



TRIBHUVAN UNIVERSITY
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THESIS NO.: T17/076

**Correlation Between CBR Value and Plasticity Index of Base Course Material in Flexible
Pavement**

by

Saroj Prasad Shah

A THESIS REPORT

**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE IN TRANSPORTATION ENGINEERING**

**DEPARTMENT OF CIVIL ENGINEERING
LALITPUR, NEPAL**

JULY, 2024

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled “**Correlation Between CBR Value and Plasticity Index of Base Course Material in Flexible Pavement**” submitted by Saroj Prasad Shah in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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ABSTRACT

The California Bearing Ratio (CBR) serves as a crucial indicator of base course strength, informing the thickness design of the pavement. It signifies the material's capacity to withstand loads and resist deformation, with higher values suggesting stronger base course materials capable of bearing heavier loads with minimal deformation. Plasticity Index (PI) is another pivotal parameter guiding engineers in assessing the suitability of the base course for pavement design. A larger PI implies a higher clay content, potentially compromising the base course's strength and stability. This prompts researchers to explore the potential relationship between CBR and PI for base course.

Twenty-one samples of base course were gathered from Lalitpur, Makwanpur, and Dhading, ensuring compliance with the Standard Specifications for Road and Bridge Works, 2016 (SSRBW). In assessing CBR, Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are also considered. Thus, OMC, MDD, and PI are treated as independent variables to formulate an expression for estimating CBR. Utilizing Multiple Linear Regression in Excel, a predictive model for CBR was established, demonstrating a strong correlation between predicted and observed CBR, with an R^2 -value of 0.81. This model streamlines testing procedures by facilitating the determination of CBR values for base courses without extensive testing. Laboratory tests indicate that even with a PI exceeding 6 (e.g., PI = 8), the CBR value remains above 80%. This underscores the negative correlation between CBR and PI, suggesting that as PI increases, the CBR value tends to decrease. Moreover, during the validation of the research, Root Mean Square Error (RMSE) values for the estimated CBR compared to the observed CBR were determined as 4.14. This underlines the model's effectiveness in CBR determination and underscores its potential to save time and resources. Adopting this model could significantly enhance its reliability for practical application in road construction projects.

Keywords: CBR, PI, MDD, OMC, Base, SSRBW, Correlation.

ACKNOWLEDGEMENT

In order to make this thesis a success, I would like to sincerely thank and appreciate everyone who has helped. Their assistance, direction, and knowledge have been really helpful to me all along the way.

First and foremost, I would like to thank my supervisor, Prof. Gautam Bir Singh Tamrakar, for his constant encouragement and guidance. His expertise and insights have played a crucial role in shaping this project and pushing it to new heights.

Furthermore, I would like to extend my thanks to the Anil Marsani, Program Coordinator, M.Sc. Program in Transportation Engineering, Asst. Prof. Dr. Rojee Pradhananga, Asst. Prof. Dr. Pradeep Kumar Shrestha and professionals who have generously shared their knowledge and insights. Their inputs have enriched this project and helped me deliver high-quality results.

I would also like to acknowledge the support and understanding of my family and friends, who have stood by me during this journey. Their unwavering support and encouragement have been a constant source of motivation.

Last but not least, I would like to thank all the resources and references that have been used throughout the thesis. Their contribution has been pivotal in broadening our understanding and providing us with valuable information.

Once again, I would like to express my heartfelt gratitude to everyone involved. This thesis would not have been possible without their support and contributions. Thanks everyone for being a part of this journey.

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LIST OF ABBREVIATIONS

AIV	Aggregate Impact Value
ANOVA	Analysis of Variance
CBR	California Bearing Ratio
DF	Degree of Freedom
F	F – test
LAA	Los Angel Abrasion
LL	Liquid Limit
MDD	Maximum Dry Density
MI	Intermediate Compressibility
ML	Low Compressibility
MS	Mean of Square
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plastic Limit
SE	Standard Error
SL	Shrinkage Limit
SS	Sum of Square
SSRBW	Standard Specifications for Road and Bridge Works, 2016

CHAPTER 1: INTRODUCTION

1.1 Background

The majority of the roads in Nepal are made of flexible pavement. The flexible pavement consists four layers such as Sub-grade, Sub-base, Base and finally Wearing courses. Base course is also most important layer to bear load that coming from vehicle to the pavement. Normally cost of base course is 15 – 20% of road cost per length of construction. The majority of flexible pavement designs rely on theoretical or empirical methods that primarily take into account the California bearing ratio (CBR) value.

The CBR is a measure of the strength of the base course material. It indicates the material's ability to withstand loads and resist deformation. Typically, a higher CBR value implies a stronger base course material, which can handle higher loads without significant deformation.

In Nepal, there are so many sources of base courses. But physical properties vary places to places. In Nepal most of base material contain lot of soil that causes plasticity property. Plasticity property may be expressed in plasticity index. In pavement design, the correlation between the California Bearing Ratio (CBR) and the Plasticity Index (PI) of the base course is employed to evaluate the strength and appropriateness of the material for sustaining the pavement structure. A lower PI value indicates lower clay content and better drainage properties, which contribute to the stability of the base course material. Ideally, a good base course material for pavement design should have a high CBR value and a low PI value. This combination ensures that the material can bear heavy loads without deformation while also having good drainage characteristics. However, the specific design requirements may vary depending on factors such as traffic volume, climate conditions, and soil properties in the project area.

Determining the CBR is a demanding, time-consuming, and labor-intensive task essential for pavement design and construction. Typically, this process takes an average of four days to complete. However, due to the lack of trained labor, there's a risk of inaccuracies in CBR test results, making it difficult to conduct tests at the required frequency for road projects. Furthermore, various soil properties such as plasticity

index, optimum moisture content (OMC), and maximum dry density (MDD) can influence CBR values, adding complexity to the assessment. To overcome these challenges, the objective is to establish a correlation between the CBR value of the base course with PI, MDD and OMC.

1.2 Problem Statement

The design and construction of durable and sustainable pavement structures is essential for ensuring safe and efficient transportation networks. One critical aspect of pavement design is the selection of appropriate base course materials, which play a key role in providing support and stability to the pavement structure.

In pavement design, the California Bearing Ratio (CBR) and Plasticity Index (PI) are two important characteristics that are commonly used to assess the strength and suitability of base course materials. The CBR test measures the load-bearing capacity of a soil or aggregate material, while the PI test determines the plasticity and potential for volume change due to moisture content.

In Nepal, despite the extensive construction of roads, ensuring proper design, quality control, and methodology remains a persistent challenge. One of the most crucial and demanding tasks is the construction of the base course layer following the completion of the sub-grade and sub-base layers. The materials available for this layer can vary widely in quality, presenting both opportunities and obstacles for pavement construction. According to the Standard Specifications for Road and Bridge Works 2016, as updated in 2022 by the Department of Road, a plasticity index of up to 6 is permissible. In contrast, the Standard Specifications for Road and Bridge Works, 2001 does not allow any plasticity in the base, meaning the base has a plasticity index of zero. Moreover, the California Bearing Ratio (CBR) for the base course must exceed 80. Hence, the objective is to determine if the CBR value can still exceed 80 even when the plasticity index exceeds 6 by conforming required laboratory test for this thesis, thereby effectively addressing this issue.

Yet, the connection between CBR and PI in base course materials remains inadequately grasped. This correlation holds considerable importance for pavement performance, influencing factors like rutting, cracking, and overall structural soundness. Therefore,

it's imperative to thoroughly study and establish a dependable correlation between CBR and PI to enhance the precision and effectiveness of pavement design.

This research aims to address the following questions:

- 1) What is the nature of the correlation between CBR and PI in base course materials?
- 2) Is it possible for the California Bearing Ratio (CBR) to remain above 80 even when the plasticity index (PI) exceeds 6 for the base course, provided that all criteria are met as per the Standard Specification of Road and Bridge Work (SSRBW) 2016?

1.3 Objective of Study

The primary goal of the research is to establish the connection between the CBR value and the Plasticity Index of the Base Course. The specific objectives are enlisted as below:

- 1) To correlate the CBR and Plasticity index of base courses.
- 2) To check and verify the minimum threshold of PI value for acceptable CBR (80%) criteria as per SSRBW 2016.

1.4 Scope of Study

The following scope of the study has been planned:

- 1) The physical properties like plasticity index reflect the classification of soils. The relation between CBR and Plasticity may help in selecting the suitable materials for construction of base course.
- 2) This study aims to understand how the CBR values and PI values are related.
- 3) The study involves collecting data from laboratory testing. The CBR values determined by conducting laboratory tests using standardized procedures, while the PI values also by conducting laboratory tests through soil testing methods.
- 4) The collected data analyzed by using statistical techniques to establish any correlations between the CBR and PI values. The analysis was included regression analysis, correlation coefficients, and hypothesis testing. The objective is to identify any significant relationship between the CBR and PI values and determine the strength and direction of this relationship.

- 5) The study also considers other factors that may influence the correlation between CBR and PI, such as moisture content, compaction characteristics, and soil type. These factors accounted in the analysis to ensure accurate conclusions.
- 6) The results of this study would be relevant for engineers and designers involved in pavement projects. By understanding the correlation between CBR and PI, more informed decisions can be made regarding the selection of suitable materials and design parameters for the base course. This can potentially lead to more cost-effective and durable pavement construction practices.

1.5 Limitation of Study

For this research, only twenty-one samples were prepared and tested for analysis. Constraints such as limited funds, time, and other resources prevented further testing and analysis for more robust results. The thesis report was prepared under following limitations:

- 1) The test sample collected from Dhading, Makwanpur, Lalitpur district of Nepal
- 2) All the required test was conducted from Laboratory of Department of Road (DOR).
- 3) Increase in PI value of base course not considering the binding effect between wearing layer and sub-base layer.

1.6 Organization of Report

The project report comprises five chapters structured as follows:

- 1) Chapter 1: Introduction describes shortly about the Base Layer of flexible pavement, CBR value and Plasticity Index.
- 2) Chapter 2: Literature Review discusses the available literature in the study related area regarding the factors affecting CBR value and Plasticity characteristics of soil and their relation.
- 3) Chapter 3: Research Methodology describes the procedure and test conducted analysis of data related area.
- 4) Chapter 4: Result Results and Discussions compile the test data and outline the findings of the model.

- 5) Chapter 5: Conclusion and Recommendations summarize the findings of the thesis and propose practical applications in relevant field scenarios.

CHAPTER 2: LITERATURE REVIEW

2.1 Estimating CBR Values Using Index Properties of Various Soils

Rehman et al. (2017) created predictive models using 59 soil sample sets that included both fine-grained and coarse-grained soils. They developed three distinct models, each designed for specific soil types, and evaluated their precision using 25 additional soil samples. The researchers distinguished between coarse-grained and fine-grained soils, constructing separate models for each type. These models were constructed based on factors like liquid limit and plasticity index for fine-grained soils, and coefficient of uniformity and maximum dry density for coarse-grained soils.

Rani and Nagaraj et al. (2017) established a correlation between CBR values and soil index properties specific to the Yadadri region. Soil index properties encompassed sieve analysis, Atterberg limits, and compaction tests. The study involved gathering eighteen samples from various parts of Yadadri and subjecting them to comprehensive laboratory testing to establish this correlation. The analysis employed both single linear regression and multiple linear regression techniques using SPSS software. It was observed that considering multiple variables such as liquid limit (LL), plastic limit (PL), maximum dry density (MDD), optimum moisture content (OMC), and plasticity index (PI) resulted in a notably improved correlation. Overall, the study concluded that soil index properties demonstrate a stronger association with CBR strength quality compared to individual soil properties. The predicted CBR values closely matched the laboratory values, with the coefficient of correlation R^2 for CBR value ranging from 0.801 to 0.692 as determined through SPSS analysis.

2.2 Correlation Between CBR Value with Other Properties of Soil

Pall and Pal (2019) conducted a comprehensive series of soil tests using samples gathered from various locations in Kolkata. Employing graphical analysis, they established a correlation equation expressing CBR in relation to Percentage Finer and Plasticity Index. The validity of this approach was confirmed across a significant number of tested samples. Given the labor-intensive and time-consuming nature of

direct CBR testing, emphasis can be placed on utilizing additional properties such as Liquid Limit, Plastic Limit, and Grain Size Analysis, obtained through more cost-effective and less time-intensive tests. In the present study, the projected CBR values closely matched the measured values. This model predicts soaked CBR values based on soil PI values and grain size analyses, thereby enhancing the ability to forecast soaking CBR values and validate laboratory-derived CBR values, which is beneficial for geotechnical engineers.

Roksana et al. (2017) gathered soil samples from Mirpur, Gazipur, Noakhali, Hatirpool, and Nawabganj to analyze soil characteristics. They then conducted regression analysis using SPSS 16.0 software to predict unsoaked CBR values based on correlation coefficients, comparing these predictions with actual CBR values. The coefficient of determination (R) for CBR with Plastic Limit ranged from 0.86 to 0.99, while for Maximum Dry Density (MDD), it varied from 0.06 to 0.2. The study concluded that there is a strong linear relationship between unsoaked CBR values and Plastic Limit (PL), whereas the association with MDD is weak. PL was identified as significantly influencing CBR values, while MDD had minimal impact on subgrade soil CBR values. Regression equations were developed using SPSS 16.0 to depict the relationship between CBR and each soil parameter measured. These equations closely matched CBR values obtained from laboratory tests using parameters such as Liquid Limit (LL), PL, Shrinkage Limit (SL), Plasticity Index (PI), MDD, and Optimum Moisture Content (OMC) as independent variables. However, the study noted limitations such as the use of disturbed soil samples and a relatively small sample size. It recommends employing undisturbed soil samples and a larger sample size for more robust findings. Furthermore, exploring both soaked and unsoaked CBR values could enhance understanding of their relationship.

Naeini et al. (2008) conducted experiments using three types of soils with different plasticity indexes (10, 16, and 23), achieved by adding varying percentages of bentonite (10% and 20%) to the original clay soil. Initially, samples were tested without geogrid under soaked and unsoaked conditions. Subsequently, a single layer of geogrid was placed at the second layer of the sample, and CBR tests were conducted on the reinforced soil. Following this, geogrid was placed at both the first and third layers, and CBR tests were repeated.

Shirur et al. (2017) based on the analysis of experimental data and SLRA (Single Linear Regression Analysis), there is no significant correlation observed for predicting CBR values based on liquid limit and plastic limit alone. However, it's important to note that despite these predictive models, significant discrepancies between experimental and predicted CBR values were observed, particularly concerning high compressible clays (CH), as indicated by correlation analysis.

