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The relationship between Los Angeles Abrasion Value and Thickness of Base Course of different aggregate samples of Nepal

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Abstract

The engineering properties of different rock types and different quarries are different and therefore the suitability of rock aggregates should be investigated and recorded prior to use for the road construction works. Los Angeles Abrasion (LAA) value and California Bearing Ratio (CBR) value are the two most useful engineering properties which determine the suitability of rock aggregates to be used in road construction works which in turn determines the Thickness of Pavement. But there is no accepted relationship between LAA value and Thickness of Pavement. The base for this thesis work comes from the fact that the specification regarding Los Angeles Abrasion (LAA) value as specified in the "STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS" of the Department of Road (DoR), Nepal does not go hand in hand with the Los Angeles Abrasion (LAA) value of aggregates obtained from different quarries all over Nepal. Thus there is a need to relate Los Angeles Abrasion (LAA) value with Thickness of the Pavement.

The main purpose of this thesis is to determine if any relation exists between Los Angeles Abrasion (LAA) value and Thickness of Base Course as obtained from the CBR method of Flexible Pavement Design. In this thesis work, rock samples from different parts of Nepal will be analyzed to examine how Los Angeles Abrasion Value (LAA) relates with Thickness of Base Course. By comparing the technical properties of aggregates i.e. Los Angeles Abrasion (LAA) value with California Bearing Ratio (CBR) value and by quantitative analysis to find the Thickness of Pavement by CBR Method of Flexible Pavement Design, it is possible to determine the correlation between Los Angeles Abrasion (LAA) value and Thickness of Base Course.

Twenty (20) Base and Subbase Course samples were collected from quarries in different localities in Nepal, and tested for their Los Angeles Abrasion Values and California Bearing Ratio. The California Bearing Ratio was used to calculate the Thickness of Pavement based on the CBR Method of Flexible Pavement Design. The results were interpreted in the form of an equation obtained from Regression Analysis as: Thickness of Base Course(cm) = 2.25 + 0.27 x LAA(%). The correlation between LAA value and Thickness of Base Course could actually justify the use of aggregates with LAA value greater than that specified in the specification of the Department of Road, Nepal for pavement construction.

Keywords

California Bearing Ratio, Los Angeles Abrasion Value, Thickness of Base Course

1. Introduction

One of the key factors responsible for the thickness of pavement is the California Bearing Ratio (CBR) value of sub grade. California Bearing Ratio (CBR) value of sub grade is used for design of flexible pavements.

In 1928 California Division of Highway in the U.S.A. developed CBR method for pavement design. The majority of design curves developed later are based on the original curves propped by O.J.Porter. California bearing ratio (CBR) is an empirical test and widely applied in design of flexible pavement over the world. This method was developed during 1928-29 by the California Highway Department. Use of CBR test results for design of roads, introduced in USA during 2nd World War and subsequently adopted as a standard method of design in other parts of the world, is recently being discouraged in some advanced countries because of the imperialness of the method [1]. The California bearing ratio (CBR) test is frequently used in the assessment of granular materials in base, sub base and sub grade layers of road and airfield pavements. The CBR test was originally developed by the California State Highway Department and was thereafter incorporated by the Army Corps of Engineers for the design of flexible pavements. It has become so globally popular that it is incorporated in many international standards ASTM 2000 and IRC: 37. The significance of the CBR test emerged from the following two facts, for almost all pavement design charts, unbound materials are basically characterized in terms of their CBR values when they are compacted in pavement layers and the CBR value has been correlated with the thickness of pavement. Because these correlations are currently readily available to the practicing engineers who have gained wide experience with them, the CBR test remains a popular one.

Most of the Nepalese highway system consists of flexible pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of flexible pavement design. It is a load test applied to the surface and used in soil investigations as an aid to the design of pavements. The design for new construction should be based on the strength of the samples prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. In case of existing road requiring strengthening, the soil should be moulded at the field moisture content and soaked for four days before testing. It has been reported that, soaking for four days may be very severe and may be discarded in some cases [2]. This test method is used to evaluate the potential strength of sub grade, sub base, and base course material for use in road and airfield pavements. It was reported that design curves (based on the curve evolved by Road Research Laboratory, U.K) are adopted by Indian Road Congress (IRC: 37-1970 and IRC: 37-1984)[2]. CBR test should be performed on remoulded soil in the laboratory[2]. In-situ tests are not recommended for design purpose [2]. The design of the pavement layers to be laid over sub grade soil starts off with the estimation of sub grade strength and the volume of traffic to be carried. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the sub grade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR). For the design of pavement CBR value is invariably considered as one of the important parameter. With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts[2]. CBR value can be measured directly in the laboratory test in accordance with IS: 2720 (Part-XVI) on sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. In addition, the test requires large quantity of the sample and the test requires skill and experience without which the results may be inaccurate and misleading.

