International Journal of Multidisciplinary Innovative Research
ISSN: 2583-0228 Volume 6, Number 1 (Jan' 2026) pp. 46-60
© CIIR, Noida, INDIA (www.ciir.in)
https://www.ijmir.org
Article Received: 06 Nov' 2025
Final Revision: 05 Dec' 2025
Accepted for Publication: 20 Dec' 2025

Review Article

OPEN ACCESS

Determination of Physical Properties and Suitability of Base Course Materials of Selected Sources in Madhesh Province, Nepal

Ram Kumar Malepati[1*] and Gopal Gautam[2]

[1]Department of Civil Engineering, Advanced College of Engineering and Management, Kathmandu, Nepal.
[2]Nepal Engineering College, Bhaktapur, Nepal.

Email: ram.malepati@acem.edu.np, gopalg@nec.edu.np

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. In Madhesh Province, different aggregate sources are used for road construction, so determining the values of the physical properties of aggregates for the base course and conducting suitability research is essential for road construction projects. The primary objective of this research is to assess the physical properties of base course aggregates available in Madhesh province and to evaluate their suitability according to the "SSRBW 2016 (2nd Amendments 2022)" published by the DoR, with a focus on strength and durability. Base course aggregate samples from Madhesh Province were collected for this research. According to the IS code and the manual of standard tests published by the DoR, laboratory tests were conducted on sixty-six samples of twenty-two locations of twenty-two rivers to determine various physical properties, including gradation analysis, water absorption & specific gravity, combined EI and FI, ACV, LAAV, AIV and CBR value. Out of twenty-two river sources, twenty-one source samples met the specified requirements.

KEYWORDS: Water Absorption, Specific Gravity, Combined EI and FI Aggregate, Impact Value Test, Gradation Analysis, Aggregate Crushing Value, Base Course, California Bearing Ratio Value Test, Los Angeles Abrasion Value Test.

INTRODUCTION

The road network in Nepal consists of strategic roads (highways and feeder roads) and local roads (district and urban roads), totalling 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 [1]. 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 [2]. The base course, which provides load-bearing capacity, is important 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 (SSRBW 2016), guiding construction practices [3].

Key engineering characteristics of road construction materials include the gradation analysis, water absorption and specific gravity, elongation index (EI), flakiness index (FI), Los Angeles abrasion value (LAAV), aggregates impact value (AIV), aggregate crushing value (ACV) and California bearing ratio (CBR) value test. 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. The high volume of road construction activities in Madesh Province [4], a significant quantity of aggregates with standard qualities. In road construction, identifying suitable sources of aggregates and determining whether they 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 queries around Nepal [12]. Determining the value of the physical strength characteristics of the aggregates for the base course and conducting suitability research for them would therefore be very beneficial to the road construction project.

Objectives of the Research

The primary objective of this research is to determine the physical properties and suitability of base course materials of selected sources in Madhesh Province as required by the DoR specification.

LITERATURE REVIEW

Materials Specifications

The "Standard Specifications for Road and Bridge Works" (Department of Roads, 2016) outlines the required physical properties of aggregates used in base, sub-base, and wearing courses as shown in Table 1. The document details the qualities and standards for materials sourced from natural quarries, riverbeds, and crusher-run materials.

Table 1: Physical requirements of aggregates for base course

Sl. No.	Types of Tests							Requirements
1	Los Angeles Abrasion Value (LAAV) max %							40
2	Aggregate Impact Value (AIV) ma%							30
3	Combined FI and EI (max %)							35
4	Water Absorption (max %)							2
5	Aggregate Crushing Value (ACV) max%							30
6	California Bearing Ratio Value (CBR) min %							80
7	Specific Gravity (min 2.5)							2.5
8	Gradation Analysis (% Passing)							
Sieve Size (mm)	40	31.5	20	10	4.75	2.36	0.6	0.075
% Passing by wt.	100	85-100	62-92	40-70	26-55	21-53	12-28	2-10

Manual of Standard Tests

In 2016, the Department of Roads (DoR) released a document outlining standard test methods for evaluating aggregates and other materials used in road pavement construction in Nepal. The document lists various accessible test methods, including gradation analysis, water absorption, specific gravity, elongation index (EI), flakiness index (FI), aggregate crushing value (ACV), Los Angeles abrasion value (LAAV), aggregate impact value (AIV), and California bearing ratio (CBR).

