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An Analysis of Relationship between Los Angeles Abrasion Value and Aggregate Crushing Value

[1*]Ram Kumar Malepati, [2]Gopal Gautam
[1]*Advanced College of Engineering and Management, Kathmandu, Nepal*
[2]*Nepal Engineering College, Bhaktapur, Nepal*
Email: [1]ram.malepati@acem.edu.np, [2]gopalg@nec.edu.np
Corresponding email: [1]malepati97@gmail.com*

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Abstract

The physical properties of materials used in the base course of pavement play a critical role in determining the quality of road construction. Aggregates from different river sources exhibit varying physical, chemical, and geotechnical properties. The objective of the study is An Analysis of Relationship between Los Angeles Abrasion Value and Aggregate Crushing Value. Focusing on strength and durability based on laboratory test results to evaluate their suitability according to the "Standard Specification for Road and Bridge Works 2016 (2nd Amendments 2022)". Base course aggregate samples from within Major River sources in Madesh Province of Nepal was collected for this research. According to the IS code and the manual of standard tests by the department of roads, laboratory tests was conducted on 66 samples of 22 location of 22 river to determine Los Angeles abrasion value and aggregate crushing value. Out of these, 21 samples met the specified requirements. Fifteen suitable samples was selected for regression analysis to evaluate the relationship and establish the relationship between the Los Angeles abrasion value and aggregate crushing value. The remaining six suitable samples was used for model validation. The results show strong relationship between Los Angeles abrasion value and Aggregate Crushing Value as: LAAV= 1.2811× ACV + 8.0895 The R - square values was found to be 0.841 respectively. From model validation, the R - square values was found 0.7646 the predicted value of Los Angeles abrasion value against actual values of Los Angeles abrasion value, respectively. Therefore, the Aggregate Crushing Value test is used as a substitute test for the Los Angeles abrasion value tests.

Keywords—*Aggregate Crushing Value, Base course, Los Angeles Abrasion Value Test*

1. INTRODUCTION

Nepal, as a landlocked developing country, emphasizes the development of well-connected, environmentally friendly, and sustainable transport services, particularly through its road network, to promote socioeconomic progress. An efficient road network reduces transportation costs, enhances access to essential resources like healthcare and education, and industries like tourism, agriculture and commerce, ultimately contributing to poverty reduction. The road network in Nepal consists of strategic roads (highways and feeder roads) and local roads (district and urban roads), totaling 80,078 km as of 2014/15 (DoR) However, the network's density is relatively low, with significant disparities in access, in Madhesh Province where connectivity remains a challenge. Road pavement, crucial for supporting both foot and vehicle traffic, involves several layers like subgrade, sub-base, base, and wearing course. Different types of road pavements, including composite, rigid, and flexible, are utilized based on durability and cost-effectiveness. The base course, which provides load-bearing capacity, is importance for both flexible and rigid pavements, often constructed using granular materials. Aggregates play a vital role in road pavement construction, with factors like strength and hardness determining their suitability. The Department of Roads (DoR) has established standard specifications for road and bridge work, guiding construction practices. Key engineering characteristics of road construction materials, Los Angeles Abrasion value (LAAV), and aggregate crushing value (ACV) test to Ensuring compliance with these specifications during material sourcing and testing is crucial for construction quality. Research on distinct material attributes informs project planning and specification adherence, necessitating advanced testing procedures and equipment.

A. STATEMENT OF PROBLEM

The high volume of road construction activities in Madesh Province [7], a significant quantity of aggregates with standard qualities is required. Aggregates frequently fall short of the required standards which has an impact on the quality of road construction. In road construction, identifying the right sources of aggregates and determining whether meet standard specifications is a common difficulty. The physical requirements of the base course materials in the pavement layer have a significant impact on the overall strength capabilities of the pavement. The specifications found in the SSRBW, 2016 do not align with the data gathered from several quarries around Nepal [21]. Determining the value of the physical characteristics of the aggregates for the base course and conducting a suitability, research for them would therefore be very beneficial to the road construction project. The LAAV test method has a number of problems when it comes to the laboratory test, such as the length of time needed to complete the test, the operational noise and dust and the space needed for the machine, if the whole procedure for a single sample is considered from start to finish, including the preparation of the materials, grading, testing and mass determination, in total, it can take up to 37 hours to obtain the Los Angeles abrasion value [2]. Aggregate Crushing Value test take less time and are less laborious. No special preparations are necessary, and the entire test can be performed in one hour. A compression testing machine is the only major piece of necessary equipment, and consequently little or no laboratory space is permanently taken up [16].