2. Literature Review

The ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5mm and 5 mm. Where the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used[3].

The difference between the original weight and the final weight coarser than 1.70 mm IS Sieve washed and dried in an oven at 105 to 110 degree celcius to a substantially constant weight after rotating the sample in the Los Angeles Abrasion Testing Machine. This value shall be reported as percentage of wear[4].

In one study, the Aggregate Impact Value (AIV) and Los Angeles Abrasion Value (LAAV) of the intact rocks of all locations of Sri Lanka were plotted on a normal scale without considering the type of rock material. It indicates that the LAAV occur between 1.64 and 1.38 times of AIV. However the average LAAV for common rock types in Sri Lanka is approximately 1.45 times of AIV. For the LAAV experiment a large quantity of materials and more time are needed than the AIV experiment. Therefore after obtaining the AIV of a rock aggregate sample within a shorter time the approximate LAAV also can be calculated. This may be very helpful to the professionals in the field of civil engineering [5].

3. The Objective of the Study

The primary objective of this thesis is to check if any relationship exists between LAA Value and Thickness of Base Course.

The specific objective is to establish a correlation between LAA Value and Thickness of Base Course.

4. Methodology

4.1 Sample Collection

The different types of material used in this study are aggregates used for base and sub base course from different quarries all over Nepal.

The source of aggregate used for the tests conducted during this research are from various locations across Nepal which include Malekhu, Khadichaur, Khotang, Gaighat, Melamchi, Chapagaun, Lele, Dolalghat, Lamatar, Dhading, Ilam, Panchthar, Parsa, Nijgad, Dang, Hetauda, Bakaiya, Dumre, Charchare, Rapti, Dhangadi, Chamuliya, Baitadi, Kanchanpur and Dadeldhura.

4.2 CBR Test and LAA Test

The CBR and LAA Tests were performed on the samples collected from various locations across Nepal to assess the requirement of CBR Method of Flexible Pavement Design and to check if any correlation exist between Thickness of Base Course and LAA Value. These tests were performed at the Central Material Testing Laboratory(CMTL), Pulchowk Campus, Lalitpur, Nepal.

4.3 Calculation of Thickness from CBR Method

The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. California bearing ratio is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm / min. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement[3].

In this method, the chart contains several curves (A, B, C, D, E, F, and G) which represent the different levels of traffic intensities. Based on this we will find out the layers thicknesses[2].

Data required for design:

- CBR value of Soil Sub Grade
- CBR value of Subbase Course
- CBR value of Base Course
- Traffic Intensity

In this step, firstly for the given value of traffic intensity select appropriate curve from classification table which is shown in the below chart. Now, from the given CBR value of sub grade soil read the total thickness (T) with respect to selected curve.

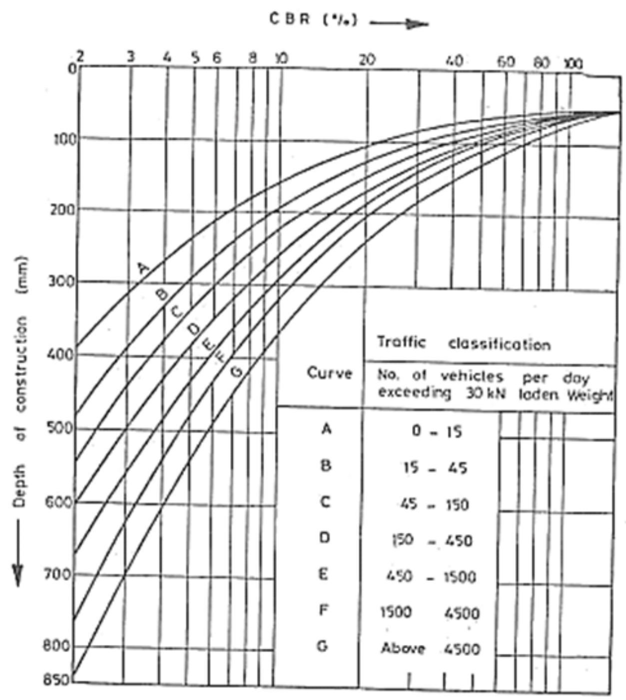

Figure 1: CBR Design Chart

4.4 Analysis and Result

The results obtained from CBR and LAA tests and the thickness calculated from CBR Method were taken as input for Regression Analysis and the results were interpreted in the form of an equation.