Talukdar et al. (2014) investigated the relationship between CBR values and various soil index properties. Using Linex statistics in Microsoft Excel (version 13.0), they developed a linear multiple regression model to determine CBR values. Their findings indicated significant correlations for fine-grained soil types, including low compressibility (ML) and silts with intermediate compressibility (MI), with parameters such as plasticity index (PI), maximum dry density (MDD), and optimum moisture content (OMC). The analysis revealed a trend where CBR values tended to decrease as the plasticity index and optimum moisture content of the soil increased, while CBR values increased with higher maximum dry density. There was a slight difference noted between laboratory-measured CBR values and those predicted by the multiple linear regression model, which considered liquid limit (LL), plastic limit (PL), plasticity index (PI), maximum dry density (MDD), and optimum moisture content (OMC). The study primarily focused on ML and MI soil types, suggesting that future research could explore additional soil types to broaden understanding in this field.

Kaushik et al. (2022) concludes that time-consuming nature of conducting CBR tests on soil samples. These properties, which can be determined through more cost-effective and less time-intensive tests, hold promise for estimating CBR values. In the current investigation, experimental findings indicate that the predicted CBR values closely align with measured CBR values. This development offers a valuable tool for Geotechnical Engineering, enabling the prediction of soaked CBR values through the correlation established in this study.

Gudeta et. al. (2018) collects several soil samples sourced from diverse regions of Pakistan were collected with the aim of formulating predictive models tailored to the country's locally available soils. These models specifically target the prediction of CBR Soaked values for both fine-grained and coarse-grained soils. For fine-grained soil, a single model was devised, while two distinct models were developed for coarse-grained

soil. The robustness of these models was assessed based on their correlation coefficient (R value) and their applicability to real-scale data. Additionally, simplified predictive curves were introduced to facilitate the determination of soaked CBR values. it's essential to note that they cannot serve as a substitute for actual tests.

2.3 Other Studies

According to “STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS 2016 (Second amendment 2022)” for Crusher run Base types of test parameter guided the study clearly. The table shown below table 2.1 Requirements for Aggregate Gradation (SSRBW) and Table 2.2 Physical requirements of Coarse Aggregates for Crusher run material Base as per SSRBW 2016 for Gradation test and other test parameter.

Table 2.1 Requirement for Aggregate Gradation (SSRBW, 2016)

Sieve size	Percentage Passing by weight
	37.5 mm nominal size
45 mm	100
22.4 mm	90 – 100
5.6 mm	35 – 55
0.71 mm	10 – 30
0.09 mm	2 – 5

Table 2.2 Physical requirements of Coarse Aggregates for Crusher run material Base (SSRBW, 2016)

S. N.	Test	Test method	Requirements
1	Loss Angeles Abrasion Value (LAA) Or Aggregate Impact Value (AIV)	IS: 2386 -4	40% maximum 30% maximum
2	Combined Flakiness and Elongation index	IS: 2386 -1	35% maximum
3	Water Absorption	IS: 1386 -3	2 % maximum
4	Liquid limit of material passing 425 micron	IS: 2720- 5	25 maximum
5	Plasticity index of material passing 425 micron	IS: 2720- 5	6 maximum

2.4 Summary of Literature Review

The association between CBR and PI has been thoroughly explored within the field of geotechnical engineering. Numerous researchers have examined this connection through various testing approaches, both in controlled laboratory settings and in the

field for soil samples only. Here are the principal discoveries drawn from these investigations: Multiple laboratory inquiries have demonstrated a significant negative correlation between CBR and PI. Additionally, CBR might be influenced by factors such as OMC and MDD. Overall, the findings suggest that determining CBR and PI values is crucial and also no any studied found correlation between CBR and PI for granular base course material, particularly for base courses, and can pose significant challenges in construction projects.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Design

A research design is a conceptual plan of a research study which shown in figure 3.1 Framework of Research.

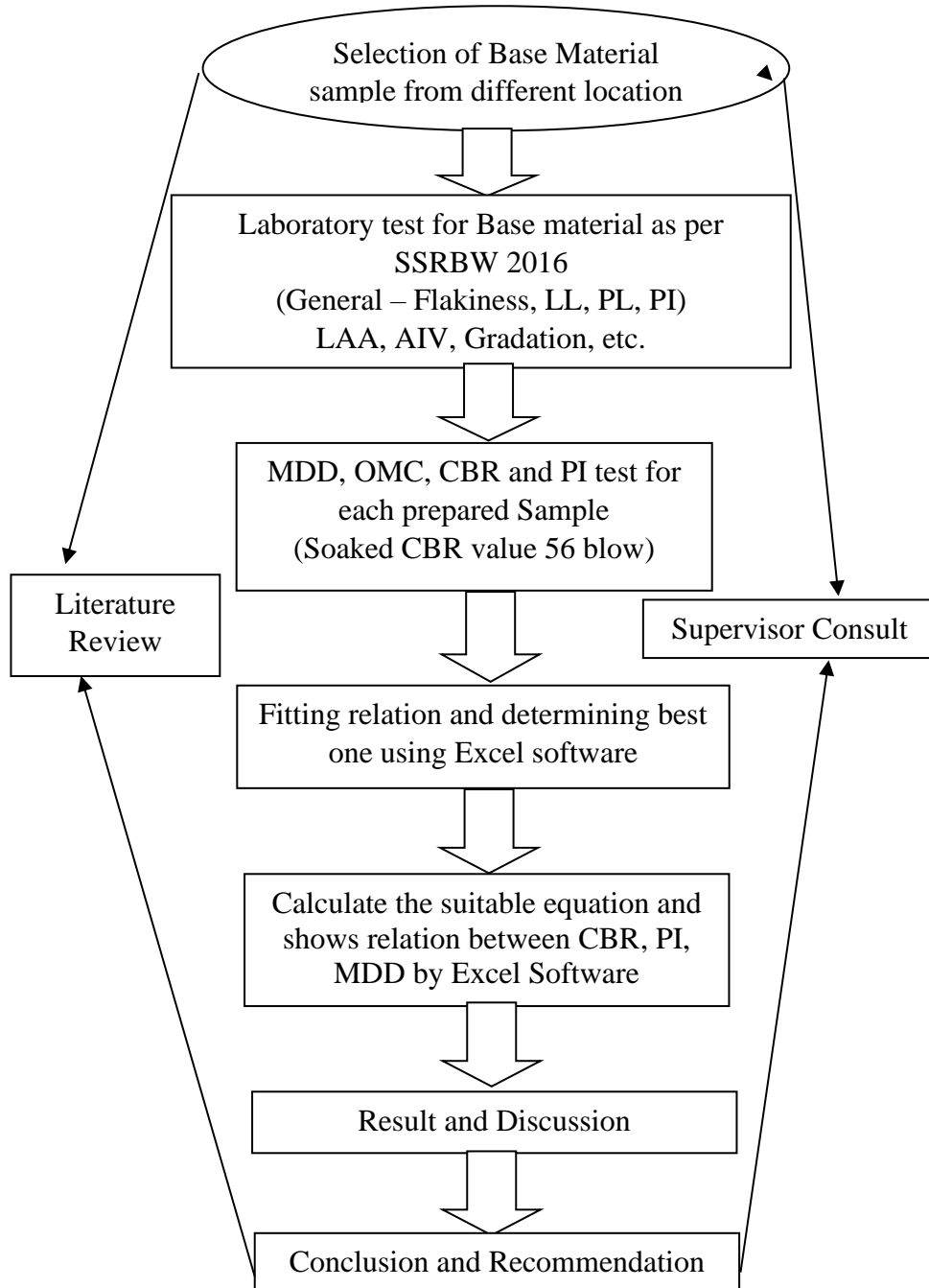


Figure 3.1 Framework of Research

Samples were gathered from three different sources for the required analysis. Base course materials were obtained from crushers located in Tikabhairav (Lalitpur), Dharke (Dhading), and Hetauda (Makwanpur), amounting to nearly 3 tippers or 18 cubic meters of test samples. After spending four months at the Department of Road (DOR) laboratory for testing, all necessary tests were conducted, and data was collected. The main challenge encountered during laboratory testing was related to gradation. Any alteration in the gradation of the sample affected the California Bearing Ratio (CBR) value and other parameters. Therefore, only the median value of gradation for each test frequency was considered. Upon completion of all required sample tests, analysis was performed using Microsoft Excel software to establish correlation results. The predicted CBR was calculated using an equation derived from Excel, yielding results closely matching the observed CBR obtained from the lab. Finally, validation of the research was conducted using a sample from Dhading.

3.2 Study Area

The study seeks to establish the connection between the California Bearing Ratio (CBR) and Plasticity Index (PI) of the Base course in flexible pavement. To check and verify the minimum threshold of PI value for acceptable CBR (80%) criteria as per SSRBW 2016. Samples were gathered from Dhading, Makwanpur, and Lalitpur districts of Nepal. Comprehensive tests were carried out to investigate the correlation between CBR and PI. The samples were selected in accordance with the specifications outlined in SSRBW, 2016.

3.3 Data collection and extraction

All data used in this study is primary data rather than collected from other sources. Firstly, sample get oven dried for any further test. Oven dried sample tested for all basic properties such as LAA, AIV, Combined Index (CI), Flakiness Index (FI), Elongation Index (EI), Water Absorption, LL, PL, PI and Gradation test table provided in **Table of Appendix A**. All basic test result of base course material shown in table 3.1

Table 3.1 Physical Test and their Test Result of Base Sample

S.N.	Test Name	Test Result		
		Lalitpur	Makwanpur	Dhading
1	Loss Angeles Abrasion Value (LAA)	30.51	31.6	38.88
2	Aggregate Impact Value (AIV)	16.07	16.62	20.78
3	Combined Flakiness and Elongation Index	33.56	34.19	34.48
4	Water Absorption	0.63	0.59	0.61
5	Liquid limit of material passing 425 micron	22.27	16.28	22.39
6	Plasticity index of material passing 425 micron	5	0	5
7	Optimum Moisture Content (%)	5	5.4	5.3
8	Maximum Dry Density, gm, cm ³	2.22	2.231	2.245
9	California Bearing Ratio (CBR)	110	219	122

According to table 3.1, LAA, AIV, and the Combined Flakiness and Elongation Index were found to be higher in the Dhading source of base course material and lower in the Lalitpur source.

A commonly cited guideline (as per "Introduction to Linear Regression Analysis" by Montgomery, Peck, and Vining) is to have at least 10-20 observations per predictor variable. For instance, with two predictor variables, the number of observations exceeds 2 times 10, which equals 20. So, we need more than 20 observations dataset to perform linear regression analysis with two predictor variables. This guideline helps ensure that the regression coefficients can be estimated reliably and that the statistical analysis has sufficient power to detect meaningful relationships between the predictors and the outcome variable. So, further studies, the number of test sample prepared is shown in table 3.2

Table 3.2 Physical Test and their number of Test Sample

S.N.	Test Name	Number of Test Sample			Total no. of test
		Lalitpur	Makwanpur	Dhading	
1	SIEVE ANALYSIS	7	8	6	21
2	PI	7	8	6	21
3	MDD	7	8	6	21
4	OMC	7	8	6	21
5	CBR	7	8	6	21

According to table 3.2, Samples for the CBR test were prepared and tested with Plasticity Index ranging from 0 to 8, yielding results of 7, 8, and 6 for Lalitpur,

Makwanpur, and Dhading respectively. Some important test in this research was conducted and their procedure with explanation shown below:

Sieve Analysis

A gradation test for base course material assesses the particle size distribution of aggregates used in construction, specifically for road bases or similar applications. Here's an explanation in simpler terms:

The gradation test checks how well the base course material (like crushed stone or gravel) is sorted by size. It's important because a good mix of sizes helps make the material strong and stable. Its procedure explained below:

1. **Collecting Samples:** Samples of the base course material are collected from different locations to make sure they represent the entire batch.
2. **Separating Sizes:** The material is separated into different size ranges using sieves with different-sized openings.
3. **Measuring Amounts:** The amount of material that passes through each sieve is weighed. This tells us how much of each size is present.
4. **Calculating Percentages:** The weight of material passing through each sieve is calculated as a percentage of the total weight.
5. **Analyzing Results:** Engineers compare these percentages to a standard or specification to see if the material meets requirements.

The goal is to have a balanced mix of sizes that provides strength and stability to the base course material.

Sample Preparation for CBR, MDD, OMC and PI

In this study, the median percentage passing by weight was used to prepare samples for CBR, MDD, OMC, and PI. Table 3.3 provides details on sample preparation, accompanied by a thorough explanation of the preparation process.

Table 3.3 Sample Preparation Table

Sieve size	Percentage Passing by weight	Median value of % passing by weight	Explanation for sample preparation
	37.5 mm nominal size		
45 mm	100	100	60% of the total weight of the prepared sample passed through the 45 mm sieve and was retained on the 4.75 mm IS sieve.
22.4 mm	90 – 100	95	
5.6 mm	35 – 55	45	
4.75 mm (For CBR fine purpose)	30 – 50	40	30% of the total weight of the prepared sample passed through the 4.75 mm sieve and was retained on the 0.425 mm IS sieve.
0.71 mm	10 – 30	20	
0.425 mm (For PI purpose)	5 – 15	10	10% of the total weight of the prepared sample passed through the 0.425 mm IS sieve.
0.09 mm	2 – 5	3.5	

According to Table 3.3, 60% of the prepared sample's total weight passed through the 45 mm sieve and was retained on the 4.75 mm IS sieve for coarse material. For fine material, 30% of the total weight passed through the 4.75 mm sieve and was retained on the 0.425 mm IS sieve. Finally, 10% of the total weight passed through the 0.425 mm IS sieve, corresponding to the Plasticity Index (PI).

Plasticity index (PI)

The plasticity index (PI) indicates the plasticity or consistency of soil. It is an important property to consider in geotechnical engineering and plays a significant role in determining the behavior of soils under different loading conditions. The plasticity index is calculated using two parameters: the liquid limit (LL) and the plastic limit (PL).

The liquid limit signifies the moisture content at which soil transitions from a liquid state to a plastic state. It is determined using a standard test known as the Casagrande method. In this test, a soil sample is divided into two halves, and each half is rolled into a thread-like shape. The soil threads are placed in a groove and subjected to a certain number of blows from a device called a Casagrande cup. The groove is then tilted at regular intervals, and the number of blows required for the soil thread to close is noted. The moisture content at which the soil thread closes is the liquid limit.

Conversely, the plastic limit indicates the moisture content at which soil transitions from a plastic state to a semi-solid state. It is determined through a test called the plastic limit test. In this test, a soil sample is mixed with a small amount of water to form a plastic mass. The mass is then rolled into a thread-like shape, and small portions of the thread are repeatedly rolled between the palms of the hands until they crumble.