Additionally, if the results of the Aggregate Crushing Value test can be used to accurately estimate the performance of the aggregates of the Los Angeles abrasion value, then time and resources was saved. This can be accomplished by determining their relationship to one another and testing their relationship.

B. RESEARCH OBJECTIVES

The objective of the study is, An Analysis of Relationship between Los Angeles Abrasion Value and Aggregate Crushing Value.

2. LITERATURE REVIEW

In this study simple technique for determining the strength characteristics of aggregates. Results suggest that strength characteristics, including crushing, impact, and abrasion values, estimated from quick tests such as the Schmidt hammer and point load. Various rocks and aggregates of different origins, types, ages, and weathering degrees were tested according to British Standard and ASTM. Laboratory tests included the Schmidt hammer and point load for rock material, and crushing, impact, and Los Angeles abrasion tests for aggregates. Regression analyses established empirical relationships between rock strength (compressive strength and point load indices) and aggregate strength (crushing, impact, and abrasion values). Strong relationships were found between rock compressive strength and aggregate crushing and impact values, with moderately strong relationships for Los Angeles abrasion values [1].

In this study the LAAV test method, used to determine the abrasion characteristics of granular materials in road construction, faces drawbacks such as time consumption, noise, dust, and space requirements. Also aimed to explore the modified compaction method as a potential alternative for determining LAAV. The modified compaction method, which closely simulates the abrasion resistance of unbound granular materials in road base and sub-base layers under dynamic loads, was tested on nineteen different aggregate samples. Results indicated a strong correlation between the LAAV and the compaction abrasion values (CAVs) obtained from the modified compaction method. Correlation between the LAAV and the compaction abrasion values (CAVs) obtained from the modified compaction method. Correlations between LAV and CAV.

Testing Grade,	Relationship	R2	
B	LAAV = 1.881 (CAV) . . .(1)	0.88	3.6
H	LAAV = 2.957 (CAV) . . .(2)	0.98	1.59
J	LAAV = 2.400 (CAV) . . .(3)	0.98	1.83
K	LAAV = 1.675 (CAV) . . .(4)	0.97	2.06

This suggests that the modified compaction method could serve as a viable alternative to the traditional LA abrasion method for evaluating the abrasion resistance of materials used in road pavements [2].

In this study the use of cement treatment to enhance the strength of locally available crushed gravel. Research focused on crushed gravel from Khopasi, Panauti, and Tikabhairab found that adding 2% PPC cement increased the California Bearing Ratio (CBR) to 80%, meeting Department of Roads (DoR) specifications. The study also demonstrated that higher cement content improved unconfined compressive strength (UCS), with 6% PPC cement achieving the IRC-37-2012 standard of 4.5 MPa in 7 days and 7 MPa in 28 days. Cost comparisons showed significant savings in transportation when using treated local materials and recommended to use 2% PPC cement for road base material and 6% for cement-treated base (CTB) to meet specified standards [3].

In this study suitability of the aggregates obtained from riverbed source of Kaski district, Nepal. Different laboratory tests i.e. gradation analysis, Los Angeles Abrasion value test, aggregate Impact value test, aggregate crushing value test and water absorption and specific gravity tests on the bulk samples taken from the different riverbed quarry sources are carried out according to the relevant IS code standards and are compared with the standard specifications for road and bridge works. Whereas only source of Rato Pairo Mishi Tunda Shanik Ghat and Gahara Ghat comply the specifications defined by Standard Specification for Road and Bridge Works -2073 (with second amendment-2078), according to the tests performed the construction materials from the different sources are decided whether they can be used or not for the construction work [4].

In this study suitability of the aggregates obtained from river source of Rupandehi and Nawalparasi District, Nepal. Different laboratory tests i.e. flakiness index test, CBR test, PI test, Los Angeles Abrasion value test, aggregate impact value test and water absorption tests on the bulk samples taken from the different river sources are carried out according to the relevant IS code standards and are compared with the standard specifications for road and bridge works. Four local rivers source aggregates, Tinau River of Rupandehi and Turiya, Binayee and Khajura Riverbed materials were comply with the standard specification for Road and Bridge works, 2001and hence, suitable for use as the road construction materials [5].