4.5 Validation

The results obtained were validated from the samples collected from Far-Western Region i.e. Dhangadi, Chamuliya, Baitadi, Mahendranagar and Dadeldhura.

5. Analysis and Result

The CBR and LAA tests were performed and the thickness was calculated as per the CBR Method of Flexible Pavement Design with surface course as Surface Dressing. As per IRC:37-2012, where the surface course adopted is upto 25mm, the thickness of surfacing should not be counted towards the total thickness of the pavement as surfacing will be purely for wearing and will not add to the structural capacity of the pavement. The result obtained were as follows:

Table 1: Calculation of Thickness of Base Course for Traffic Classification-E

Location	CBR of Subase(%)	CBR of Base(%)	LAA of Base(%)	Thickness (cm)
Malekhu	64.56	78.11	30.11	10.2
Khadichaur	69.66	84.14	25.67	9.4
Khotang	65.44	80.9	30	10
Gaighat	50	75.69	34.83	11.5
Melamchi	41.63	64.96	41.88	13
Chapagaun	52.56	78	31.9	10.5
Lele	70.1	85	23.87	9.2
Dollalghat	44.21	65.43	35.47	12.5
Lamatar	34.33	61.26	36.7	14
Dhading	66.01	81.58	28.44	9.8
Ilam	36.26	62.88	42.01	13.5
Panchthar	69.89	84.96	25	9.3
Parsa	65.98	81.24	29.11	9.9
Nijgad	51.11	76.56	33.32	11
Dang	48.13	70.88	34.96	12
Hetauda	42.81	65.11	36.88	12.8
Bakaiya	67.94	83.19	27.22	9.7
Dumre	58	78.06	31.09	10.3
Butwal	65.12	79.89	30.11	10.1
Charchare	68.13	83.98	26.31	9.6

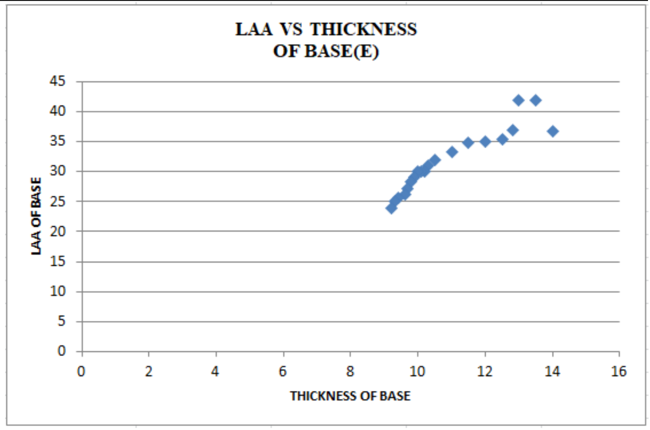

Figure 2: LAA VS Thickness of Base Course (Traffic Classification-E)

The results were interpreted in the form of an equation obtained from Regression Analysis as: Thickness of Base Course(cm) = 2.25 + 0.27 x LAA(%).

5.1 Comparison of DoR Guidelines and CBR Method

The DoR Flexible Pavement Design is based on IRC:37-2001. The IRC:37-2001 is an amendement of the CBR Method of Flexible Pavement Design. The amendement resulted in the difference in total thickness as calculated form CBR Method of Flexible Pavement Design(Traffic Intensity is as per the Traffic Class) and IRC:37-2012 (Traffic Intensity is caluculated in msa).

As per IRC:37-2001, the cumulative number of standard axles is calculated based on the following equation:

$$N = 365 * [(1+r)n-1] * A * D * F/r$$

N=Cumulative number of standard axles to be catered for in the design in terms of msa.

A=Initial traffic in the year of construction in terms of number of Commercial Vehicles Per Day(CPVD)

D=Lane Distribution Factor=0.75 for Two Lane Single Carriageway.

F=Vehicle Damage Factor(VDF) (As per Table 4.2 of IRC:37-2001)

n=Design life in years=15 years (As per Table 4.2 of IRC:37-2001for NH ans SH) r=Annual growth rate of commercial vehicles in decimal=7% (As per DoR)

For, A= 450 CPVD and F = 0.5 for hilly terrain

N=2.66 msa, say 3 msa

For, A= 1500 CPVD and F = 0.5 for hilly terrain

N=8.87 msa, say 9 msa

Table 2: Comparison of Thickness for Traffic Class E(450 CPVD) and Traffic Intensity(4 msa)

CBR of Subgrade(%)	Thickness(cm) (DoR Guidelines)	Thickness(cm) (CBR Method)
5	53	51
6	49	45
7	46	44
8	45	43
9	45	41
10	45	36

Table 3: Comparison of Thickness for Traffic Class F(1500 CPVD) and Traffic Intensity(9 msa)

CBR of Subgrade(%)	Thickness(cm) (DoR Guidelines)	Thickness(cm) (CBR Method)
5	66	56
6	61.5	51
7	58	48
8	55	46
9	54	45
10	54	44

The maximum difference in thickness between the DoR Guidelines and IRC:37-2012 is 10.5cm in total pavement thickness.