Sample Preparation for PI

For Plasticity Index (PI), samples passing through the IS 425 micron sieve were used. To achieve different PI values, additional materials were incorporated: Makwanpur stone dust (having PI 0 %) to decrease PI and Lalitpur Tikabhairab soil (having PI 8 %) to increase PI. The proportions of these materials used for the PI samples shown in table 3.4, 3.5 and 3.6 respectively.

Table 3.4 Sample Preparation Table for PI with proportions of materials For Lalitpur Sample

Percentage of Lalitpur material passing through IS 425 micron sieve	Percentage of Makwanpur material passing through IS 425 micron sieve	PI obtained in Laboratory by using these proportions
0	100	0
20	80	2
40	60	4
50	50	5
60	40	6.5
80	20	7
100	0	8

Table 3.5 Sample Preparation Table for PI with proportions of materials For Makwanpur Sample

Percentage of Lalitpur material passing through IS 425 micron sieve	Percentage of Makwanpur material passing through IS 425 micron sieve	PI obtained in Laboratory by using these proportions
0	100	0
0	90	1
20	80	2
40	60	4
50	50	5.6
60	40	6
66	33	6.6
100	0	8

Table 3.6.: Sample Preparation Table for PI with proportions of materials For Dhading Sample

Percentage of Lalitpur material passing through IS 425 micron sieve	Percentage of Makwanpur material passing through IS 425 micron sieve	Percentage of Dhading material passing through IS 425 micron sieve	PI obtained in Laboratory by using these proportions
0	100	0	0
0	80	20	2.3
0	60	40	4
0	0	100	5
40	0	60	6
100	0	0	8

For varying PI 0 to 8 sample mixed Percentage of fine particle passing through IS 425 micron sieve in proportion as given in table 3.4, 3.5 and 3.6 respectively.

Optimum moisture content (OMC) and maximum dry density (MDD)

Optimum moisture content and maximum dry density are two fundamental concepts in soil mechanics and geotechnical engineering. These properties are crucial in determining the compaction characteristics and engineering behavior of soils.

Optimum moisture content refers to the moisture level at which soil achieves its highest compaction and strength. It represents the moisture content that yields the highest dry density achievable for a given soil compaction effort. The compaction effort may involve the use of mechanical equipment, such as compactors or rollers, to reduce the air voids and increase the soil density.

Maximum dry density, on the other hand, is the maximum achieved density of a soil when compacted at its optimum moisture content. It is a measure of the soil's ability to pack together and resist deformation. The higher the dry density, the greater the soil's strength and load-bearing capacity.

OMC can be found through a laboratory test called the Standard Proctor Test or the Modified Proctor Test. The test involves compacting a representative soil sample at different moisture contents and measuring the corresponding dry densities.

For this test, a total of 6500 grams of sample was used. The proportions of materials used for sample preparation shown in the table 3.7.

Table 3.7 Sample Preparation Table for OMC and MDD (Proctor Density Test)

Sieve size	Percentage Passing by weight	Median value of % passing by weight	Weight taken for Sample preparation	Explanation for sample preparation
	37.5 mm nominal size			
45 mm	100	100	6500 * 0.60 = 3900 gm. So, 3900gm of sample have size between 19mm to 4.75mm.	Over size than 19mm particle replaced by same amount of material passes a 19 mm sieve but retained on a 4.75 mm IS sieve.
22.4 mm	90 – 100	95		
5.6 mm	35 – 55	45		
4.75 mm	15 – 35	25	6500 * 0.30 = 1950 gm. So, 1950gm of sample have size between 4.75mm to 0.425mm.	30 % of the total weight of the prepared sample passed through the 4.75 mm sieve and was retained on the 0.425 mm IS sieve.
0.71 mm	10 – 30	20		
0.425 mm	5 – 15	10	6500 * 0.10 = 650 gm. So, 650gm of sample have size lower than 0.425mm.	10% by weight of total prepared sample was taken passing through 0.425 mm. Material taken for varying PI as per table 3.4, 3.5 and 3.6.
0.09 mm	2 – 5	3.5		

During the test, the soil sample is moistened to a specific moisture content and placed in a mould with a known volume. The sample is then subjected to a specified number of blows from a standardized compaction hammer as per table 3.7. After compaction, the moisture content and the weight of the compacted soil are found. The process is repeated at different moisture contents until the maximum dry density is obtained.

California Bearing Ratio (CBR)

The CBR laboratory test is conducted to assess the strength of subgrade soils and determine the thickness of pavement materials. It measures the load-bearing capacity of a soil sample and helps engineers determine the suitability of the soil for road construction or other infrastructure projects.

The procedure that conducted during CBR test typically involves the following steps:

- 1) Specimen Preparation: The oven dried soil sample is then compacted into a cylindrical mould of standard dimensions. The compaction is achieved by using a manual rammer. The soil is compacted in five layers, and each layer is

subjected to a specified number of blows to achieve the desired compaction level.

- 2) Soaking: The compacted soil specimen is then soaked in water for 96 hours.
- 3) Testing: Once the specimen has been soaked, it is placed in a CBR testing machine. This machine consists of a piston, a load frame, and a penetration piston.

For CBR, a total of 7000 grams of material was used. The proportions of materials used for sample preparation shown in the table 3.8

Table 3.8.: Sample Preparation Table for CBR

Sieve size	Percentage Passing by weight	Median value of % passing by weight	Weight taken for Sample preparation	Explanation for sample preparation
	37.5 mm nominal size			
45 mm	100	100	7000 * 0.60 = 4200 gm. So, 4200gm of sample have size between 19mm to 4.75mm.	Over size than 19mm particle replaced by same amount of material passes a 19 mm sieve but retained on a 4.75 mm IS sieve.
22.4 mm	90 – 100	95		
5.6 mm	35 – 55	45		
4.75 mm	15 – 35	25	7000 * 0.30 = 2100 gm. So, 2100gm of sample have size between 4.75mm to 0.425mm.	30 % of the total weight of the prepared sample passed through the 4.75 mm sieve and was retained on the 0.425 mm IS sieve.
0.71 mm	10 – 30	20		
0.425 mm	5 – 15	10	7000 * 0.10 = 700 gm. So, 650gm of sample have size lower than 0.425mm.	10% by weight of total prepared sample was taken passing through 0.425 mm. Material taken for varying PI as per table 3.4, 3.5 and 3.6.
0.09 mm	2 – 5	3.5		

3.4 Data Analysis

3.4.1 Correlation

Correlation is a tool of statistical that shows how strongly and in what direction two variables are related, revealing how changes in one variable coincide with changes in another variable. Correlation analysis is often used to test hypotheses and validate theories. By analyzing the correlation between variables, researchers can determine if

there is evidence to support their hypotheses or theories. Correlation helps in making informed decisions by providing insights into the relationship between variables.

3.4.2 Regression Analysis

Regression analysis plays a crucial role in data analysis by allowing us to understand the relationship between variables and make predictions or forecasts based on that relationship. Overall, it plays a fundamental role in data analysis by facilitating the understanding, prediction, and interpretation of relationships.

3.4.3 R – value and R² – value

The R-value, also known as the correlation coefficient, quantifies the linear relationship between two variables. It ranges from -1 to +1, where a value of -1 represents a perfect negative correlation, +1 represents a perfect positive correlation, and 0 indicates no correlation.

Alternatively, the R-square value, also known as the coefficient of determination, quantifies the proportion of variance in the dependent variable that is accounted for by the independent variable(s) in the regression model. It ranges from 0 to 1: a value of 1 indicates that all variance in the dependent variable is explained by the independent variable(s), while a value of 0 signifies that the independent variable(s) do not contribute to explaining the variance.

3.4.4 Multiple Linear Regression

It is used to describe the relationship between one dependent variable, also known as the outcome variable or response variable, and several independent variables, also known as predictor variables or features.

It basically expands on the concept of simple linear regression, which considers scenarios with a single independent variable, to scenarios with several independent factors that could potentially affect the dependent variable as a whole.

A multiple linear regression model with ‘n’ independent variables can be expressed in the following generic form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \epsilon$$

Where: Y is the dependent variable.

X_1, X_2, \dots, X_n are the independent variables.

$\beta_0, \beta_1, \beta_2, \dots, \beta_n$ are the coefficients (parameters) of the model, representing the relationship between the independent variables and the dependent variable.

The error term ϵ represents the discrepancy between the observed dependent variable and its predicted value by the model.

3.4.5 ANOVA

ANOVA, short for Analysis of Variance, is a statistical technique employed to assess whether there are significant differences among the means of three or more groups. It tests the null hypothesis that the group means are equal, against the alternative hypothesis that at least one mean differs from the rest.

3.4.6 Root Mean Square Error (RMSE)

Root Mean Square Error (RMSE) is a widely utilized metric for assessing how well a regression model performs. It quantifies the average size of the discrepancies between predicted values and actual values. RMSE is computed by taking the square root of the average of the squared variances between predicted and actual values.

Here's the formula for RMSE:

$$\text{RMSE} = \sqrt{\left\{ \frac{1}{n} \sum_{i=1}^n (y_i - y'_i)^2 \right\}}$$

Where, n is the number of observations in the dataset.

Y_i – represents the actual value of the target variable for observation i.

Y'_i – represents the predicted value of the target variable for observation i.

$$\sum_{i=1}^n \text{ denotes the sum over all observations.}$$

3.4.7 Validation of research

Validating research in a thesis is essential to verify the accuracy, reliability, and credibility of the study's findings. This process entails a methodical assessment and confirmation of the research methodology, data collection procedures, analysis techniques, and interpretation of results.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Overview

Table 4.1 lists the laboratory test results for various parameters such as CBR, PI, OMC, and MDD, with variations in PI values ranging from 0 to 8. It includes corresponding values for CBR, OMC, and MDD.

Table 4.1 Lab Test Result by varying PI and their Corresponding CBR, MDD and OMC of Base Sample from Lalitpur, Makwanpur and Dhading District

S.N.	CBR (%)	PI	MDD (gm/cm ³)	OMC (%)	Sources
1	93	8	2.245	5.85	LALITPUR
2	96	7	2.262	6	
3	97	6.5	2.288	4.8	
4	110	5	2.22	5	
5	120	4	2.256	4.8	
6	124	2	2.268	6.1	
7	140	0	2.261	6.2	
8	219	0	2.231	5.4	
9	185	1	2.215	5.8	
10	190	2	2.219	5.9	
11	142	4.08	2.22	6.15	
12	122	5.6	2.224	5.5	
13	115	6	2.214	5.6	
14	114	6.6	2.22	5.7	
15	94	8	2.236	5.4	DHADING
16	180	0	2.243	6	
17	146	2.3	2.245	5.9	
18	135	4	2.238	5.4	
19	122	5	2.245	5.3	
20	115	6	2.24	5.8	
21	96	8	2.242	5.7	

Descriptive statistics data of table 4.1 shown in table 4.2, 4.3 and 4.4 respectively for each source of base course material.

Table 4.2 Descriptive Table for Lalitpur Sample of base course Material

CBR	Value	PI	Value	MDD	Value	OMC	Value
Mean	111.4	Mean	4.64	Mean	2.26	Mean	5.54
Median	110	Median	5.00	Median	2.26	Median	5.85
Standard Deviation	17.49	Standard Deviation	2.87	Standard Deviation	0.02	Standard Deviation	0.64
Range	47	Range	8.00	Range	0.07	Range	1.40

From the table above, the average values for CBR, PI, MDD, and OMC of the base course were found to be 111.40, 4.64, 2.26, and 5.56 respectively, while the median values were 110, 5, 2.26, and 5.85 respectively. The ranges for CBR, PI, MDD, and OMC of the base course were determined to be 47, 8, 0.07, and 1.40 respectively.

Table 4.3 Descriptive Table for Makwanpur Sample of base course Material

CBR	Value	PI	Value	MDD	Value	OMC	Value
Mean	147.63	Mean	4.16	Mean	2.222	Mean	5.68
Median	132.00	Median	4.84	Median	2.22	Median	5.65
Standard Deviation	44.79	Standard Deviation	2.88	Standard Deviation	0.008	Standard Deviation	0.26
Range	125.00	Range	8.00	Range	0.022	Range	0.75

From the table above, the average values for CBR, PI, MDD, and OMC of the base course were found to be 147.63, 4.16, 2.222, and 5.68 respectively, while the median values were 132, 4.84, 2.22, and 5.65 respectively. The ranges for CBR, PI, MDD, and OMC of the base course were determined to be 125, 8, 0.022, and 0.75 respectively.

Table 4.4 Descriptive Table for Dhading Sample of base course Material

CBR	Value	PI	Value	MDD	Value	OMC	Value
Mean	132.33	Mean	4.22	Mean	2.242	Mean	5.68
Median	128.50	Median	4.50	Median	2.243	Median	5.75
Standard Deviation	28.96	Standard Deviation	2.81	Standard Deviation	0.003	Standard Deviation	0.28
Range	84.00	Range	8.00	Range	0.007	Range	0.70

From the table above, the average values for CBR, PI, MDD, and OMC of the base course were found to be 132.33, 4.22, 2.242, and 5.68 respectively, while the median values were 128.50, 4.50, 2.243, and 5.75 respectively. The ranges for CBR, PI, MDD, and OMC of the base course were determined to be 84, 8, 0.007, and 0.70 respectively.

Range of CBR value higher for Makwanpur Source i.e., 125 and lower for Lalitpur i.e., 47 respectively.

The study's analysis was performed utilizing 15 sets of test data collected from Lalitpur and Makwanpur districts. Six additional sets of test data from Dhading were utilized to validate this research.

4.2 Correlation

Correlation matrix of above table 4.1 shown in table 4.5.

Table 4.5 Correlation matrix table for CBR, PI, MDD and OMC

	CBR	PI	MDD	OMC
CBR	1			
PI	-0.84	1		
MDD	-0.39	0.07	1	
OMC	0.20	-0.27	-0.15	1

From table 4.5 it is clearly shown that relation between CBR with PI and CBR with MDD are negative but CBR with OMC is positive. Relation between CBR and PI highly related than other variables.

4.3 Graph and its nature

Figure 4.1 depicts the plot of CBR against PI based on the data in Table 4.1. The graph illustrates a linear relationship between CBR and PI, but with a negative correlation; this indicates that as the PI value increases, the CBR value decreases, and vice versa.