Related Previous Studies

The simple technique for determining the strength characteristics of aggregates. Results suggest that strength characteristics, including crushing, impact, and abrasion values, are 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 [1]. The suitability of rocks from quarries in the Central Development Region was assessed 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 [6].

The suitability of the aggregates obtained from the 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 complied with the standard specification for Road and Bridge works, 2001and hence, suitable for use as the road construction materials [3].

The aggregates obtained from the 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 determined whether they can be used or not for the construction of the base course of the roads [5].

The physical properties of riverbed aggregates (RBA), crushed aggregates, and their combinations for road sub-base align with the 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 [9]. 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 determined whether they can be used or not for the construction of the base course of the roads [10].

The suitability of the aggregates obtained from the 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 the source of Rato Pairo Mishi Tunda Shanik Ghat and Gahara Ghat comply with the specifications defined by Standard Specification for Road and Bridge Works-2015 (with second amendment-2022), 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 [2].

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 sources are suitable for Base and Surface Courses of Flexible Pavement [8].

METHODOLOGY

An appropriate approach was developed to meet the goals outlined in the first chapter. The process includes data collected from laboratory tests, literature reviews, study area selection, extraction, analysis, and interpretation.

Sampling Method

To assess the quality and characteristics of riverbed aggregates, samples were gathered from different locations across Madhesh Province. The sampling focused on areas known for their frequent use of aggregate sources, where extraction and utilization are most common. These sampling areas were selected based on their relevance to pavement construction activities and their geological diversity, ensuring a representative sample of the province's aggregate resources. The sampling procedure involved collecting materials from different locations within the riverbeds, ensuring a comprehensive assessment of the aggregates. All samples were carefully documented and transported for further analysis, following standard protocols to maintain the integrity of the materials [11].

Sample Collection

To accurately assess the characteristics of riverbed aggregates, a total of 66 samples were collected from various study areas across 22 rivers within Madesh Province. At each river, three distinct samples were gathered from different points to capture the natural variability of the aggregates at each river location [11]. This approach ensured that the samples represented a wide range of geological and environmental conditions present in the region. During sample collection to identify the exact locations of aggregate sources, a survey was conducted with residents to determine the most widely used sources. In Madhesh Province, most aggregates are sourced from rivers, specifically from 50 meters upstream and downstream of highway bridges, where tenders for aggregate extraction are opened annually.

The sampling locations were chosen based on their significance as primary sources of aggregates for local use, ensuring that the collected samples would provide relevant data for both analysis and model development. The samples were collected in compliance with standard sampling protocols to preserve their natural state and characteristics. Each sample was carefully labelled, documented, and transported to the laboratory for subsequent testing and analysis, which would contribute to a comprehensive model for understanding the distribution and quality of riverbed aggregates in the study area. Table 2 shows the detailed location of the sample collection area.

