS Software 16.0 to predict the CBR value.Correlation quantifies the degree to which dependent and independent variables are related.

4. Result and Discussion

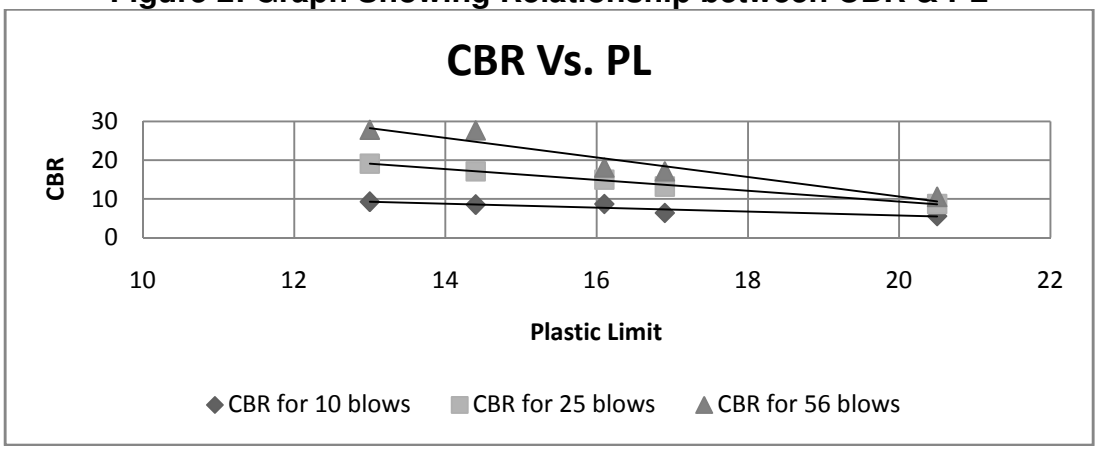
The relationship between CBR (10, 25,56 blows) and other soil properties such as LL, Pl, SL, PI, MDD, OMC using Microsoft Excel are shown in figure 1-6.

Figure 1: Graph Showing Relationship between CBR & LL



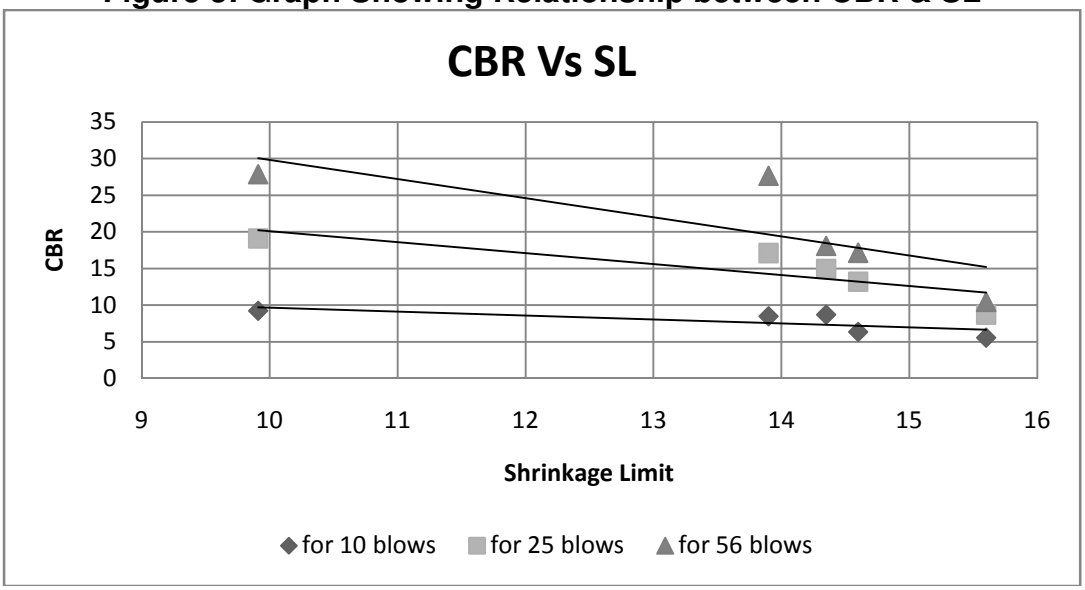
From the above CBR vs. liquid limit graph, it can be said that there is a proportional relationship between CBR and liquid limit test. The CBR values are increasing with the increasing of liquid limit. For 10 blows of compaction the linear relation can be expressed as y=0.1728x+1.206, with coefficient of determination, R^2=0.4729, which means poor linear regression. For 25 blows of compaction the relation is y=0.881x-12.961, with R^2=0.5779, indicating there is a fair relationship between CBR with LL for compacted mold with 25 blows. But mold compacted with 56 blows has a linear equation of y=0.533x-5.323 with a coefficient of determination R^2=0.7329. So that it can be said that there is comparatively a good relationship between CBR and LL for the mold compacted with 56 blows.