In this study explore the potential of using the light compaction test as an alternative method for predicting aggregate impact and crushing values. After determining the test results, they employed regression analysis to develop predictive models for the crushing and impact values of aggregates based on light compaction test data. Fourteen sample results were used to create these models, while six additional samples were employed for validation. The findings showed a strong correlation between the crushing test and light compaction test values, with an R^2 value of 0.988, represented by the equation: "Crushing value = 0.951 * light compaction value – 0.042." Similarly, the regression analysis indicated an R^2 value of 0.908 for the relationship between light compaction and impact test values, expressed as: "Impact Value = 1.004 * light compaction value + 10.788." The study concluded that light compaction test results could effectively predict aggregate crushing and impact values [6].

In this study conducted field and laboratory investigations to explore the correlation between two rock parameters in Sri Lanka. The research revealed that the Los Angeles Abrasion (LAA) value is between 1.64 and 1.38 times the aggregate impact value (AIV) when plotted on a normal scale. A regression analysis established the relationship between LAA value and AIV as follows: LAA Value = 1.1749 * AIV + 1.5636 [8].

In this study suitability of the aggregates obtained from riverbed of Gandaki province, different laboratory tests i.e. flakiness index test, Los Angeles Abrasion value test, aggregate impact value test and water absorption tests on the bulk samples taken from the different river sources are carried out according to the relevant AASHTO/ASTM/IS code standards and are compared with the standard specifications for road and bridge works. According to the tests performed the construction materials from the different sources are decided whether they can be used or not for the construction of base coarse of the roads and relationship between AIV and LAAV was LAAV=1.247*AIV+ 6.61 [9].

In this study the comparison with strength, thickness, and life cycle cost of cement-treated base (CTB) versus granular base in pavement construction in Pathlaiya-Nijgadh Section of East-West Highway and different laboratory tests was carried out such as LAAV, AIV, ACV, PI, FI, LL and demonstrates that CTB significantly enhances pavement strength, evidenced by higher unconfined compressive strength (UCS) and flexural strength (FS), with 5% cement content proving optimal to resist cracks. For a 15-year design period on Nepal's Pathlaiya-Nijgadh Highway, CTB and granular base required thicknesses of 357.43 mm and 500 mm respectively for a design traffic of 34.86 msa, with total pavement thicknesses of 457.43 mm for CTB and 590 mm for granular base. Cost analysis showed a 5.63% reduction in per km cost for CTB compared to granular base. Maintenance using CTB was 47.31% more economical, and overall pavement construction costs were 24.39% lower with CTB. Thus, CTB is presented as a more sustainable and cost-effective option for pavement design [10].

In this study investigated the suitability of rocks from quarries in the Central Development Region by conducting various laboratory tests, including the Flakiness Index Test, Los Angeles Abrasion Value Test, Aggregate Crushing Value Test, Aggregate Impact Value Test, and Water Absorption Test on bulk samples from different quarries. These tests were carried out in accordance with the relevant codes and compared against the Standard Specifications for Road and Bridge Works. Based on the results, the construction materials from various sources were evaluated for their suitability in different pavement layers of roads [11].

In this study the base material for concrete. To assess their performance, tests evaluating resistance to degradation are vital but time-consuming. Thus, establishing empirical links between degradation and strength parameters becomes valuable. The article aimed to compile existing literature on relationships between parameters such as aggregate impact value (AIV), aggregate crushing value (ACV), ten percent fines value (TFV), Los Angeles Abrasion value (LAAV), and micro-Deval coefficient (MDE), and rock strength indicators like uniaxial compressive strength (UCS) and point load strength index (IS(50)). It sought to offer best-fit formulas for different rock types while acknowledging the challenges and limitations in these relationships [12]. In this study suitability of the aggregates obtained from riverbed of Sudurpashchim province, different laboratory tests i.e. Atterberg limits, Los Angeles abrasion value test, aggregate impact value test and water absorption tests modified compaction value test, on the bulk samples taken from the different sources are carried out according to the relevant AASHTO/ASTM/IS Code standards and are compared with the standard specifications for road and bridge works. All the aggregate source suitable for Base and Surface Courses of Flexible Pavement and One m^3 Asphalt concrete for two combine sources Khutiya (60%) – Mahakali (40%) and Godawari (65%) – Mahakali (35%) reduces the cost of construction by 2.43% and 2.63% respectively[13].