Table 2: Aggregate sample collection location of Madesh province

Sl.	Sample No.	District	Local Level	Ward No.	River
1	1	Saptari	Kanchanrup Municipality	6	Paoda River
	2		Surunga Municipality	5	Balan River
2	3	Siraha	Lahan Municipality	10	Khutti River
	4		Dhangadhimai Municipality	7	Chure River
	5		Karjanha Municipality	2	Kamala River
3	6	Dhanusha	Charnath Municipality	4	Charnath River
	7		Mithila Municipality	4	Basaniya/Jaladha River
	8		Mithila Municipality	5	Aauri River
4	9	Mahottari	Bardibas Municipality	1	Rato River
	10		Gausala Municipality	1	Janga River
	11		Bardibas Municipality	11	Baake River
5	12	Sarlahi	Ishworpur Municipality	5	Phuljor River
	13		Lalbadi Municipality	6	Puljhor River
	14		Hariwan Municipality	4	Lakhandei River
6	15	Rautahat	Chandrapur Municipality	2	Paurai River
	16		Chandrapur Municipality	5	Chhadi River
	17		Gujara Municipality	3	Dhansar River
7	18	Bara	Kolhabi Municipality	2	Lal Bakaiya River
	19		Jitpur Simara Municipality	16	Pashah River
	20		Jitpur Simara Municipality	1	Dudhaura River
8	21	Parsha	Thori/Subarnapur Rural Municipality	4	Sikari River
	22			3	Sukhaura River

Data Collection

Primary data were collected by laboratory tests, and secondary data were collected from standard specifications and reports published by the DoR, Nepal (2016). All the tests are done in the laboratory of the Advanced College of Engineering and Management.

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 tests. Laboratory tests were performed to determine the suitability of aggregates for pavement construction in the study area. The following physical properties for base course material were tested as per the Specifications and related codes of conduct.

- Gradation analysis IS: 2386 (Part 1)

- Specific gravity and water absorption test - IS: 2386 (Part III)
- Elongation index and flakiness index test - IS: 2386 (Part 1)
- Aggregates crushing value (ACV) test - IS: 2386 (Part IV)
- Aggregates impact value (AIV) test - IS: 2386 (Part IV)
- Los Angeles abrasion value (LAAV) test - IS: 2386 (Part IV)
- California bearing ratio (CBR) test – IS: 2720 (Part XVI)

Secondary Data Collection: The secondary data was collected from SSRBW 2016 and the codes of Indian standards. The specification provided standard tests involved in representing the quality of materials for different layers of pavement. Physical requirements of base course materials for secondary data sources from SSRBW 2016.

Data Analysis

Samples were collected from the study area, and Laboratory tests for each physical property were conducted in accordance with the manual of standard tests, DoR (2015) and IS codes. Data analysis was done as per the objectives.

Suitability Analysis: The data obtained from the tests was entered into an Excel sheet for analysis as per the requirements of standard specifications in accordance with SSRBW 2016 (second amendment 2022). Value of physical properties compared with the requirements as mentioned in SSRBW 2016 to determine the suitability of the aggregate's sources in reference to the strength and durability properties like Gradation, Specific gravity & Water Absorption, EI & FI, AIV, LAAV, ACV and CBR were checked.

RESULTS AND DISCUSSION

Physical Properties and Suitability of Different Aggregate Samples

Suitability of Aggregates Gradation Test Results: Table 3 presents a comparison of the aggregate gradation test results for riverbed materials collected from different rivers in Madesh Province against standard specifications. The gradation test is a common procedure used to determine the distribution of particle sizes within an aggregate sample, which is important for the suitability of these materials for construction purposes [11], such as road bases. Out of the 22 rivers, samples from 21 rivers (including Balan, Khutti, Chure, Kamala, and others) have aggregate gradation test results that meet the standard specifications. Only one river, the Paoda River, has aggregates that do not comply with the standards specification. Similar types of gradation analysis tests and compared with the specification and suitable materials for different types of road construction in Sudurpashchim Province [8].

Table 3: Comparison of aggregates gradation test results with standard specification

Sieve Size (mm)	40	31.5	20	10	4.75	2.36	0.6	0.075	Remarks
Specifications/ Names of Rivers	100	85-100	62-92	40-70	26-55	21-53	12-28	2-10	
Paoda River	100	88.96	74.17	63.51	58.16	56.99	52.41	0.69	×
Balan River	100	93.29	83.48	58.67	40.88	36.39	23.24	4.43	✓
Khutti River	100	93.99	84.07	66.79	48.87	40.99	23.76	4.47	✓
Chure River	100	96.12	84.85	64.35	45.89	36.87	16.59	4.36	✓