Figure 2: Graph Showing Relationship between CBR & PL



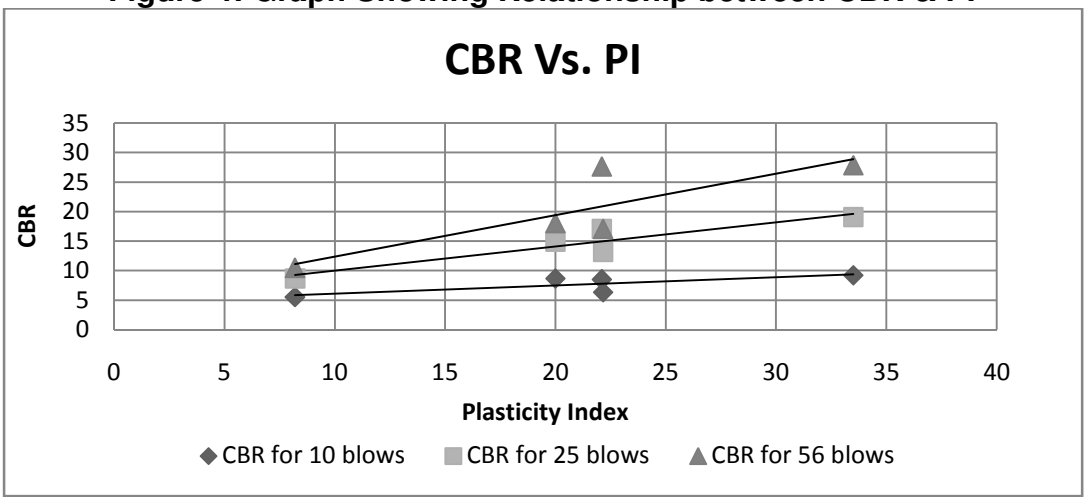
From the observation of the above CBR vs. plastic limit graph it can be said that there exists an inversely proportional relationship between CBR and plastic limit. The CBR values are decreasing with the increasing of plastic limit. For 10 blows of compaction the linear relation can be expressed as y=-0.5103x+15.92, with coefficient of determination, R^2=0.8175, which means very good linear regression. For 25 blows of compaction the relation is y=-0.13963x+37.198, with R^2=0.9962, indicating that an excellent linear relationship between CBR with PL.And the mold compacted with 56 blows has a linear equation of y=-2.52x+61.004, with a coefficient of determination R^2=0.9226. So that it can be said that there is the very good linear relationship between CBR and PL for the mold compacted with 56 blows.

Figure 3: Graph Showing Relationship between CBR & SL



From the observation of the above CBR vs. shrinkage limit graph it can be said that there exists an inverse relationship between CBR and plastic limit. From all these graphs it can be stated that as the SL increases the CBR value decreases. For 10 blows of compaction the linear relationship can be expressed as y=-0.5344x+14.97 with a coefficient of determination, R^2=0.5314, which indicates the regression moderately fits with the data. For 25 blows the relation can be expressed as y=-1.498x+35.086 with R^2 = 0.6796 which means regression line moderately fits with the data obtained from the test. But mold compacted with 56 blows has a linear equation y=-2.6102x+55.917 with R^2 =0.5866. So the regression line is also moderate in the compacted mold with 56 blows.