In this study conducted a comparative study assessing the physical properties of riverbed aggregates (RBA), crushed aggregates, and their combinations for road sub-base, aligning with department of roads' guidelines. Laboratory tests included various aggregate compositions ranging from 100% Crushed to 100% RBA, evaluating properties like gradation, Atterberg's Limits, compaction, water absorption, specific gravity, CBR, LAA, AIV, ACV, FI, and EI. Results showed all properties met specified limits. RBAs outperformed crushed aggregates in LAA and AIV, while crushed aggregates excelled in ACV, CBR, FI, and EI. Considering physical, strength, and cost aspects, RBAs demonstrated advantages over crushed aggregates [14].

In this study suitability of the aggregates obtained from riverbed of Bagmati province, different laboratory tests i.e. Atterberg limits, Los Angeles abrasion value test, aggregate impact value test and water absorption tests, modified compaction value (MCV) test, on the bulk samples taken from the different sources are carried out according to the relevant AASHTO/ASTM/IS code standards and are compared with the standard specifications for road and bridge works. According to the tests performed the construction materials from the different sources are decided whether they can be used or not for the construction of base coarse of the roads and relationship between AIV and LAAV with MCV. The relationship between AIV and MCV was developed by linear regression analysis indicating strong correlation is mentioned as AIV= 0.930*MCV - 0.206 with R2 value 0.921. And the relationship between LAA Value and MCV was developed by linear regression analysis indicating strong correlation is mentioned as LAAV = 12.796 +0.9678*MCV with R2 value 0.6033[15].

In this study conducted rock samples from various regions in Nepal were analyzed to investigate the relationship between the Los Angeles abrasion value (LAA) and the thickness of the base course. This study involved comparing the technical properties of aggregates, specifically the LAA values, with the California bearing ratio (CBR) values, to determine the correlation between the LAA values and the base course thickness. The research involved collecting twenty samples from base and sub-base courses from different quarries across Nepal. These samples were then tested for their LAA and CBR values. The findings were presented through a regression analysis, which resulted in the following equation: Thickness of base course = 2.25 + 0.27 x LAA [21].

3. METHODOLOGY

The process includes data collected from laboratory test, literature reviews, study area selection, extraction, analysis, and interpretation. Throughout the entire investigation, the experimental method was employed. To gather information, laboratory tests were conducted on retrieved coarse aggregate samples for base course materials and existing literature were reviewed. Statistical tools was used to analyze the data.

A. STUDY AREA

Madhesh Province of Nepal has eight districts with Koshi, Bagmati, Bishnumati, Paoda, Balan, Khutti, Chure, Kamala, Charnath, Basaniya/ Jaladha, Aauri, Rato, Janga, Baake, Phuljor, Puljhor, Lakhandei, Paurai, Chhadi, Dhansar, Bakiya, Pashah, dudhaura, Sikari, and Sukhaura River are the main rivers of the Madhesh Province. Samples of riverbed aggregates were gathered from study area throughout Madesh Province of Nepal focusing on areas with the widely used aggregate sources.

B. SAMPLE COLLECTION

Sample were collected from study areas of 22 rivers, 3 samples with in 30m radius from each of the locations and total 66 samples were collected from the study area for analysis.

C. DATA COLLECTION

Primary data were collected by surveying selected study area and then laboratory test was performed. Secondary data were collected from standard specifications and report published by DoR, Nepal (2016).

1. PRIMARY DATA COLLECTION

Physical properties of aggregate are gradation, water absorption, specific gravity, Elongation index, Flakiness index, California bearing ratio value test, Los Angeles Abrasion value test, aggregate impact value test and aggregate crushing value test were determined through laboratory test. Laboratory test were performed to determine suitability of aggregates for pavement construction on study area. The following physical properties for base course material were tested as per Specifications and related codes of conduct.

Aggregates crushing value (ACV) test - IS: 2386 (Part IV)

Los Angeles abrasion value (LAAV) test - IS: 2386 (Part-4)

D. DATA ANALYSIS

Samples was collected from study area to check suitability against the requirements of standard specifications in accordance with SSRBW 2016 (second amendment 2022).