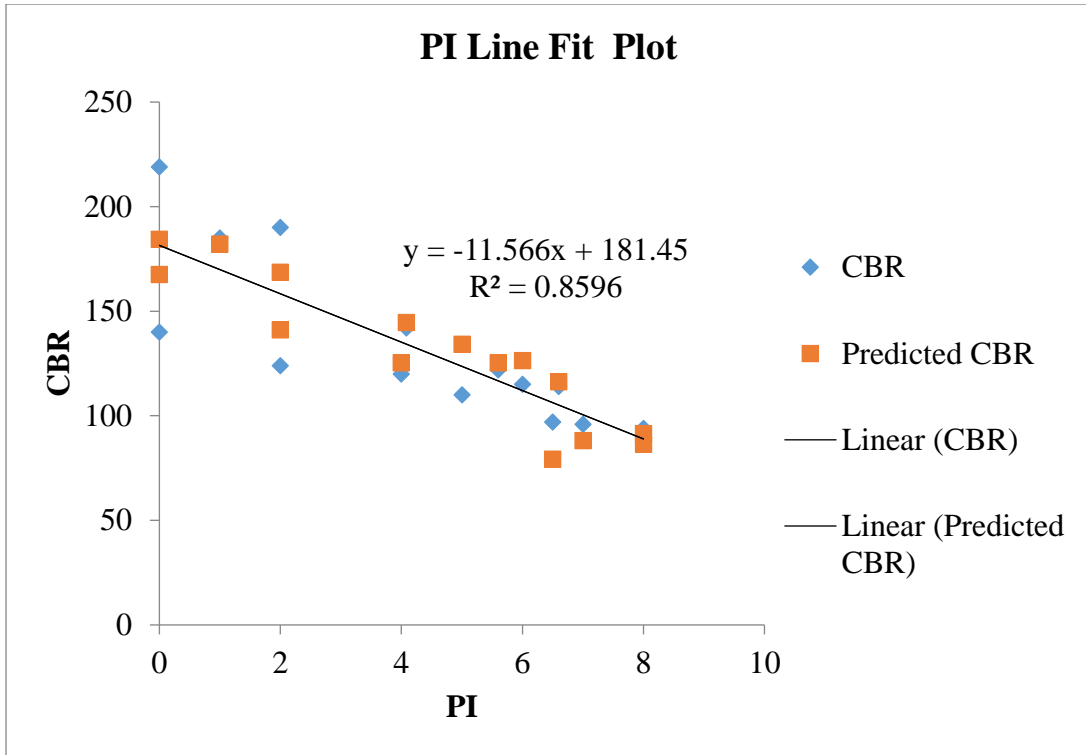


Figure 4.1 Plot of CBR value and PI

From above graph it is shown that lower the PI value have high value of CBR and vice-versa. The equation from graph is given below:

$$y = -11.566x + 181.45 \dots \dots \dots (1)$$

Where y = Predicted CBR and x = PI value then equation (1) becomes

$$\text{CBR}_p = -11.566 \cdot \text{PI} + 181.45 \dots \dots \dots (2)$$

With the help of equation (2) Predicted CBR can be obtained which shown in table 4.6.

Table 4.6 observed CBR, PI, and Predicted CBR

Observed CBR	PI	Predicted CBR
93	8	88.92
96	7	100.49
97	6.5	106.27
110	5	123.62
120	4	135.19
124	2	158.32
140	0	181.45
219	0	181.45
185	1	169.88
190	2	158.32
142	4.08	134.26
122	5.6	116.68
115	6	112.05

Observed CBR	PI	Predicted CBR
114	6.6	105.11
94	8	88.92

Table 4.6 clearly demonstrates a correlation coefficient R^2 of 0.86 between the measured CBR and the predicted CBR obtained from equation (2), where only the PI serves as the independent variable.

4.4 Model Interpretation

A multiple linear regression model with '3' independent variables can be expressed in the following generic form:

We have general type of equation with three variable X_1 , X_2 and X_3 is given below:

$$Y = a_0 + a_1 * X_1 + a_2 * X_2 + a_3 * X_3 \dots \dots \dots (3)$$

Where a_0 , a_1 , a_2 and a_3 are constant.

Assume CBR is linearly dependent on PI, MDD, and OMC as follows:

$$CBR = a_0 + a_1 * PI + a_2 * MDD + a_3 * OMC \dots \dots \dots (4)$$

Where, Y= CBR dependent variable

X_1 = PI independent variable 1

X_2 = MDD independent variable 2

X_3 = OMC independent variable 3 and we have four unknown a_0 , a_1 , a_2 and a_3 .

For further analysis taken 15 test value data of CBR, PI, MDD and OMC that coming from lab by varying PI 0 to 8. Now, with the help of Excel get result that shown in table 4.7, 4.8 and 4.9.

Table 4.7 Summary output

S.N.	Regression Statistics	Value
1	R Square	0.82
2	Standard Error	18.59
3	Observations	15

Table 4.8 ANOVA output

	Df	SS	MS	F	Significance F
Regression	3	16973.4	5657.81	16.38	0.00023
Residual	11	3799.52	345.411		

	Df	SS	MS	F	Significance F
Total	14	20772.9			

Table 4.9 ANOVA output for coefficient

	Coefficients	SE	t Stat	P-value	Lower 95%	Upper 95%
Intercept	1510.15	496.75	3.04	0.01	416.81	2603.49
PI	-11.54	1.86	-6.21	0.00	-15.63	-7.45
MDD	-577.53	216.23	-2.67	0.02	-1053.44	-101.61
OMC	-6.41	11.26	-0.57	0.58	-31.18	18.37

Based on the analysis shown in table 4.7, 4.8 and 4.9, the coefficient for OMC has a P-value of 0.58, exceeding the significance level of 0.05. This suggests that there might not be a significant linear relationship between the independent variable associated with that coefficient.

So above model was again run without taking OMC as an independent variable with the help of Excel. The test result that comes from Excel shown in table 4.10, 4.11 and 4.12.

Table 4.10 Summary output without OMC

S.N.	Regression Statistics	Value
1	R Square	0.81
2	Standard Error	18.05
3	Observations	15

Table 4.11 ANOVA output without OMC

	Df	SS	MS	F	Significance F
Regression	2	16861.49	8430.74	25.86	4E-05
Residual	12	3911.44	325.95		
Total	14	20772.93			

Table 4.12 ANOVA output for coefficient without OMC

	Coefficients	SE	t Stat	P-value	Lower 95%	Upper 95%
Intercept	1435.51	465.44	3.08	0.01	421.39	2449.62
PI	-11.26	1.74	-6.48	0.00	-15.04	-7.47
MDD	-560.80	208.10	-2.69	0.02	-1014.22	107.38

Following analysis conducted using Excel software, data has been tabulated in tables 4.10, 4.11, and 4.12. The results include the intercept value, significance, and P-value for the predicted CBR (dependent variable), indicating the best fit for the curve. Therefore, we now have the modified equation (5).

$$CBR_P = 1435.51 - 11.26*PI - 560.80*MDD \dots\dots\dots (5)$$

Residuals means the difference between Observed CBR and Predicted CBR. The maximum and minimum difference in CBR were observed 34.64 and 2.24 respectively. The predicted CBR value obtained from equation 5. Table of Residual Output with Predicted CBR and Observed CBR and fitting curve graph shown in table 4.13 and graph 4.2.

Table 4.13 Residual Output with Predicted CBR and Observed CBR

Observation	Predicted CBR	Residuals	Observed CBR
1	86.46	6.54	93
2	88.18	7.82	96
3	79.23	17.77	97
4	134.25	-24.25	110
5	125.31	-5.31	120
6	141.10	-17.10	124
7	167.53	-27.53	140
8	184.36	34.64	219
9	182.07	2.93	185
10	168.57	21.43	190
11	144.60	-2.60	142
12	125.25	-3.25	122
13	126.35	-11.35	115
14	116.24	-2.24	114
15	91.50	2.50	94

Table 4.13 reveals that the maximum and minimum differences in CBR were found to be 34.64 and -2.24 respectively. Following the analysis, a correlation value of 0.81 was determined, clearly depicted in Figure 4.2. The graph in Figure 4.2 demonstrates a clear linear correlation between predicted CBR and observed CBR.

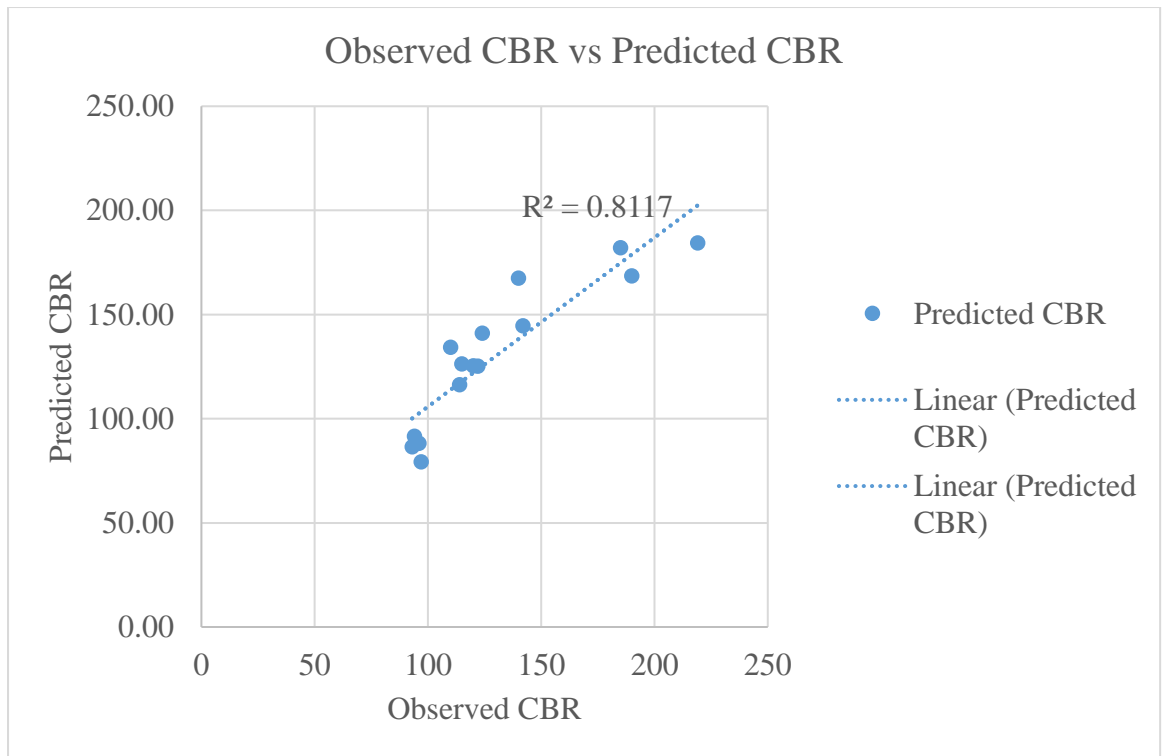


Figure 4.2 Plot of Observed CBR value and Predicted CBR value

4.5 Validation

Validation is done for the sample collected from Dhading and tested. Error Percentage of Predicted CBR with observed CBR shown in table 4.14.

Table 4.14 Error % of Observed CBR and Predicted CBR

Observed CBR	PI	MDD	OMC	Predicted CBR	Error in %
180	0	2.243	6	177.64	1.31
146	2.3	2.245	5.9	150.62	-3.16
135	4	2.238	5.4	135.40	-0.30
122	5	2.245	5.3	120.21	1.46
115	6	2.24	5.8	111.76	2.82
96	8	2.242	5.7	88.12	8.21

From table 4.14, maximum and minimum difference between observed CBR and predicted CBR are 8.21% and -0.30% respectively. Similarly, root mean square error (RMSE) for Observed CBR and Predicted CBR was calculated and shown in table 4.15.

Table 4.15 Calculation table of RMSE between Observed CBR with predicted CBR

Observed CBR (CBRo)	Predicted CBR (CBRp)	(CBRo-CBRp)	(CBRo-CBRp)²
180	177.64	2.36	5.590
146	150.62	-4.62	21.307
135	135.40	-0.40	0.160
122	120.21	1.79	3.190
115	111.76	3.24	10.511
96	88.12	7.88	62.151
Number of observation (n)= 6		Total	102.91
		Total/n =	20.12
Root Mean Square Error =		sqrt (Total/n) =	4.14

From table 4.15, Root Mean Square Error was observed 4.14 and R^2 – value 0.98 while validate from Dhading data.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Samples of base material collected from three districts – Lalitpur, Makwanpur, and Dhading were subjected to testing as per the specifications outlined in "SSRBW 2016" for sample preparation. A total of 21 samples were prepared from the tested base material, varying in Plasticity Index (PI), leading to different values of Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and California Bearing Ratio (CBR) respectively.

For the analysis in this study, 15 sample test data were utilized, collected from Lalitpur and Makwanpur districts. Additionally, six samples prepared and tested data obtained from Dhading were employed to validate the findings of this research.

The correlation coefficients (R-value, R²-value) between CBR and PI, CBR and MDD, CBR and OMC were observed as (-0.84, 0.70), (-0.39, 0.15), and (0.20, 0.04) respectively. Despite efforts to establish a stronger relationship between CBR and PI, OMC, and MDD through multiple linear regression modeling, it was found that the p-values exceeded 0.05 (for OMC variable), indicating no statistical significance. Consequently, a model considering only CBR with PI and MDD was developed. Utilizing Multiple Linear Regression in Excel, a predictive model for CBR ($CBR_p = 1435.51 - 11.26*PI - 560.80*MDD$) was derived, showing a strong correlation between predicted and observed CBR with an R-value of 0.90 and an R²-value of 0.81. This equation facilitates the determination of CBR for base courses without the need for time-consuming tests.

Based on comprehensive lab tests, it was determined that even when PI exceeds 6 (e.g., PI = 8), the CBR value remains above 80% as specified by SSRBW 2016. It was concluded that there exists a negative correlation between CBR and PI, indicating that as PI increases, the CBR value tends to decrease.

5.2 Recommendation

Given the significant correlation observed between California Bearing Ratio (CBR) and Plasticity Index (PI), it is advisable to prioritize further investigation into this relationship for enhanced understanding and potential practical applications. Additionally, considering the robust predictive model derived from the Multiple Linear Regression analysis, which incorporates CBR, PI, and Maximum Dry Density (MDD), it is recommended to utilize this model for efficient determination of CBR values for base courses, thereby streamlining testing procedures and saving time. This thesis also suggested that if there is a shortage of base course material as per SSRBW 2016, a PI of up to 8 could be considered for minor road projects instead of PI of up to 6 as specified in SSRBW 2016. Moreover, the validation of research findings through data collected from Dhading reinforces the reliability and applicability of the developed model across different districts, enhancing its credibility for practical implementation in pavement construction projects.