Kamala River	100	97.11	90.03	69.09	54.60	48.55	21.68	4.09	✓
Charnath River	100	98.55	84.96	64.32	49.97	41.89	26.44	3.75	✓
Jaladha River	100	99.32	90.23	69.36	48.88	39.69	16.93	2.97	✓
Aauri River	100	98.55	89.44	67.65	51.88	44.00	22.73	3.99	✓
Rato River	100	96.92	87.48	68.27	52.47	45.16	22.69	3.56	✓
Janga River	100	94.48	78.97	64.36	49.31	43.08	26.44	4.87	✓
Baake River	100	98.93	88.65	65.77	42.35	33.76	20.21	4.37	✓
Phuljor River	100	93.84	78.87	60.17	48.12	43.95	27.11	4.57	✓
Puljhor River	100	97.20	87.87	68.67	54.43	49.40	27.08	3.33	✓
Lakhandei River	100	89.97	79.73	66.41	53.51	48.69	26.71	3.87	✓
Paurai River	100	99.28	88.24	65.93	49.81	41.39	18.43	3.73	✓
Chhadi River	100	93.85	88.03	67.96	48.55	41.69	21.92	4.05	✓
Dhansar River	100	94.45	81.11	56.83	42.91	39.51	24.92	2.39	✓
Lal Bakaiya River	100	97.92	90.84	68.43	49.85	44.45	27.19	3.89	✓
Pashah River	100	95.92	87.92	68.17	48.33	40.76	22.2	2.21	✓
dudhaura River	100	91.53	76.47	61.93	48.85	42.79	24.12	4.04	✓
Sikari River	100	94.07	85.27	66.67	51.17	44.71	20.24	2.57	✓
Sukhaura River	100	93.64	82.17	62.97	48.51	44.17	26.37	2.44	✓

✓ = Complied × = Not Complied

The aggregates from most rivers are within the acceptable range for particle size distribution, making them suitable for use in construction applications, such as road construction. The non-compliance aggregate from the Paoda River may require further processing, such as washing or blending with coarser material.

Water absorption value test results: Table 4 shows the comparison of the water absorption test results for aggregate samples collected from different river sources across several districts in Madhesh Province against the standard specification. The standard specification for water absorption of aggregates is a maximum of 2%. Aggregates with water absorption exceeding this limit may be unsuitable for construction purposes [11]. Also, similar types of water absorption tests were conducted and compared with the specification and find suitable materials for flexible pavement construction in Bagmati Province [10].

Table 4: Comparison of water absorption test results with standard specification

Sl.	District	Sources	Water Absorption (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda River	Maximum 2%	2.22	Not Complied
2		Balan River		0.99	Complied
3	Siraha	Khutti River		0.76	Complied
4		Chure River		0.59	Complied
5		Kamala River		0.79	Complied
6	Dhanusha	Charnath River		0.95	Complied

7		Jaladha River		1.03	Complied
8		Aauri River		1.03	Complied
9	Mahottari	Rato River		1.49	Complied
10		Janga River		1.11	Complied
11		Baake River		1.15	Complied
12	Sarlahi	Phuljor River		1.41	Complied
13		Puljhor River		1.57	Complied
14		Lakhandei River		1.25	Complied
15	Rautahat	Paurai River		1.69	Complied
16		Chhadi River		1.41	Complied
17		Dhansar River		0.77	Complied
18	Bara	Lal Bakaiya River		1.39	Complied
19		Pashah River		0.76	Complied
20		dudhaura River		0.71	Complied
21	Parsha	Sikari River		0.67	Complied
22		Sukhaura River		0.51	Complied

Out of the 22 river sources tested, 21 sources have aggregate samples that comply with the maximum water absorption limit of 2%. This indicates that the aggregates from these sources are suitable for use in construction, as their water absorption rates fall within the acceptable range. Paoda River has an aggregate sample that does not comply with the standard specification, with a water absorption value of 2.22%, which is slightly above the maximum permissible limit.