Laboratory tests for each physical property was conducted in accordance with the manual of standard tests, DoR (2015) and IS codes. The data obtained from these tests was entered into an excel sheet for analysis as per the requirements. Required relationship was established by regression. Consequently, the values of the test results was analyzed and compared with SSRBW 2016. For data analysis, the following tasks were performed: Simple linear regression analysis for output data from laboratory analysis was done in order to establish the relationship between Los Angeles Abrasion Value (LAAV) with aggregates Crushing values (ACV).

1. **MODEL AND VALIDATION OF MODEL**

Data are validated in two ways. Out of 26 samples, 6 suitable samples were used to validate the regression model. Also, model is validated with theoretical and trend basis of previous studies [15]. Such that the results and relationship were validated to ensure the data analysis was corrected. 15 suitable samples source were used to create model and 6 suitable samples source were used for modal validation.

4. RESULTS AND DISCUSSION

A. Suitability of Aggregates for base course

1. Aggregate Crushing Value Test Results

Table 4.1: Comparison of ACV Test Result with Standard Specification

SN	District	Sources	ACV (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda Khola	Maximum 30 %	21.31	Complied
2		Balan River		20.25	Complied
3	Siraha	Khutti Khola		19.29	Complied
4		Chure Khola		20.73	Complied
5		Kamala River		21.37	Complied
6	Dhanusha	Charnath Khola		17.63	Complied
7		Jaladha Khola		19.69	Complied
8		Aauri Khola		16.39	Complied
9	Mahottari	Rato Khola		16.98	Complied
10		Janga Khola		18.16	Complied
11		Baake Khola		14.26	Complied

12	Sarlahi	Phuljor Khola		17.72	Complied
13		Puljhor Khola		17.77	Complied
14		Lakhandei Khola		16.07	Complied
15	Rautahat	Paurai Khola		23.35	Complied
16		Chhadi Khola		17.52	Complied
17		Dhansar Khola		16.79	Complied
18	Bara	Lal Bakaiya Khola		17.31	Complied
19		Pashah Khola		14.21	Complied
20		dudhaura Khola		17.90	Complied
21	Parsha	Sikari Khola		15.18	Complied
22		Sukhaura Khola		18.75	Complied

Maximum allowable value of ACV as per specification for base course is 30%. The values of ACV from 22 Location are below than 30% and meet the requirement. Further, only complied samples are used for regression analysis.

2. **Los Angeles abrasion value test results**

Table 4.2: Comparison of LAAV Test Result with Standard Specification

S N	District	Sources	LAAV (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda Khola	Maximum 40 %	40.24	Not Complied
2		Balan River		35.63	Complied
3	Siraha	Khutti Khola		28.82	Complied
4		Chure Khola		35.64	Complied
5		Kamala River		30.99	Complied
6	Dhanusha	Charnath Khola		28.83	Complied
7		Jaladha Khola		32.43	Complied
8		Aauri Khola		34.89	Complied
9	Mahottari	Rato Khola		29.53	Complied
10		Janga Khola		32.13	Complied
11		Baake Khola		27.6	Complied

12	Sarlahi	Phuljor Khola		28.97	Complied
13		Puljhor Khola		29.65	Complied
14		Lakhandei Khola		27.15	Complied
15	Rautahat	Paurai Khola		32.85	Complied
16		Chhadi Khola		29.21	Complied
17		Dhansar Khola		29.63	Complied
18	Bara	Lal Bakaiya Khola		29.51	Complied
19		Pashah Khola		27.51	Complied
20		dudhaura Khola		27.67	Complied
21	Parsha	Sikari Khola		27.15	Complied
22		Sukhaura Khola		30.05	Complied

Maximum allowable value of LAAV as per specification for base course is 40%. The values of LAAV from 21 location are below than 40% and meet the requirement. Further, only complied samples are used for regression analysis.

B. The relationship between Los Angeles Abrasion Value and Aggregate Crushing Value

1. Regression Analysis

Relationship between LAAV and ACV was established with the help of regression analysis which is presented in figure 4.1 with necessary charts and figures from 15 Sample which meet standard specifications as below table 4.3.