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APPENDIX A: Summary of Data

Table 1. Lab Test Result CBR, PI, MDD and OMC

S.N.	CBR (%)	PI	MDD (gm/cm ³)	OMC (%)	Sources
1	93	8	2.245	5.85	LALITPUR
2	96	7	2.262	6	
3	97	6.5	2.288	4.8	
4	110	5	2.22	5	
5	120	4	2.256	4.8	
6	124	2	2.268	6.1	
7	140	0	2.261	6.2	
8	219	0	2.231	5.4	MAKWANPUR
9	185	1	2.215	5.8	
10	190	2	2.219	5.9	
11	142	4.08	2.22	6.15	
12	122	5.6	2.224	5.5	
13	115	6	2.214	5.6	
14	114	6.6	2.22	5.7	
15	94	8	2.236	5.4	DHADING
16	180	0	2.243	6	
17	146	2.3	2.245	5.9	
18	135	4	2.238	5.4	
19	122	5	2.245	5.3	
20	115	6	2.24	5.8	
21	96	8	2.242	5.7	

1. AIV Test Report

Table 2. Laboratory test results of Aggregate Impact Value (AIV) test for Lalitpur base course material

Notation	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
A1	Wt. of Measure + Compacted Sample, (gm)	1353.5	1363.6	1377.2	
A2	Wt. of Measure, (gm)	1000	1000	1000	
A	Wt. of Compacted Sample (A1-A2), (gm)	353.5	363.6	377.2	
B	Wt. Passing 2.36mm Sieve, (gm)	56.1	59.1	60.7	
C	Wt. Retained 2.36mm Sieve, (gm)	297.4	304.5	316.5	
D	Total Wt. (B+C), (gm)	353.5	363.6	377.2	
	AIV Value = (B)/(A)*100%	15.87	16.25	16.09	
	Average Percentage of AIV in %	16.07%			

Table 3. Laboratory test results of Aggregate Impact Value (AIV) test for Makwanpur base course material

Notation	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
A1	Wt. of Measure + Compacted Sample, (gm)	1379.9	1394.5	1359.8	
A2	Wt. of Measure, (gm)	1000	1000	1000	
A	Wt. of Compacted Sample (A1-A2), (gm)	379.9	394.5	359.8	
B	Wt. Passing 2.36mm Sieve, (gm)	63.1	65.7	59.7	
C	Wt. Retained 2.36mm Sieve, (gm)	316.8	328.8	300.1	
D	Total Wt. (B+C), (gm)	379.9	394.5	359.8	
	AIV Value = (B)/(A)*100%	16.61	16.65	16.59	
	Average Percentage of AIV in %	16.62%			

**Table 4. Laboratory test results of Aggregate Impact Value (AIV) test for
Dhading base course material**

Notation	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
A1	Wt. of Measure + Compacted Sample, (gm)	1388.1	1369.1	1359.8	
A2	Wt. of Measure, (gm)	1000	1000	1000	
A	Wt. of Compacted Sample (A1-A2), (gm)	388.1	369.1	359.8	
B	Wt. Passing 2.36mm Sieve, (gm)	80.8	76.1	75.2	
C	Wt. Retained 2.36mm Sieve, (gm)	307.3	293	284.6	
D	Total Wt. (B+C), (gm)	388.1	369.1	359.8	
	AIV Value = (B)/(A)*100%	20.82	20.62	20.90	
	Average Percentage of AIV in %	20.78%			

2. Gradation Test Report

Table 5. Laboratory test results of Gradation test for Lalitpur base course material

Sieve Size (mm)	Course Fraction				Fine Fraction				Cumulative % passing (Total) gm	Remarks
	Weight retained on Individual sieve (gm)	Cum Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing	Weight retained on Individual sieve (gm)	Cum Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing		
63	0.00		0.00	100.00		0.00	0.00	100.00	100.00	
45	0.00	0.00	0.00	100.00		0.00	0.00	100.00	100.00	
22.4	1848.00	1848.00	9.86	90.14		0.00	0.00	100.00	90.14	
5.6	8156.00	10004.00	53.37	46.63		0.00	0.00	100.00	46.63	
0.71		10004.00	53.37	46.63	398.30	398.30	68.58	31.42	14.65	
0.09		10004.00	53.37	46.63	126.50	524.80	90.36	9.64	4.50	
Pan	8740.00	18744.00	100.00	0.00	2.40	527.20	90.77	9.23	0.00	
Wash		18744.00	100.00	0.00	53.60	580.80	100.00	0.00	0.00	
Total	18744.00				580.80					

Table 6. Laboratory test results of Gradation test for Makwanpur base course material

Sieve Size (mm)	Course Fraction				Fine Fraction				Cumulative % passing (Total) gm	Remarks
	Weight retained on Individual sieve (gm)	Cum Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing	Weight retained on Individual sieve (gm)	Cumulative Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing		
63	0.00		0.00	100.00		0.00	0.00	100.00	100.00	
45	0.00	0.00	0.00	100.00		0.00	0.00	100.00	100.00	
22.4	1664.00	1664.00	8.63	91.37		0.00	0.00	100.00	91.37	
5.6	9804.00	11468.00	59.47	40.53		0.00	0.00	100.00	40.53	
0.71		11468.00	59.47	40.53	408.00	408.00	71.48	28.52	11.56	
0.09		11468.00	59.47	40.53	101.10	509.10	89.19	10.81	4.38	
Pan	7816.00	19284.00	100.00	0.00	2.10	511.20	89.56	10.44	0.00	
Wash		19284.00	100.00	0.00	59.60	570.80	100.00	0.00	0.00	
Total	19284.00				570.80					

Table 7. Laboratory test results of Gradation test for Dhading base course material

Sieve Size (mm)	Course Fraction				Fine Fraction				Cumulative % passing (Total) gm	Remarks
	Weight retained on Individual sieve (gm)	Cum Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing	Weight retained on Individual sieve (gm)	Cum Weight Retained (gm)	%age Cumulative Weight Retained (gm)	% passing		
63	0.00		0.00	100.00		0.00	0.00	100.00	100.00	
45	0.00	0.00	0.00	100.00		0.00	0.00	100.00	100.00	
22.4	1687.00	1687.00	8.58	91.42		0.00	0.00	100.00	91.42	
5.6	9952.00	11639.00	59.23	40.77		0.00	0.00	100.00	40.77	
0.71		11639.00	59.23	40.77	394.60	394.60	66.81	33.19	13.53	
0.09		11639.00	59.23	40.77	131.10	525.70	89.01	10.99	4.48	
Pan	8013.00	19652.00	100.00	0.00	1.50	527.20	89.27	10.73	0.00	
Wash		19652.00	100.00	0.00	63.40	590.60	100.00	0.00	0.00	
Total	19652.00				590.60					

3. LAA Test Report

Table 8. Laboratory test results of LAA test for Lalitpur base course material

S.N.	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
1	Wt. of Specimen, W1 (gm)	5004	5002	5000	
2	Wt. of Specimen after abrasion test, Coarser than 1.70 mm IS sieve, W2 (gm)	3478	3474	3476	
3	LAA Value = $(W1 - W2)/W1 * 100\%$	30.50	30.55	30.48	
	Average Percentage of LAA in %	30.51%			

Table 9. Laboratory test results of LAA test for Makwanpur base course material

S.N.	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
1	Wt. of Specimen, W1 (gm)	5002	5004	5000	
2	Wt. of Specimen after abrasion test, Coarser than 1.70 mm IS sieve, W2 (gm)	3422	3430	3412	
3	LAA Value = $(W1 - W2)/W1 * 100\%$	31.59	31.45	31.76	
	Average Percentage of LAA in %	31.60%			

Table 10. Laboratory test results of LAA test for Dhading base course material

S.N.	Description	Test Result 1	Test Result 2	Test Result 3	Remarks
1	Wt. of Specimen, W1 (gm)	5002	5000	5002	
2	Wt. of Specimen after abrasion test, Coarser than 1.70 mm IS sieve, W2 (gm)	3052	3050	3068	
3	LAA Value = $(W1 - W2)/W1 * 100\%$	38.98	39.00	38.66	
	Average Percentage of LAA in %	38.88%			

4. Combined Flakiness and Elongation Index Test Report

Table 11. Laboratory test results of Combined Flakiness and Elongation Index test for Lalitpur base course material

Sieve Size (mm)	For Flakiness			
	A	B	C	D
	Flakiness Plate Slot Size Identification	Weight retained on Flakiness Plate (gm)	Weight Passing Slot on Flakiness Plate (gm)	Total Weight Tested (B+C)
63	63 to 50			0.00
50	50 to 40			0.00
40	40 to 25	3458.00	966.00	4424.00
25	25 to 20	2248.00	472.00	2720.00
20	20 to 16	1436.00	366.00	1802.00
16	16 to 12.5	762.00	88.00	850.00
12.5	12.5 to 10	428.00	106.00	534.00
10(9.5)	10 to 6.3	138.00	36.00	174.00
6.3				0.00
Total			2034.00	10504.00

Flakiness Index (%) = (Total of Column C / Total of Column D)*100%

Flakiness Index (%) = 19.36

Elongation Index of Aggregate				
1	2	3	4	5
IS Sieve Size (mm)	Retained on IS Sieve Size (mm)	Weight of Fraction Consisting at least 200 pieces of Aggregate (gm)	Length of Gauge Sieze (1.8 times mean Sieve) mm	Wt. of Aggregate in each fraction retained on Length Gauge (gm)
50	50 to 40		81.00	
40	40 to 25	3458.00	58.50	124.00
25	25 to 20	2248.00	40.50	488.00
20	20 to 16	1436.00	32.40	284.00
16	16 to 12.5	762.00	25.65	194.00
12.5	12.5 to 10	428.00	20.25	76.00
10(9.5)	10 to 6.3	138.00	14.67	36.00
6.3				0.00
Total		8470.00		1202.00

Elongation Index (%) = (Total of Column 5 / Total of Column 3)*100%

Elongation Index (%) = 14.19

Combined FI and EI (%) = 33.56

**Table 12. Laboratory test results of Combined Flakiness and Elongation
Index test for Makwanpur base course material**

Sieve Size (mm)	For Flakiness			
	A	B	C	D
	Flakiness Plate Slot Size Identification	Weight retained on Flakiness Plate (gm)	Weight Passing Slot on Flakiness Plate (gm)	Total Weight Tested (B+C)
63	63 to 50			0.00
50	50 to 40			0.00
40	40 to 25	3364.00	870.00	4234.00
25	25 to 20	2120.00	520.00	2640.00
20	20 to 16	1136.00	222.00	1358.00
16	16 to 12.5	596.00	90.00	686.00
12.5	12.5 to 10	330.00	126.00	456.00
10(9.5)	10 to 6.3	116.00	40.00	156.00
6.3				0.00
Total		7662.00	1868.00	9530.00

Flakiness Index (%) = (Total of Column C/ Total of Column D)*100%

Flakiness Index (%) = 19.60

Elongation Index of Aggregate				
1	2	3	4	5
IS Sieve Size (mm)	Retained on IS Sieve Size (mm)	Weight of Fraction Consisting at least 200 pieces of Aggregate (gm)	Length of Gauge Sieze (1.8 times mean Sieve)mm	Wt. of Aggregate in each fraction retained on Length Gauge (gm)
50	50 to 40		81.00	
40	40 to 25	3364.00	58.50	184.00
25	25 to 20	2120.00	40.50	398.00
20	20 to 16	1136.00	32.40	244.00
16	16 to 12.5	596.00	25.65	168.00
12.5	12.5 to 10	330.00	20.25	92.00
10(9.5)	10 to 6.3	116.00	14.67	32.00
6.3				0.00
Total		7662.00		1118.00

Elongation Index (%) = (Total of Column 5 / Total of Column 3)*100%

Elongation Index (%) = 14.59

Combined FI and EI (%) = 34.19

**Table 13. Laboratory test results of Combined Flakiness and Elongation
Index test for Dhading base course material**

Sieve Size (mm)	For Flakiness			
	A	B	C	D
	Flakiness Plate Slot Size Identification	Weight retained on Flakiness Plate (gm)	Weight Passing Slot on Flakiness Plate (gm)	Total Weight Tested (B+C)
63	63 to 50			0.00
50	50 to 40			0.00
40	40 to 25	3728.00	1454.00	5182.00
25	25 to 20	2460.00	422.00	2882.00
20	20 to 16	1584.00	170.00	1754.00
16	16 to 12.5	814.00	144.00	958.00
12.5	12.5 to 10	450.00	90.00	540.00
10(9.5)	10 to 6.3	156.00	22.00	178.00
6.3				0.00
Total		9192.00	2302.00	11494.00

Flakiness Index (%) = (Total of Column C/ Total of Column D)*100%

Flakiness Index (%) = 20.03

Elongation Index of Aggregate				
1	2	3	4	5
IS Sieve Size (mm)	Retained on IS Sieve Size (mm)	Weight of Fraction Consisting at least 200 pieces of Aggregate (gm)	Length of Gauge Sieze (1.8 times mean Sieve)mm	Wt. of Aggregate in each fraction retained on Length Gauge (gm)
50	50 to 40		81.00	
40	40 to 25	3728.00	58.50	82.00
25	25 to 20	2460.00	40.50	684.00
20	20 to 16	1584.00	32.40	258.00
16	16 to 12.5	814.00	25.65	216.00
12.5	12.5 to 10	450.00	20.25	54.00
10(9.5)	10 to 6.3	156.00	14.67	34.00
6.3				0.00
Total		9192.00		1328.00

Elongation Index (%) = (Total of Column 5 / Total of Column 3)*100%

Elongation Index (%) = 14.45

Combined FI and EI (%) = 34.48

5. Water Absorption Test Report

Table 14. Laboratory test results of Water Absorption test for Lalitpur base course material

Notation	Determination Number	Weight	Unit	Remarks
B1	Wt. of Pan+Saturated Surface Dry Sample	2443.90	gm	
B2	Wt. of Pan	395.40	gm	
B	Wt. of Saturated Surface Dry Sample (B1-B2)	2048.50	gm	
C1	Wt. of Basket+Sample in Water	1830.70	gm	
C2	Wt. of Basket in Water	549.40	gm	
C	Wt. of Sample in Water (C1-C2)	1281.30	gm	
A1	Wt. of Pan+Oven Dry Sample	2431.00	gm	
A2	Wt. of Pan	395.40	gm	
A	Wt. of Oven Dry Sample	2035.60	gm	
	Bulk G Oven Dry (A/(B-C))	2.65		
	Bulk G (SSD) (B/(B-C))	2.67		
	Apparent G (A/(A-C))	2.70		
	Absorption ((B-A)/A)*100%	0.63		