Specific gravity value test results: Table 5 shows the comparison of the specific gravity test results for aggregate samples from various river sources across different districts in Madhesh Province against a standard specification. Specific gravity is a critical parameter for assessing the quality of aggregates, as it relates to the density of the material and its suitability for construction purposes. The minimum acceptable specific gravity for aggregates is 2.5. Also, similar types of Specific Gravity tests were conducted and compared with the specification and the suitable materials for road base construction in Gandaki Province [5].

Table 5: Comparison of specific gravity test result with standard specification

Sl.	District	Sources	Specific Gravity		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda River	Minimum 2.5	2.47	Not Complied
2		Balan River		2.51	Complied
3	Siraha	Khutti River		2.52	Complied
4		Chure River		2.54	Complied
5		Kamala River		2.55	Complied
6	Dhanusha	Charnath River		2.53	Complied
7		Jaladha River		2.53	Complied
8		Aauri River		2.71	Complied
9	Mahottari	Rato River		2.65	Complied
10		Janga River		2.67	Complied

11		Baake River		2.65	Complied
12	Sarlahi	Phuljor River		2.72	Complied
13		Puljhor River		2.69	Complied
14		Lakhandei River		2.77	Complied
15	Rautahat	Paurai River		2.67	Complied
16		Chhadi River		2.50	Complied
17		Dhansar River		2.58	Complied
18	Bara	Lal Bakaiya River		2.51	Complied
19		Pashah River		2.57	Complied
20		dudhaura River		2.54	Complied
21	Parsha	Sikari River		2.54	Complied
22		Sukhaura River		2.55	Complied

Out of 22 river sources, 21 sources have aggregate samples that comply with the minimum specific gravity specification of 2.5, indicating they are suitable for use in construction. One source Paoda River in Saptari District, does not comply with a specific gravity of 2.47, which is slightly below the minimum requirement.

Combine EI and FI Test Results: Table 6 shows the comparison of the combined Elongation Index and Flakiness Index test results for aggregate samples collected from various river sources across different districts in Madesh Province against the standard specification. The combined EI and FI percentage is an important parameter for assessing the shape and angularity of aggregates. Also, similar types of combined EI and FI tests and compared with the specification and the suitable materials for different types of road construction in Sudurpashchim Province [8].

The maximum permissible value for the combined Elongation Index and Flakiness Index is 35%. Aggregates with combined EI and FI values above this threshold are considered unsuitable for use in construction. All 22 river sources have aggregate samples that comply with the maximum limit of 35% for the combined EI and FI. This suggests that the aggregates from all tested sources are within the acceptable range for shape and angularity. This indicates that the aggregates from these sources are well-shaped and suitable for use in construction applications [11].

Table 6: Comparison of combined EI and FI test results with standard specification

Sl.	District	Sources	Combined EI & FI (%)		
			Specifications	**Tests Results**	**Remarks**
1	Saptari	Paoda River	Maximum 35%	31.30	Complied
2		Balan River		16.20	Complied
3	Siraha	Khutti River		18.45	Complied
4		Chure River		17.60	Complied
5		Kamala River		26.51	Complied
6	Dhanusha	Charnath River		17.16	Complied
7		Jaladha River		22.96	Complied
8		Aauri River		27.14	Complied
9	Mahottari	Rato River		12.24	Complied

10		Janga River		20.35	Complied
11		Baake River		19.76	Complied
12	Sarlahi	Phuljor River		23.43	Complied
13		Puljhor River		18.48	Complied
14		Lakhandei River		19.53	Complied
15	Rautahat	Paurai River		26.73	Complied
16		Chhadi River		18.27	Complied
17		Dhansar River		14.50	Complied
18	Bara	Lal Bakaiya River		15.58	Complied
19		Pashah River		16.07	Complied
20		dudhaura River		21.42	Complied
21	Parsha	Sikari River		22.39	Complied
22		Sukhaura River		14.77	Complied