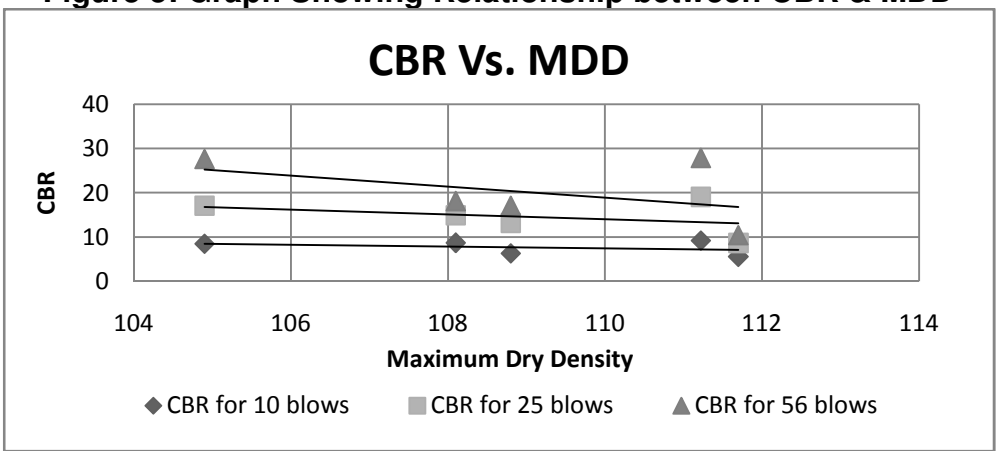
Figure 4: Graph Showing Relationship between CBR & PI



From the observation of the above CBR vs. plasticity index graph it can be said that there exists a proportional relationship between CBR and plasticity index. For 10 blows of compaction the linear relationship between CBR and plasticity index is expressed as, y=0.1387x+4.7246. The coefficient of determination, R^2 is equal to 0.6018, which

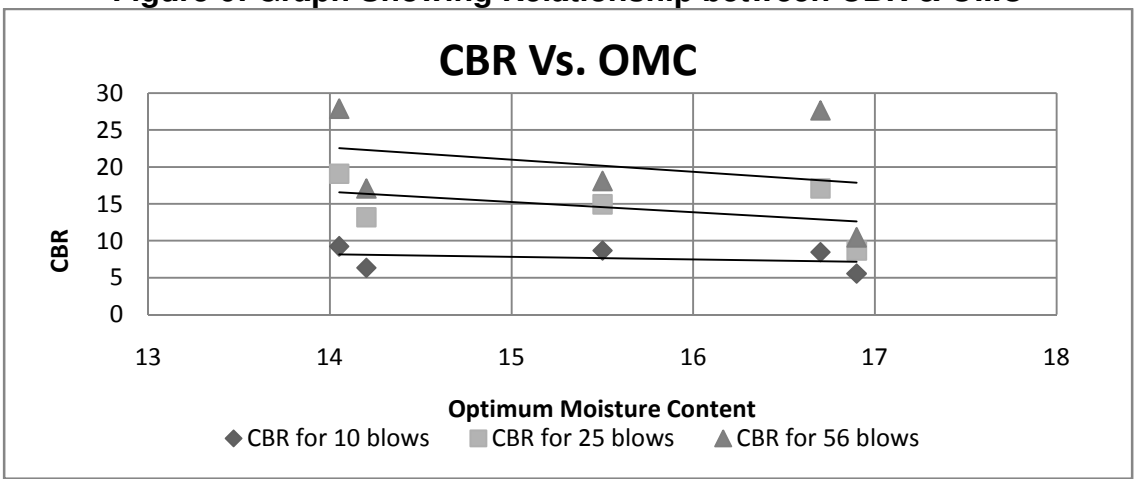
means regression line moderately fits with the data obtained from the test. For 25 blows of compaction the linear relationship between CBR and plasticity index is expressed as, y=0.4101x+5.9148. The coefficient of determination, R^2 is equal to 0.8562, which means regression line fits very well with the data obtained from the test. . For 56 blows of compaction the linear relationship between CBR and plasticity index is expressed as, y=0.7026x+5.3413. The coefficient of determination, R^2 is equal to 0.7144, which means regression line fits well with the data obtained from the test. Thus there is a quite acceptable linear relationship between CBR and PI.