**Table 15. Laboratory test results of Water Absorption test for Makwanpur
base course material**

Notation	Determination Number	Weight	Unit	Remarks
B1	Wt. of Pan+Saturated Surface Dry Sample	2664.00	gm	
B2	Wt. of Pan	383.30	gm	
B	Wt. of Saturated Surface Dry Sample (B1-B2)	2280.70	gm	
C1	Wt. of Basket+Sample in Water	1970.00	gm	
C2	Wt. of Basket in Water	547.70	gm	
C	Wt. of Sample in Water (C1-C2)	1422.30	gm	
A1	Wt. of Pan+Oven Dry Sample	2650.60	gm	
A2	Wt. of Pan	383.30	gm	
A	Wt. of Oven Dry Sample	2267.30	gm	
	Bulk G Oven Dry (A/(B-C))	2.64		
	Bulk G (SSD) (B/(B-C))	2.66		
	Apparent G (A/(A-C))	2.68		
	Absorption ((B-A)/A)*100%	0.59		

**Table 16. Laboratory test results of Water Absorption test for Dhading base
course material**

Notation	Determination Number	Weight	Unit	Remarks
B1	Wt. of Pan+Saturated Surface Dry Sample	2410.80	gm	
B2	Wt. of Pan	395.40	gm	
B	Wt. of Saturated Surface Dry Sample (B1-B2)	2015.40	gm	
C1	Wt. of Basket+Sample in Water	1818.80	gm	
C2	Wt. of Basket in Water	548.40	gm	
C	Wt. of Sample in Water (C1-C2)	1270.40	gm	
A1	Wt. of Pan+Oven Dry Sample	2398.60	gm	
A2	Wt. of Pan	395.40	gm	
A	Wt. of Oven Dry Sample	2003.20	gm	
	Bulk G Oven Dry (A/(B-C))	2.69		
	Bulk G (SSD) (B/(B-C))	2.71		
	Apparent G (A/(A-C))	2.73		
	Absorption ((B-A)/A)*100%	0.61		

6. LL, PL and PI Test Report

Table 17. Laboratory test results of LL, PL and PI test for Lalitpur base course material

Liquid Limit

S.N.	Description	Sample Number				Remarks
		1	2	3	4	
2	Container number	P6	DC	FC	BC	
3	Number of Blows	34	28	23	20	
4	Mass of empty container (M1), gm	46.52	45.82	44.59	46.32	
5	Mass of container + wet soil (M2), gm	78.79	78.79	80.79	75.89	
6	Mass of container + dry soil (M3), gm	73.55	73.05	74.11	70.11	
7	Water content= $w = (M2 - M3/M3 - M1) \times 100 \%$	19.39	21.08	22.63	24.3	

Calculations:

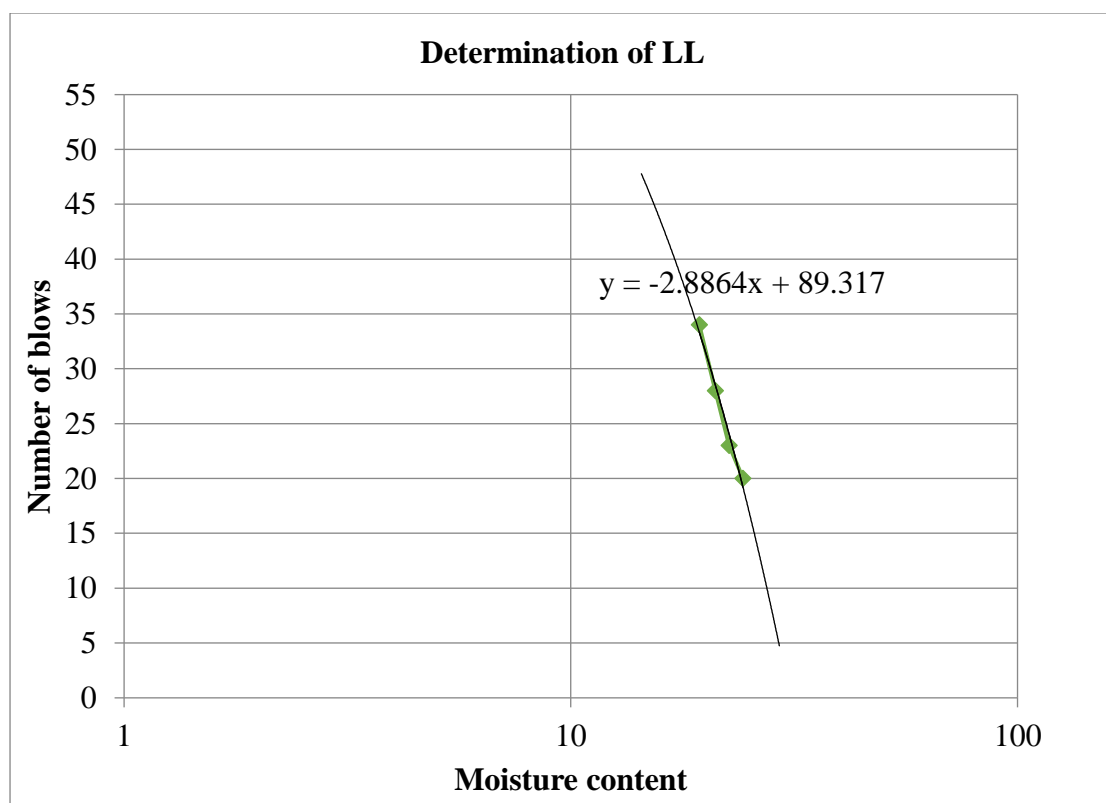


Figure 1. Plot of Number of blows and Water Content

Figure 1. Plot the relationship between the water content, w, and the corresponding number of drops, N, of the cup on a semi-logarithmic graph with water content as the ordinates and arithmetical scale, and the number of drops on the abscissas on a logarithmic scale. Draw the best fit straight line through the five or more plotted points. Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit, LL, of the soil.

Water content Corresponding to 25 number of Blows (LL) = $X = (89.317-25)/2.888 = 22.27$.

Plastic Limit

S.N.	Description	Sample Number		Remarks
		1	2	
1	Container designation	CC	Dc	BC
2	Weight of empty container(M1) gm	51.78	45.82	46.33
3	Weight of container + wet soil (M2) gm	56.56	48.47	49.77
4	Weight of container + dry soil (M3) gm	55.86	48.08	49.26
5	(PL)Water content = $(M2-M3)/(M3-M1)100 \%$	17.15	17.25	17.40

Calculations:

Average Plastic limit Value = 17.27%
Liquid limit = 22.27%
Plasticity Index (PI) = 5.00%

Table 18. Laboratory test results of LL, PL and PI test for Makwanpur base course material

Liquid Limit

S.N.	Description	Sample Number				Remarks
		1	2	3	4	
2	Container number	AC	EC	DC	CC	
3	Number of Blows	34	28	23	17	
4	Mass of empty container (M1), gm	53.48	54.43	45.84	51.77	
5	Mass of container + wet soil (M2), gm	79.07	79.96	74.89	79.15	
6	Mass of container + dry soil (M3), gm	75.72	76.51	70.74	75.08	
7	Water content= $w = (M2 - M3/M3 - M1) \times 100 \%$	15.07	15.63	16.67	17.47	

Calculations:

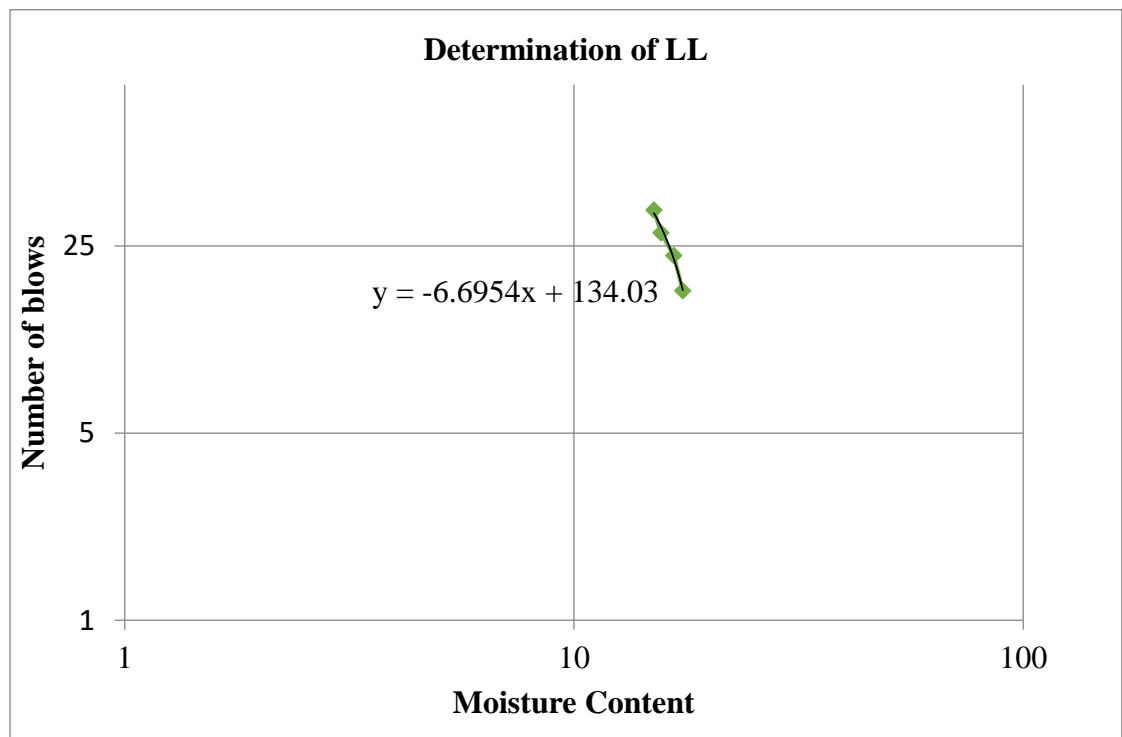


Figure 2. Plot of Number of blows and Water Content

Figure 3. Plot the relationship between the water content, w , and the corresponding number of drops, N , of the cup on a semi-logarithmic graph with water content as the ordinates and arithmetical scale, and the number of drops on the abscissas on a logarithmic scale. Draw the best fit straight line through the five or more plotted

points. Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit, LL, of the soil.

Water content Corresponding to 25 number of Blows (LL) = $X = (134.03-25)/6.696 = 16.28$.

Plastic Limit

S.N.	Description	Sample Number		Remarks
		1	2	
1	Container designation	AC	P4	CC
2	Weight of empty container(M1) gm	53.48	53.34	46.32
3	Weight of container + wet soil (M2) gm	56.76	57.46	49.01
4	Weight of container + dry soil (M3) gm	56.31	56.87	48.64
5	(PL)Water content = $(M2-M3)/(M3-M1)100 \%$	15.90	16.71	15.94

Calculations:

Average Plastic limit Value = 16.18%
Liquid limit = 16.28%
Plasticity Index (PI) = 0.10%

Table19. Laboratory test results of LL, PL and PI test for Dhading base course material

Liquid Limit

S.N.	Description	Sample Number				Remarks
		1	2	3	4	
2	Container number	BC	FC	DC	P6	
3	Number of Blows	34	28	21	17	
4	Mass of empty container (M1), gm	46.32	44.59	45.82	46.51	
5	Mass of container + wet soil (M2), gm	75.63	69.98	76.24	72	
6	Mass of container + dry soil (M3), gm	70.46	65.36	70.64	67.18	
7	Water content= $w = (M2 - M3/M3 - M1) \times 100 \%$	21.42	22.25	22.57	23.32	

Calculations:

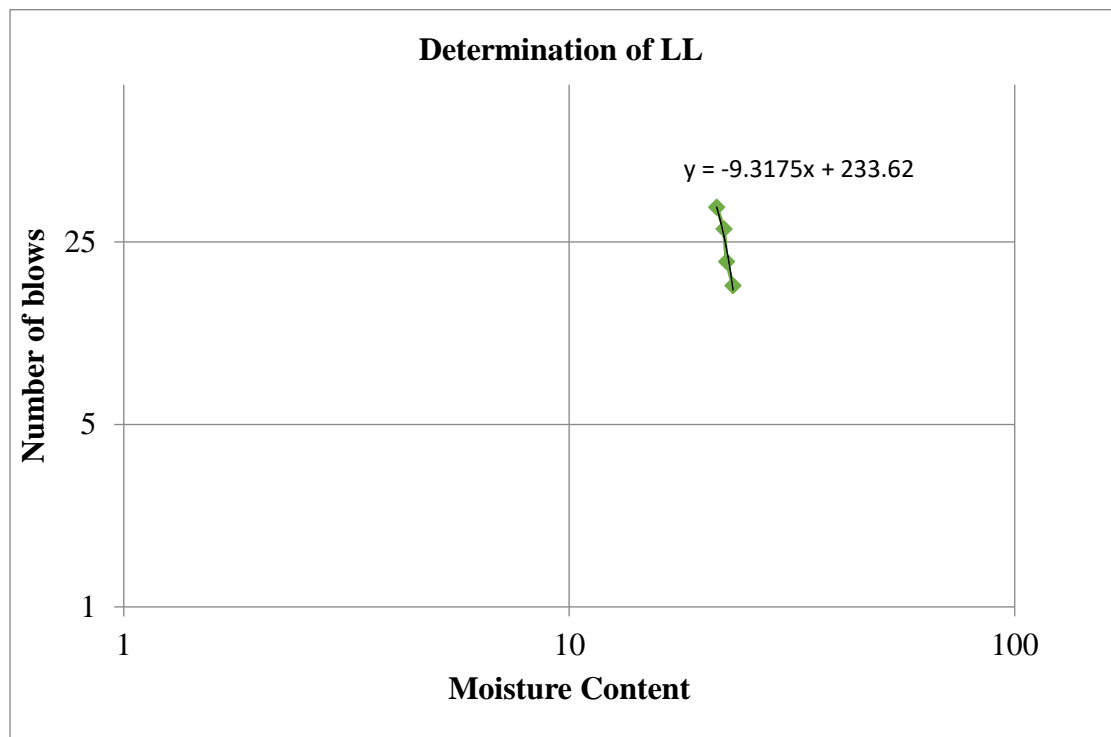


Figure 3. Plot of Number of blows and Water Content

Figure 3. Plot the relationship between the water content, w , and the corresponding number of drops, N , of the cup on a semi-logarithmic graph with water content as the ordinates and arithmetical scale, and the number of drops on the abscissas on a logarithmic scale. Draw the best fit straight line through the five or more plotted

points. Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit, LL, of the soil.

Water content Corresponding to 25 number of Blows (LL) = X = (233.62-25)/9.317 = **22.39**.