Aggregate Crushing Value Test Results: Table 7 provides a comparison of the ACV test results for aggregate samples from various river sources across different districts in Madesh Province against the standard specification. The ACV is a measure of the strength of aggregate material, indicating its resistance to crushing under a gradually applied compressive load. Also, similar types of Aggregate Crushing Value (ACV) tests for various combinations of RBA and Crushed sub-base materials and compare with the relationship between ACV and RBA content, focused on Indrawati River, Sindhupalchowk. [8] The maximum permissible ACV is 30%. Aggregates with a value above 30% may be too weak to provide adequate load-bearing capacity in base course construction applications. All 22 river sources have aggregate samples that comply with the maximum limit of 30% for the ACV, indicating that all tested aggregates have sufficient crushing resistance to be considered suitable for construction.

Table 7: Comparison of ACV test results with the standard specification

Sl.	District	Sources	ACV (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda River	Maximum 30%	21.31	Complied
2		Balan River		20.25	Complied
3	Siraha	Khutti River		19.29	Complied
4		Chure River		20.73	Complied
5		Kamala River		21.37	Complied
6	Dhanusha	Charnath River		17.63	Complied
7		Jaladha River		19.69	Complied
8		Aauri River		16.39	Complied
9	Mahottari	Rato River		16.98	Complied
10		Janga River		18.16	Complied
11		Baake River		14.26	Complied
12	Sarlahi	Phuljor River		17.72	Complied
13		Puljhor River		17.77	Complied
14		Lakhandei River		16.07	Complied
15	Rautahat	Paurai River		23.35	Complied

16		Chhadi River		17.52	Complied
17		Dhansar River		16.79	Complied
18	Bara	Lal Bakaiya River		17.31	Complied
19		Pashah River		14.21	Complied
20		dudhaura River		17.90	Complied
21	Parsha	Sikari River		15.18	Complied
22		Sukhaura River		18.75	Complied

Los Angeles Abrasion Value Test Results: Table 8 shows the comparison of the Los Angeles Abrasion Value test results for aggregate samples collected from different river sources across different districts in Madesh Province, against the standard specification. The Los Angeles Abrasion Value test measures the resistance of aggregates to abrasion and wear, which is crucial for evaluating their suitability for use in road construction. The maximum permissible Los Angeles Abrasion Value for aggregates is 40%. Aggregates with a Los Angeles Abrasion Value above this limit are considered too prone to abrasion and are unsuitable for use in applications, such as base course construction.

Out of 22 river sources, 21 have aggregate samples that comply with the maximum limit of 40% for the Los Angeles Abrasion Value, while one source (Paoda River) does not comply, with Los Angeles Abrasion Value of 40.24%, which slightly exceeds the maximum limit of 40%, This suggests that the aggregates from this river may be more prone to wear and may not be suitable for applications for base course construction and indicating that most of the aggregates sources have acceptable resistance to abrasion and are suitable for use in construction. Also, similar types of LAAV tests and compared with the specification and suitable materials for flexible pavement construction in Bagmati Province [10].

Table 8: Comparison of LAAV test results with standard specification

Sl.	District	Sources	LAAV (%)		
			Specifications	**Tests Results**	**Remarks**
1	Saptari	Paoda River	Maximum 40%	40.24	Not Complied
2		Balan River		35.63	Complied
3	Siraha	Khutti River		28.82	Complied
4		Chure River		35.64	Complied
5		Kamala River		30.99	Complied
6	Dhanusha	Charnath River		28.83	Complied
7		Jaladha River		32.43	Complied
8		Aauri River		34.89	Complied
9	Mahottari	Rato River		29.53	Complied
10		Janga River		32.13	Complied
11		Baake River		27.6	Complied
12	Sarlahi	Phuljor River		28.97	Complied
13		Puljhor River		29.65	Complied
14		Lakhandei River		27.15	Complied
15	Rautahat	Paurai River		32.85	Complied
16		Chhadi River		29.21	Complied