Figure 5: Graph Showing Relationship between CBR & MDD



From the above CBR vs. MDD graph it can be stated that there exists an inverse relationship between the CBR and MDD. For 10 blows the linear relationship can be expressed as y=0.1545x+24.495 with R^2=0.0689. So the relationship is very poor for 10 blows. For compacted soil with 25 blows the linear equation is y= -0.5028x+69.388 with a coefficient of determination, R^2 =0.1188. It also indicates a very poor relationship. For 56 blows the equation is y=-1.2284x+154.06 with value of R^2 =0.2016. That's mean the linear relationship very poor fits with the data. Above all the relationship is very poor for CBR vs. MDD.

Figure 6: Graph Showing Relationship between CBR & OMC



Compaction test has been carried out to find out the optimum moisture content with the maximum dry density. For this test, five different optimum moisture contents recorded for five different soil samples. These graphsshow that there is an inverse relationship between the CBR and OMC. For 10 blows the linear relationship can be expressed as y=0.7734x+19.628 with R^2 =0.4157. So the relationship is very poor for 10 blows. For compacted soil with 25 blows the linear equation is y=-1.7047x+40.977 with a coefficient of determination, R^2 equal to 0.3287. It also indicates a very poor relationship. For 56 blows the equation is y=-1.8148x+48.304 with value of R^2 = 0.1059, that's mean the linear relationship poorly fits with the data.

The relation of CBR with soil index properties (LL, PL, SL, and PI) and soil parameters like OMC, MDD has been observed also on SPSS 16.0 to acquire an equation of CBR value relating all these test parameters for 10,25,56 blows is given respectively in Table1.

Table 1: Mathematical Equation of CBR for 10, 25 and 56 Blows

For 10 Blows	CBR = 43.012 – 0.728*PL - 0.221*SL – 0.341*MDD + 1.126*OMC
For 25 Blows	CBR = 39.06 – 1.492*PL - 0.58*SL – 0.05*MDD + 0.398*OMC
For 56 Blows	CBR = - 58.406 – 2.682*PL + 0.467*SL + 1.073*MDD – 0.223*OMC

The comparison between calculated CBR and actual CBR are shown in figure 7-9.

Figure 7: Comparison between the CBR from Laboratory Test and Predicted CBR (for 10 Blows)

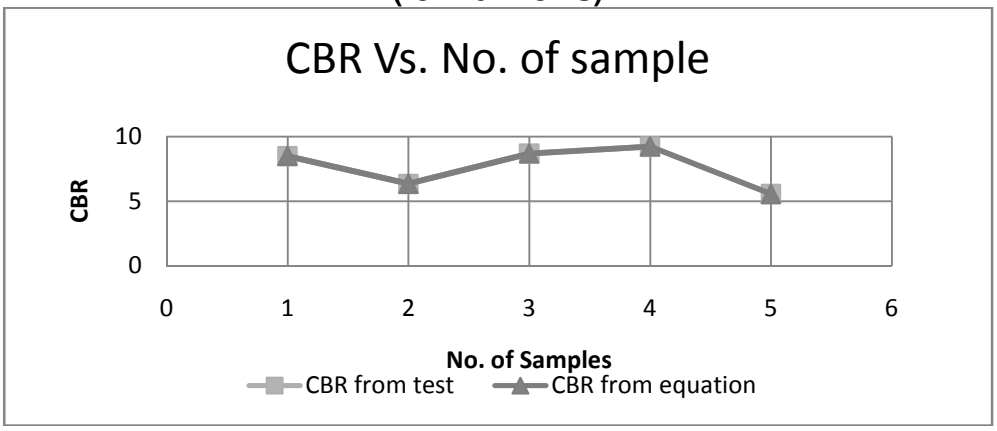


Figure 8: Comparison between the CBR from Laboratory Test and Predicted CBR (for 25 blows)