Plastic Limit

S.N.	Description	Sample Number		Remarks
		1	2	
1	Container designation	P4	AC	
2	Weight of empty container(M1) gm	53.33	53.47	
3	Weight of container + wet soil (M2) gm	56.49	57.12	
4	Weight of container + dry soil (M3) gm	56.03	56.57	
5	(PL)Water content = (M2-M3)/(M3-M1)100 %	17.03	17.74	

Calculations:

Average Plastic limit Value = 17.39%
Liquid limit = 22.39%
Plasticity Index (PI) = 5.00%

7. MDD and OMC Test Report

Table 20. Laboratory test results of MDD and OMC test for Lalitpur base course material

Volume of Mould 2262.24 cc

Density

Water added %				
Test No	1	2	3	4
Cylinder +Soil(gm)	11616	11986	12012	11884
Cylinder (gm)	6744	6744	6744	6744
Wet Soil (W) in gm	4872	5242	5268	5140
Wet Density(g/cc)	2.15	2.32	2.33	2.27

Moisture Content

Container No.	DA	N10	S1	A
Wet soil + Container (gm)	1327.94	1392.16	1314.66	1305.76
Dry soil + Container(gm)	1308.06	1349.26	1261.46	1234.52
Container(gm)	387.16	398.23	386.99	386.2
Dry Soil	920.9	951.03	874.47	848.32
Moisture(gm)	19.88	42.9	53.2	71.24
Moisture Content %	2.2	4.5	6.1	8.4
Average Moisture Content %	5.29			
Dry Density g/cc mg/m ³	2.108	2.217	2.195	2.096

Moisture content	Dry Density
2.2	2.108
4.5	2.217
6.1	2.195
8.4	2.096

OMC = 5.00% MDD = 2.220

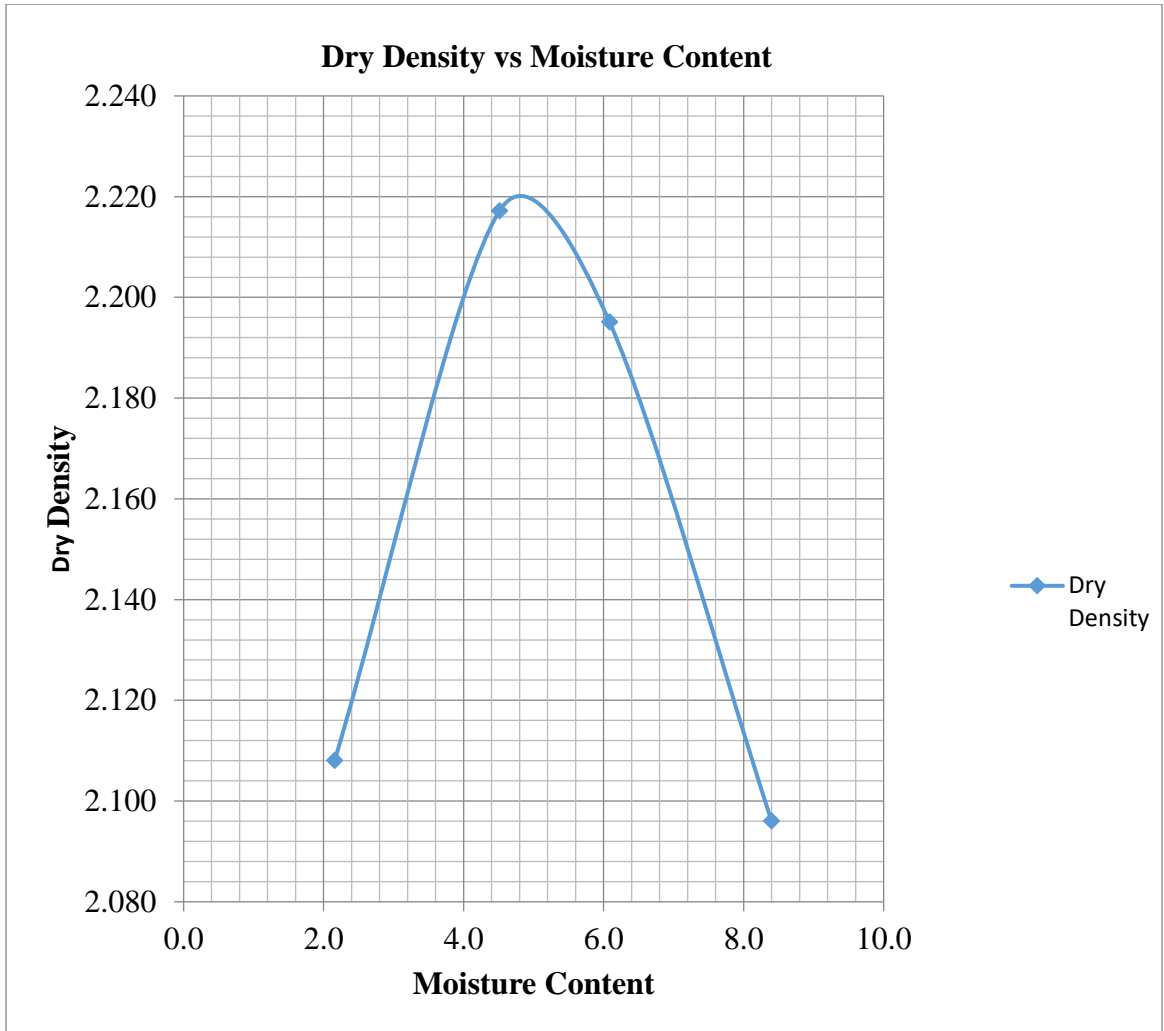


Figure 4. Dry Density vs Moisture Content

**Table 21. Laboratory test results of MDD and OMC test for Makwanpur
base course material**

Volume of Mould 2262.24 cc

Density

water added %	2	4	6	8
Test No	1	2	3	4
Cylinder +Soil(gm)	11761	11998	12066	11928
Cylinder (gm)	6744			
Wet Soil (W) in gm	5017	5254	5322	5184
Wet Density(g/cc)	2.22	2.32	2.35	2.29

Moisture Content

Container No.	BA	CK	N1	S
Wet soil + Container (gm)	1328.79	1397.03	1337.02	1482.22
Dry soil + Container(gm)	1312.14	1352.42	1286.66	1403.03
Container(gm)	386.84	399.48	392.65	395.74
Dry Soil	925.3	952.94	894.01	1007.29
Moisture(gm)	16.65	44.61	50.36	79.19
Moisture Content %	1.8	4.7	5.6	7.9
Average Moisture Content %	4.99			
Dry Density g/cc mg/m3	2.179	2.219	2.227	2.125

Moisture content	Dry Density
1.8	2.179
4.7	2.219
5.6	2.227
7.9	2.125

OMC = 5.40% MDD = 2.231

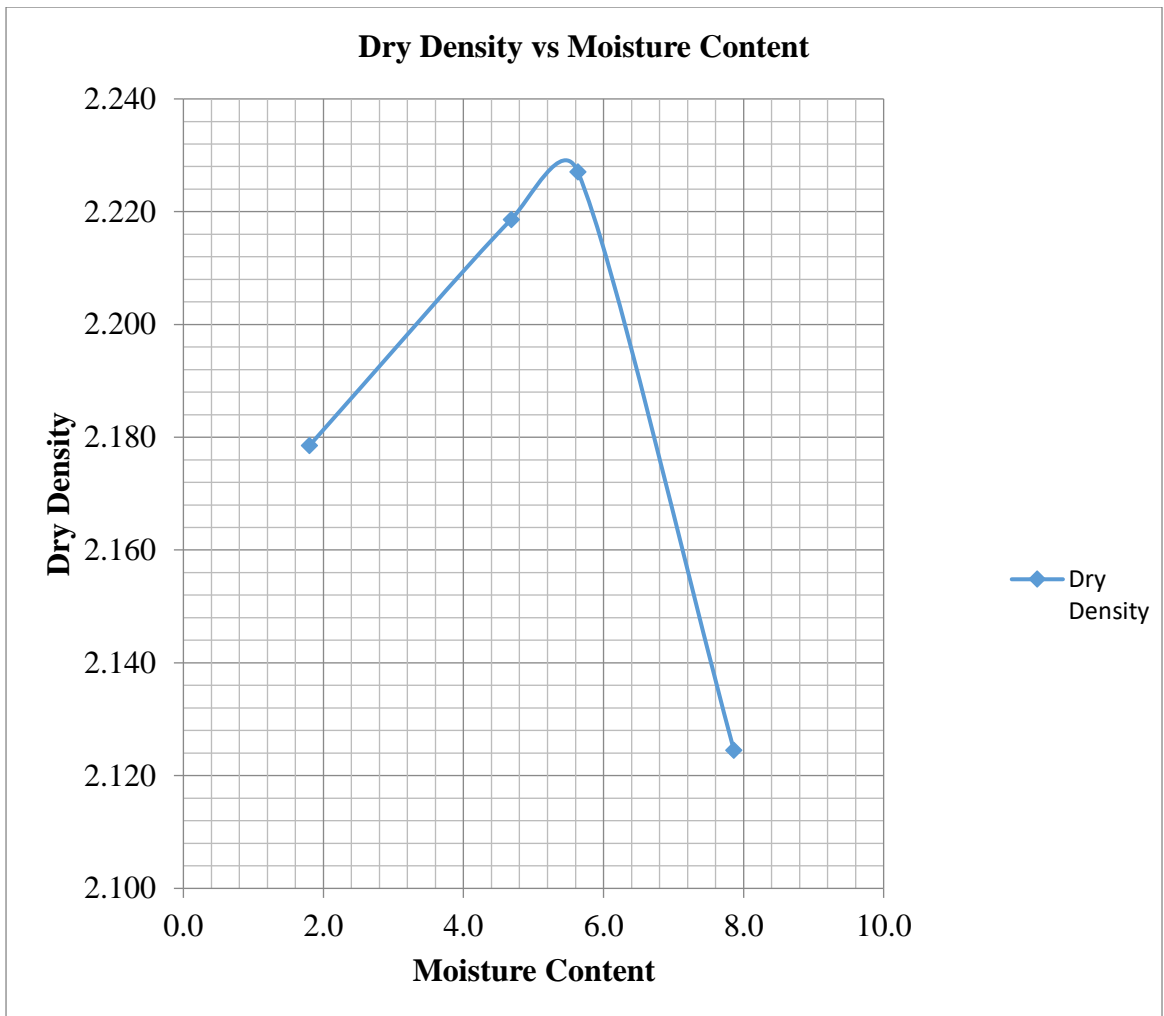


Figure 5. Dry Density vs Moisture Content

Table22. Laboratory test results of MDD and OMC test for Dhading base course material

Volume of Mould 2262.24 cc

Density

water added %	2	4	6	8
Test No	1	2	3	4
Cylinder +Soil(gm)	11778	11916	12110	11984
Cylinder (gm)	6744			
Wet Soil (W) in gm	5034	5172	5366	5240
Wet Density(g/cc)	2.23	2.29	2.37	2.32

Moisture Content

Container No.	A	AC	S1	T1
Wet soil + Container (gm)	1318.69	1386.93	1326.92	1472.12
Dry soil + Container(gm)	1302.04	1350.32	1275.56	1392.93
Container(gm)	387.2	383	383.9	387.6
Dry Soil	914.84	967.32	891.66	1005.33
Moisture(gm)	16.65	36.61	51.36	79.19
Moisture Content %	1.8	3.8	5.8	7.9
Average Moisture Content %	4.81			
Dry Density g/cc mg/m3	2.185	2.203	2.243	2.147