17		Dhansar River		29.63	Complied
18	Bara	Lal Bakaiya River		29.51	Complied
19		Pashah River		27.51	Complied
20		dudhaura River		27.67	Complied
21	Parsha	Sikari River		27.15	Complied
22		Sukhaura River		30.05	Complied

Aggregate Impact Value Test Results: Table 9 shows the comparison of the Aggregate Impact Value test results for aggregate samples collected from different river sources in Madesh Province against the standard specification. The Aggregate Impact Value test measures the resistance of aggregates to impact and is crucial for evaluating their durability and suitability for use in base course construction. The maximum permissible AIV for aggregates is 30%.

Table 9: Comparison of AIV test result with standard specification

Sl.	District	Sources	AIV (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda River	Maximum 30%	28.57	Complied
2		Balan River		26.14	Complied
3	Siraha	Khutti River		19.51	Complied
4		Chure River		19.77	Complied
5		Kamala River		19.66	Complied
6	Dhanusha	Charnath River		19.69	Complied
7		Jaladha River		19.78	Complied
8		Aauri River		25.05	Complied
9	Mahottari	Rato River		17.84	Complied
10		Janga River		19.44	Complied
11		Baake River		19.23	Complied
12	Sarlahi	Phuljor River		18.48	Complied
13		Puljhor River		16.8	Complied
14		Lakhandei River		19.48	Complied
15	Rautahat	Paurai River		18.29	Complied
16		Chhadi River		19.93	Complied
17		Dhansar River		13.45	Complied
18	Bara	Lal Bakaiya River		14.98	Complied
19		Pashah River		18.23	Complied
20		dudhaura River		18.82	Complied
21	Parsha	Sikari River		18.64	Complied
22		Sukhaura River		15.27	Complied

Aggregates with AIV values above this limit may not be suitable for use in high-impact construction applications. All 22 river sources have aggregate samples that comply with the maximum limit of 30% for the AIV, indicating that all tested aggregates have acceptable resistance to impact and are suitable for use in base course construction. Also, similar types of AIV tests and compared with specifications and suitable materials for road base construction in Gandaki Province [5].

Calculation of California Bearing Ratio Value Tests: Table 10 shows the results of the California Bearing Ratio test for aggregates collected from different river sources in Madesh Province, compared against the standard specification. The CBR test measures the strength and load-bearing capacity of aggregate materials, which is essential for determining their suitability for use in road construction and other structural applications. The minimum acceptable CBR value for aggregates is 80%. Aggregates with a CBR value below this threshold may not provide adequate load-bearing capacity and thus might not be suitable for use in road construction or similar applications.

Table 10: Comparison of CBR value test results with standard specifications

Sl.	District	Sources	CBR (%)		
			Specifications	Tests Results	Remarks
1	Saptari	Paoda River	Minimum 80%	77.43	Not Complied
2		Balan River		82.73	Complied
3	Siraha	Khutti River		82.60	Complied
4		Chure River		81.93	Complied
5		Kamala River		82.07	Complied
6	Dhanusha	Charnath River		82.46	Complied
7		Jaladha River		82.86	Complied
8		Aauri River		84.19	Complied
9	Mahottari	Rato River		82.07	Complied
10		Janga River		82.33	Complied
11		Baake River		82.07	Complied
12	Sarlahi	Phuljor River		82.86	Complied
13		Puljhor River		82.20	Complied
14		Lakhandei River		82.46	Complied
15	Rautahat	Paurai River		83.13	Complied
16		Chhadi River		82.07	Complied
17		Dhansar River		82.33	Complied
18	Bara	Lal Bakaiya River		82.60	Complied
19		Pashah River		80.74	Complied
20		Dudhaura River		82.33	Complied
21	Parsha	Sikari River		81.14	Complied
22		Sukhaura River		82.33	Complied

One river source (Paoda River in Saptari District) has a CBR value below 80% and does not comply with the specification. With lowest CBR value recorded is 77.43% which is below the minimum acceptable limit, and 21 river sources have aggregate samples that meet the minimum CBR specification of 80%, indicating that the majority of the tested aggregates have sufficient load-bearing capacity. The highest CBR value recorded is 84.19% for the Aauri River in Dhanusha District, indicating strong load-bearing capacity.