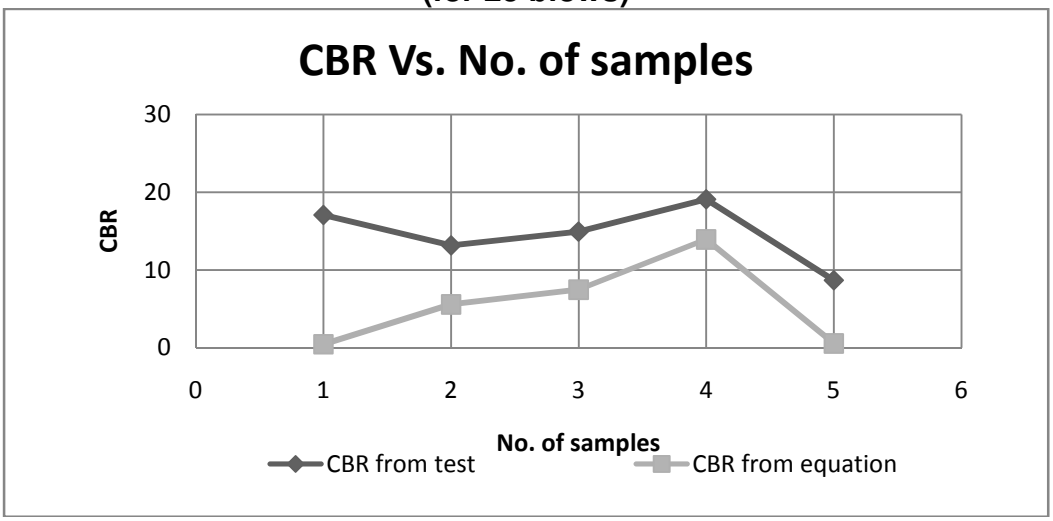
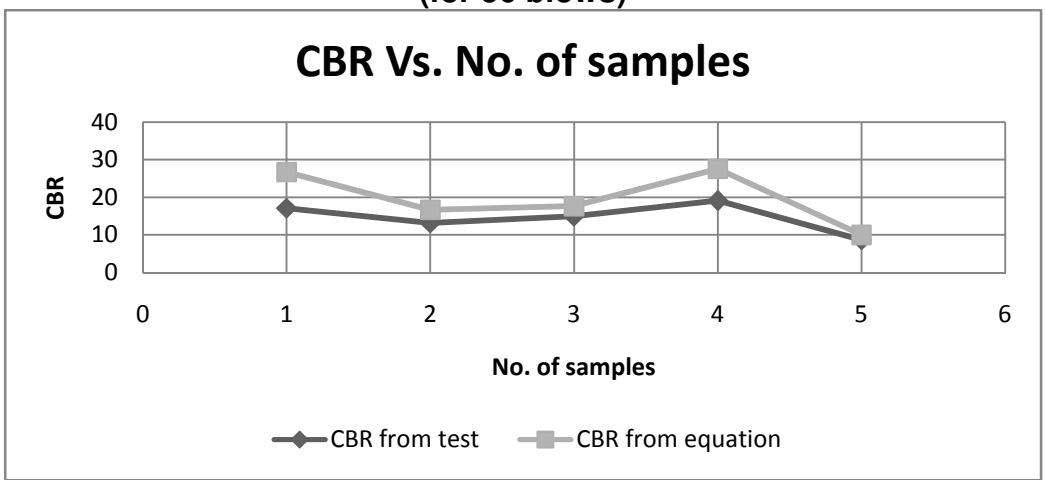


Figure 9: Comparison between the CBR from Laboratory Test and Predicted CBR (for 56 blows)



5. Conclusion

From this study it has been found that CBR values are highly affected by the plastic limit; on the other hand MDD poorly affects the CBR values of the subgrade soil. From the correlation graph it can be stated that CBR values are inversely proportional with SL, PL, MDD, and OMC but directly proportional with LL,and PI. The relation between CBR and other soil parameter changes with the change of the number of blows used in compacting molds. SPSS 16.0 software analysis provided a regression equation representing the relationship between CBR and all other tested soil parameters. The values of CBR obtained from the regression equation considering LL, PL, SL, PI, MDD, and OMC as independent variables provided by SPSS 16.0 software are close to the values obtained from the laboratory tests. The regression equation also changes with the change of the number of blows. One of major limitations of this study is disturbed soil sample was used here. Along with the number of soil sample was small. For better

result in large number of soil samples may be used. Due to time constraints and limited soil data, there are some aspects which have not been covered in the study. Following are some of the recommendations for future study or research in relation to the subject study:

- Here, surface soil or disturbed soil sample has been used. For better result, undisturbed soil sample should be used.
- This relation should be conducted with large number of samples for better result.
- For better understanding, soaked and unsoaked CBR values may be used.

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