Table 4.3: Regression Analysis between LAAV & ACV Data Sources

SN	District	Sources	Types of tests & Result		Remarks
			ACV	LAAV	
1	Saptari	Balan River	20.25	35.63	
2	Siraha	Chure Khola	20.73	35.64	
3		Kamala River	21.37	30.99	
4	Dhanusha	Jaladha Khola	19.69	32.43	
5		Aauri Khola	16.39	34.89	

6	Mahottari	Janga Khola	18.16	32.13	
7		Baake Khola	14.26	27.60	
8	Sarlahi	Puljhor Khola	17.77	29.65	
9		Lakhandei Khola	16.07	27.15	
10	Rautahat	Chhadi Khola	17.52	29.87	
11		Dhansar Khola	16.79	29.43	
12	Bara	Pashah Khola	14.21	27.51	
13		dudhaura Khola	17.90	27.67	
14	Parsha	Sikari Khola	15.18	27.15	
15		Sukhaura Khola	18.75	30.05	

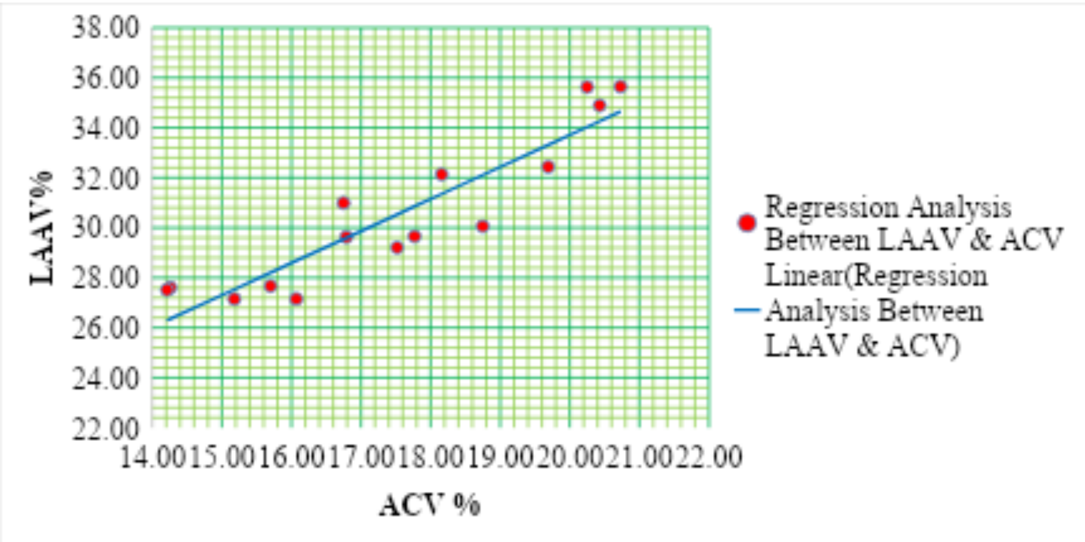

Figure 4.1: Linear Regression Analysis between LAAV and ACV

Using simple linear regression analysis between LAAV and ACV, relationship was found as: LAAV= 1.2811*ACV+ 8.0895 with R – Square value equal to 0.841. The R-square (R^2) value, also known as the coefficient of determination, measures how well a regression model fits the data, ranging from 0 to 1. A value close to 1 indicates a linear correlation, while a value close to 0 indicates a poor linear correlation. In the established model, the R^2 value is 0.841, meaning 84.1% of the variation in the dependent variable (LAAV) is explained by the independent variable (ACV). This suggests that 84.1% of the data fits the regression model.

2. **Validation of Regression Analysis between LAAV and ACV**

   Validation of the model equation LAAV= 1.2811*ACV+ 8.0895 and R2 value is 0.841 is:

Table 4.4: Data Sources used for Validation of Regression Analysis between LAAV and ACV

SN	District	Sources	Types of tests & Result		Remarks
			ACV	LAAV	
1	Siraha	Khutti Khola	19.29	28.82	
2	Dhanusha	Charnath Khola	17.63	28.83	
3	Mahottari	Rato Khola	16.98	29.53	
4	Sarlahi	Phuljor Khola	17.72	28.97	
5	Rautahat	Paurai Khola	23.35	32.85	
6	Bara	Lal Bakaiya Khola	17.31	30.05	