Moisture content	Dry Density
1.8	2.185
3.8	2.203
5.8	2.243
7.9	2.147

OMC= 5.30% MDD 2.245

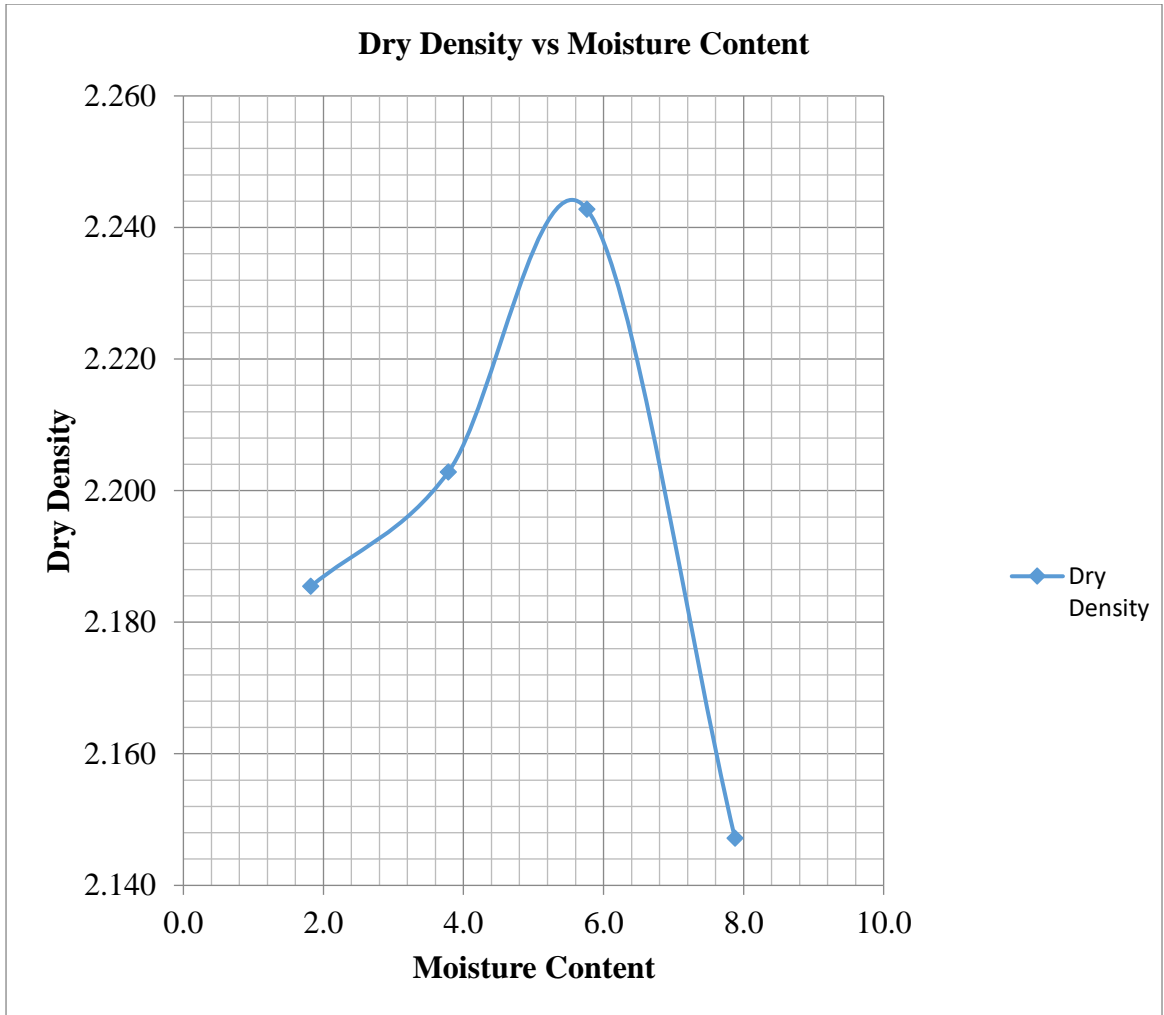


Figure 6. Dry Density vs Moisture Content

8. CBR Test Report

Table 23. Laboratory test results of CBR test for Lalitpur base course material

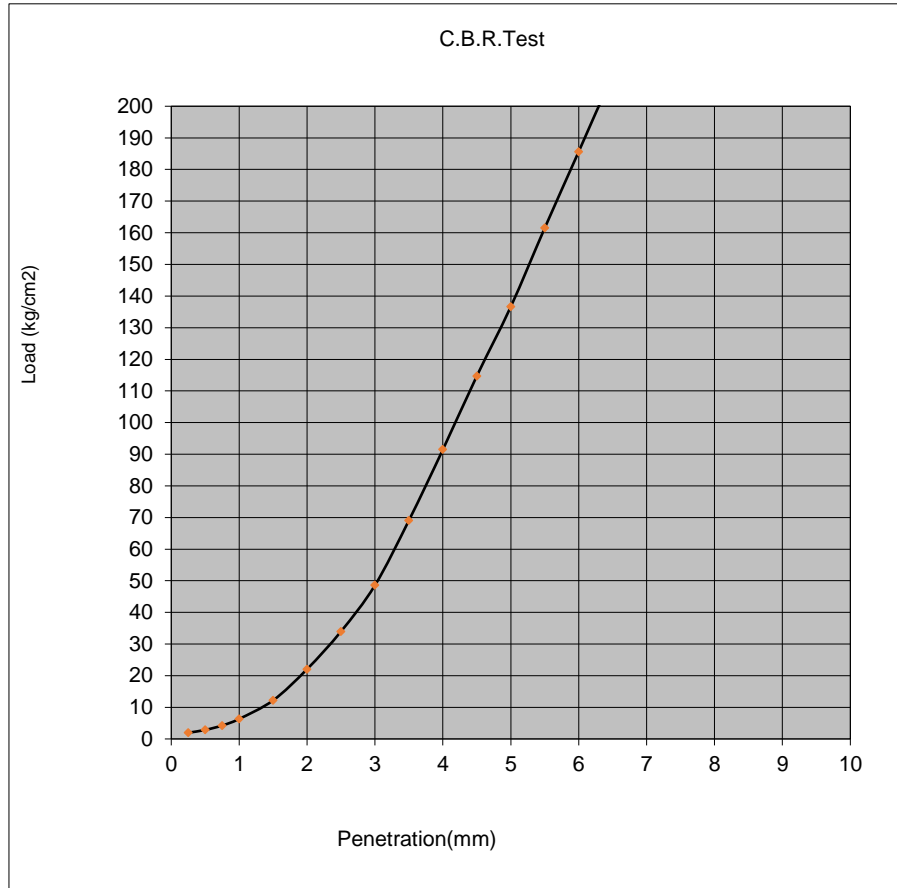
Mould No.	X	Y	Z
No of Blows	56	30	10
Volume of mould(cc)	2209.92	2209.92	2209.92
Wt. of Soil + Mould Before Soaking (gm)	12082.00	11530.00	11722.00
Tare Wt. of Mould (gm)	6548.00	6408.00	6706.00
Wt. of Soil Before Soaking (gm)	5534.00	5122.00	5016.00
Wet Density (gm/cc)	2.504	2.317	2.270
Can No.	S1	S	KG
Wt.of Moist Soil + can(gm)	1172.56	1274.09	1287.94
Wt. of Dry Soil + Can (gm)	1128.26	1223.79	1235.62
Wt. of Water (gm)	44.30	50.30	52.32
Tare Wt. of Can (gm)	386.12	396.47	386.49
Wt.of Dry Soil (gm)	742.14	827.32	849.13
Moisture content (%)	5.97	6.08	6.16
Dry Density (gm/cc)	2.363	2.184	2.138
M.D.D.(gm/cc)	2.220	2.220	2.220
Compaction (%)	106.44	98.38	96.30

Calculations:

Penetration Test (56 blows)

Penetration (mm)	Load (KN)	Load(Kg)	Area of plunger	Load kg/cm ²
0.25	0.38	38.73	19.635	1.972
0.50	0.55	56.06	19.635	2.855
0.75	0.82	83.58	19.635	4.256
1.00	1.22	124.4	19.635	6.333
1.50	2.35	239.6	19.635	12.200
2.00	4.25	433.2	19.635	22.064
2.50	6.55	667.7	19.635	34.004
3.00	9.36	954.1	19.635	48.592
3.50	13.31	1357	19.635	69.099
4.00	17.62	1796	19.635	91.475
4.50	22.1	2253	19.635	114.733
5.00	26.32	2683	19.635	136.642
5.50	31.11	3171	19.635	161.510

Penetration (mm)	Load (KN)	Load(Kg)	Area of plunger	Load kg/cm ²
6.00	35.76	3645	19.635	185.650
6.50	40.41	4119	19.635	209.791
7.00	44.8	4567	19.635	232.582



Corrected CBR at 2.5 mm penetration = $112/70 \times 100 = 160\%$

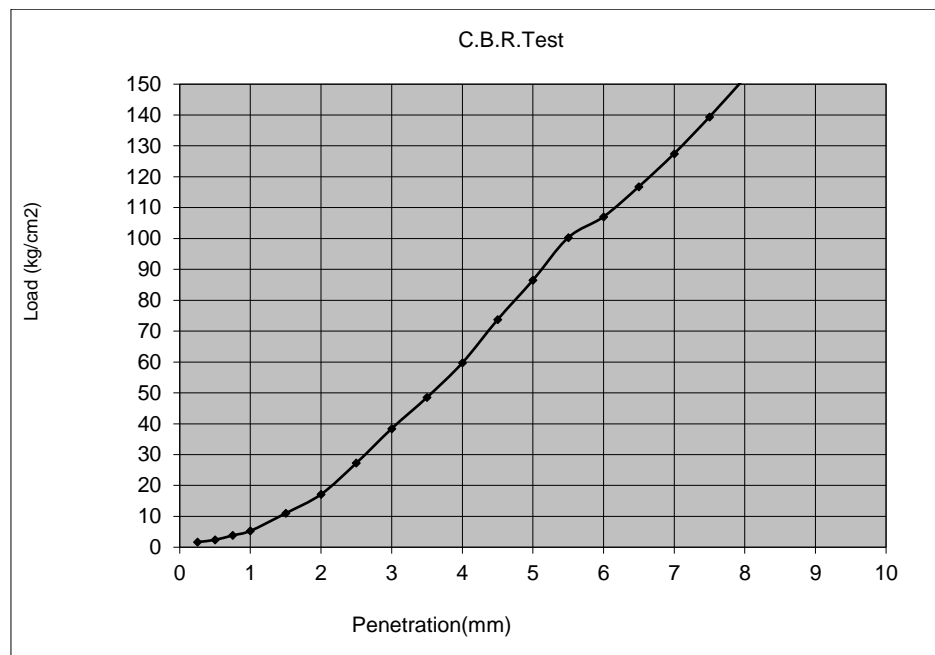
Corrected CBR at 5 mm penetration = $200/105 \times 100 = 190.5\%$

Compaction = 106.44%

Penetration Test (30 blows)

Penetration (mm)	Load (KN)	Load(Kg)	Area of plunger	Load kg/cm ²
0.25	0.32	32.61	19.635	1.660
0.50	0.46	46.89	19.635	2.388
0.75	0.74	75.43	19.635	3.841
1.00	1.02	104	19.635	5.295
1.50	2.12	216.1	19.635	11.005

Penetration (mm)	Load (KN)	Load(Kg)	Area of plunger	Load kg/cm ²
2.00	3.3	336.4	19.635	17.132
2.50	5.25	535.2	19.635	27.255
3.00	7.4	754.3	19.635	38.417
3.50	9.35	953.1	19.635	48.540
4.00	11.5	1172	19.635	59.703
4.50	14.2	1448	19.635	73.720
5.00	16.67	1699	19.635	86.508
5.50	19.32	1969	19.635	100.300
6.00	20.62	2102	19.635	107.050
6.50	22.5	2294	19.635	116.810
7.00	24.56	2504	19.635	127.504
7.50	26.85	2737	19.635	139.393
8.00	29.29	2986	19.635	152.1



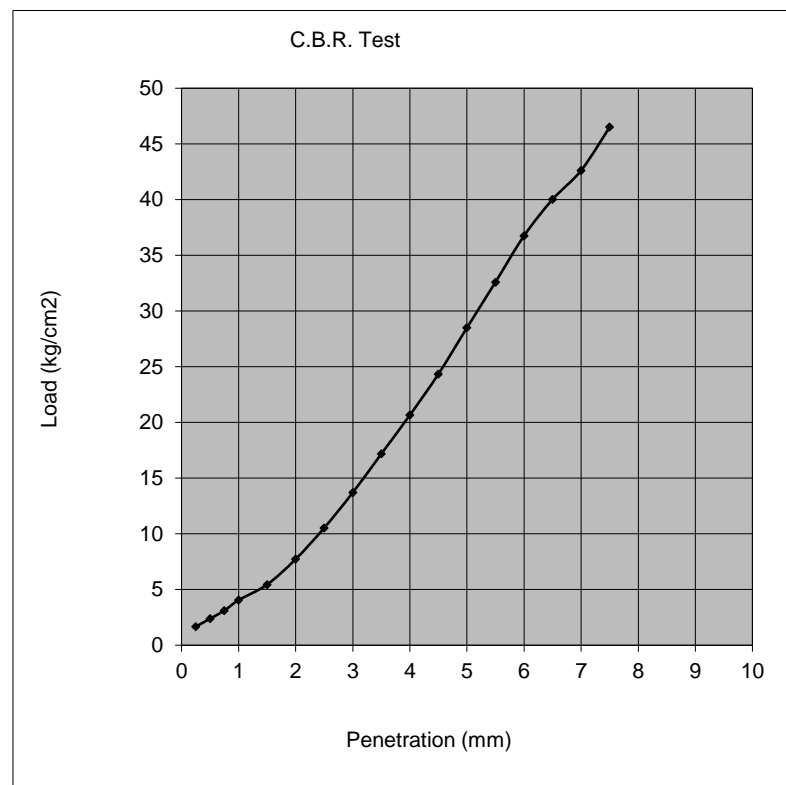
Corrected CBR at 2.5 mm penetration = $60/70 * 100 = 85.7\%$

Corrected CBR at 5 mm penetration = $118/105 * 100 = 112.4\%$

Compaction = 98.59%

Penetration Test (10 blows)

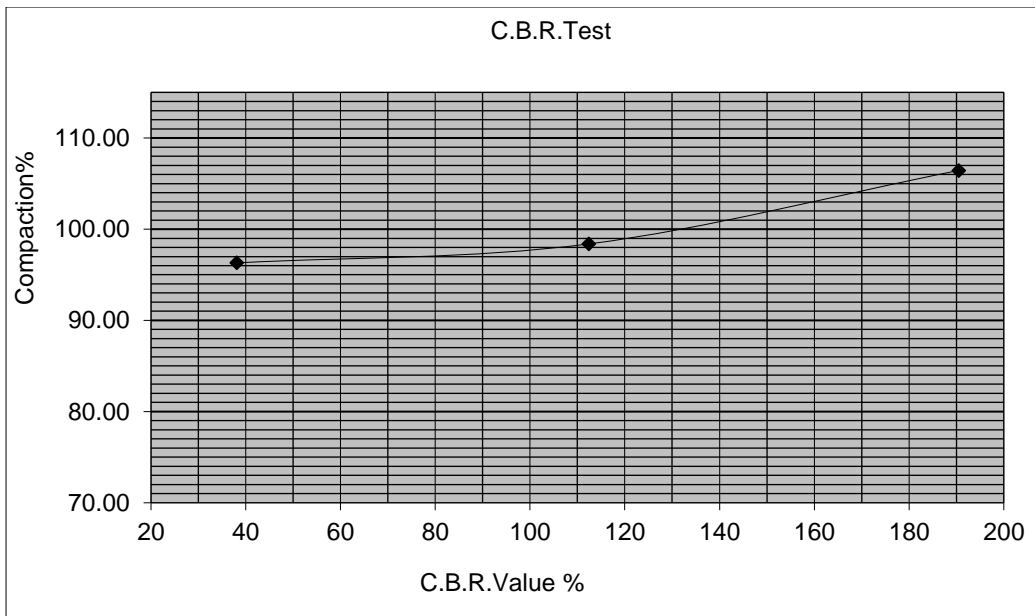
Penetration (mm)	Load (KN)	Load(Kg)	Area of plunger	Load kg/cm ²
0.25	0.32	32.6	19.635	1.660
0.50	0.46	46.9	19.635	2.388
0.75	0.6	61.2	19.635	3.114
1.00	0.78	79.5	19.635	4.049
1.50	1.05	107	19.635	5.450
2.00	1.49	152	19.635	7.735
2.50	2.03	207	19.635	10.538
3.00	2.64	269	19.635	13.705
3.50	3.31	337	19.635	17.184
4.00	3.98	406	19.635	20.662
4.50	4.69	478	19.635	24.348
5.00	5.49	560	19.635	28.501
5.50	6.28	640	19.635	32.603
6.00	7.08	722	19.635	36.756
6.50	7.71	786	19.635	40.026



Corrected CBR at 2.5 mm penetration = $20/70 * 100 = 28.60\%$

Corrected CBR at 5 mm penetration = $40/105 * 100 = 38.10\%$

Compaction = 96.30%



Now from above CBR vs Compaction % curve, CBR value observed 110% at 98% compaction.

APPENDIX B: Some Photograph



Figure 1. Sample Collecting from Dhading



Figure 2. Sample Collecting from Lalitpur



Figure 3. Sample Collecting from Makwanpur



Figure 4. Sieve Analysis Test in DOR Laboratory



Figure 5. Modified Proctor Compaction test in DOR Laboratory



Figure 6. CBR sample prepared in DOR Laboratory