6. Validation

The results obtained were validated from the samples collected from Far-Western Region i.e. Dhangadi, Chamuliya, Baitadi, Mahendranagar and Dadeldhura as follows:

Table 4: Calculation of Thickness of Base Course for Traffic Classification-E

Location	CBR of Subbase(%)	CBR of Base(%)	LAA of Base(%)	Thickness (cm)
Dhangadi	68.98	86.16	27.59	9.5
Chamuliya	57.85	79.18	32.59	10.4
Baitadi	43.11	68.59	36.18	12.6
Kanchanpur	52.44	75.11	34.67	10.8
Dadeldhura	48.16	73.12	37.18	11.9

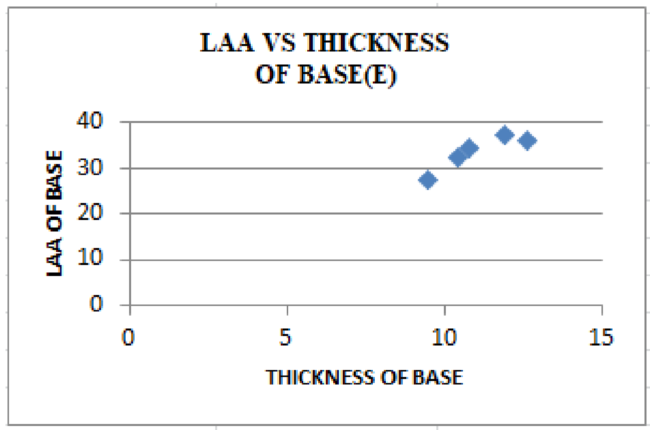

Figure 3: LAA VS Thickness of Base Course (Traffic Classification-E)

7. Limitation

- The correlation between LAA value and Thickness of Base Course is based on assuming the CBR Value of Sub Grade and Traffic Intensity.

  The CBR value of sub grade depends on the following factors:

  - Maximum dry density (MDD)
  - Optimum moisture content(OMC)
  - Liquid limit (LL)
  - Plastic limit (PL)
  - Plasticity index (PI)
  - Type of soil
  - Permeability of soil

  The traffic in MSA depends on the following factors:

  - No. of commercial vehicles as per last count (in both directions)
  - Annual rate of traffic increase
  - Expected period of completion of the road after last count
  - Design life of the pavement

- The Gradation Test on the aggregates was not performed.
- Surface Dressing of 25mm was considered as the Surface Course for the calculation of Thickness of Pavement.

8. Findings and Conclusions

- Thickness of Base Course(cm) = 2.25 + 0.27 x LAA(%)
- Though the CBR method is not in practise and also there is a small difference of maximum 10.5cm in the total thickness as calculated from DoR Guidelines and CBR Method, but this is the only method which incorporates the CBR of Base and Subbase Course which is a primary input data for CBR Method of Flexible Pavement Design and only this method is able to link the LAA value with the Thickness of Base Course. So, the result of this method could be practically assessed in the construction of roads to observe it's suitability.
- CBR method is found out to be a reliable method to establish the correlation between LAA value and Thickness of Base Course.

9. Recommendation

The relationship obtained between LAA and Thickness of Base Course could be used in the construction of new roads and the deterioration could be assessed to observe the suitability of the relationship.

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References

[1] S. F. BROWN. Soil mechanics in pavement engineering. 1996.

[2] S.P. Bindra. *A Course of Highway Engineering*. Dhanpat Rai Publications, 4th edition, 2003.

[3] BDC 23 Soil Engineering Sectional Committee. *IS: 2720 (Part 16)-1987*. Bureau of Indian Standards, 2nd edition, 2002.

[4] Cement and BDC 2 Concrete Sectional Committee. *IS: 2386 (Part IV)-1983*. Bureau of Indian Standards, 10th edition, 1997.

[5] U.de S. Jayawardena. A study on the relationship between aggregate impact values (aiv) and los angeles abrasion values (laav) of charnockites/charnockitic gneisses in sri lanka. 39(3), 2008.