Table 4.5: Validation of Regression Analysis Equation between LAAV and ACV

SN	District	Sources	ACV %	Actual LAAV %	Predicted LAAV %	% Difference	Remarks
1	Siraha	Khutti Khola	19.29	28.82	32.80	3.98	
2	Dhanusha	Charnath Khola	17.63	28.83	30.68	1.85	
3	Mahottari	Rato Khola	16.98	29.53	29.84	0.31	
4	Sarlahi	Phuljor Khola	17.72	28.97	30.79	1.82	
5	Rautahat	Paurai Khola	23.35	32.85	38.00	5.15	
6	Bara	Lal Bakaiya Khola	17.31	29.51	30.27	0.76	

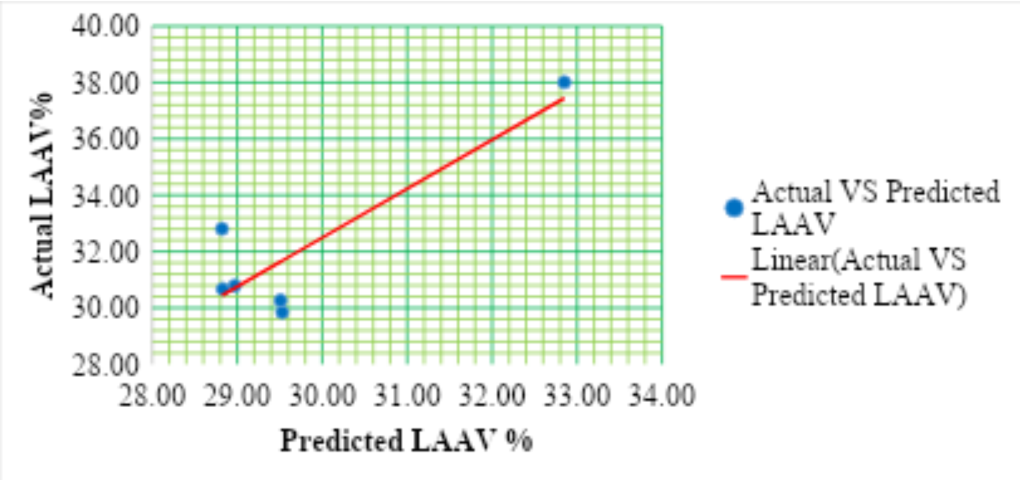

Figure 4.2: Actual vs. Predicted LAAV

C. Interpretation and Discussion

Based on the findings in tables 4.1 to 4.2, the experimental results show strong correlations, Furthermore, by analyzing the plotted graphs of predicted versus observed values during validation, it can be concluded that the models are reasonable, as the points are generally evenly distributed around the trend line. This indicates that the model is significantly validated. Additionally, when comparing the R-squared values with the studies by Kalaunee (2019) and Sharma (2022), the error results for LAAV are found to be similar to those in previous research. The low R-squared values obtained from the actual and predicted data further support the argument that the Aggregate Crushing Value (ACV) test could be a suitable substitute test for the LAAV tests of aggregates. However, the equations from previous studies cannot be used to validate ACV values due to differences in methodology and laboratory setup standards.

5. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The objective of this study was to establish the relationship of LAAV and ACV. Thus, laboratory tests on 66 samples of 22 location of 22 rivers was done to determine the, LAAV, and ACV tests. The requirements of aggregates to be used in the construction of base course as specified in SSRBW 2016 was compared with obtained values to check the suitability. The relationship between LAAV and ACV was developed by linear regression analysis as LAAV= 1.2811xACV + 8.0895 with $R^2 = 0.841$. Using these equations, relationship are validated using six suitable samples and predicted values are close to actual values of test results.

B. Recommendations

Using obtained relationship, LAAV can be predicted. Therefore, it is recommended to perform ACV to predict LAAV to get close to actual values.

It is recommended to use ACV test instead of LAAV with their relationship established to reduce time & cost for laboratory tests.

C. Recommendations for Further Studies

It is recommended to conduct further research using additional sources beyond those selected sources for this study, which were based in Madhesh Province. While unable to find correlation, analyzing more samples is necessary to ensure the accuracy of the relationship and to enhance the equation's predictive power.

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