Summary of Suitability of Different Tests Results: Table 11 shows the Summary of the suitability of aggregates from different sources.

Table 11: Summary of the suitability of aggregates of different sources

Sl.	District	Sources	Types of tests and their results (%)							
			Gradation analysis	Water Absorption	Specific Gravity	Combine EI & FI	ACV	LAAV	AIV	CBR
1	Saptari	Paoda River	×	×	×	✓	✓	×	✓	×
2		Balan River	✓	✓	✓	✓	✓	✓	✓	✓
3	Siraha	Khutti River	✓	✓	✓	✓	✓	✓	✓	✓
4		Chure River	✓	✓	✓	✓	✓	✓	✓	✓
5		Kamala River	✓	✓	✓	✓	✓	✓	✓	✓
6	Dhanusha	Charnath River	✓	✓	✓	✓	✓	✓	✓	✓
7		Jaladha River	✓	✓	✓	✓	✓	✓	✓	✓
8		Aauri River	✓	✓	✓	✓	✓	✓	✓	✓
9	Mahottari	Rato River	✓	✓	✓	✓	✓	✓	✓	✓
10		Janga River	✓	✓	✓	✓	✓	✓	✓	✓
11		Baake River	✓	✓	✓	✓	✓	✓	✓	✓
12	Sarlahi	Phuljor River	✓	✓	✓	✓	✓	✓	✓	✓
13		Puljhor River	✓	✓	✓	✓	✓	✓	✓	✓
14		Lakhandei River	✓	✓	✓	✓	✓	✓	✓	✓
15	Rautahat	Paurai River	✓	✓	✓	✓	✓	✓	✓	✓
16		Chhadi River	✓	✓	✓	✓	✓	✓	✓	✓
17		Dhansar River	✓	✓	✓	✓	✓	✓	✓	✓
18	Bara	Lal Bakaiya River	✓	✓	✓	✓	✓	✓	✓	✓
19		Pashah River	✓	✓	✓	✓	✓	✓	✓	✓
20		dudhaura River	✓	✓	✓	✓	✓	✓	✓	✓
21	Parsha	Sikari River	✓	✓	✓	✓	✓	✓	✓	✓
22		Sukhaura River	✓	✓	✓	✓	✓	✓	✓	✓

✓ Meets the requirements
× Does not meet the requirements

CONCLUSION

The objective of this study was to determine the physical properties of selected base course aggregates samples to evaluate the suitability in reference to SSRBW 2016 and to establish the relationship of LAAV and CBR with Aggregate Crushing value, i.e. ACV. Thus, laboratory tests on 66 samples of 22 locations of 22 rivers were done to determine the gradation, specific gravity and water absorption, EI and FI, LAAV, AIV, ACV and CBR. The requirements of aggregates to be used in the construction of base course, as specified in SSRBW 2016, were compared with the obtained values to check the suitability. Further, it can be concluded that out of 22 samples, 21 samples except Paoda River meet the requirement as per specification for gradation, specific gravity and water absorption, EI and FI, ACV, LAAV, AIV and CBR and hence, these aggregate samples are suitable as a base course material. Out of 22 River source samples, 21 River sources, except the Paoda River sample, are recommended for use as base course construction in Madhesh Province.

REFERENCES

[1] A. A. Al Harthi 2001, a field index to determine the strength characteristics of crushed aggregates Department of Engineering and Environmental Geology, Faculty of Earth Sciences, King Abdulaziz University Saudi Arabia.

[2] Banstola *et al*. 2023, Assessment on Quality of Corse and Fine Aggregate of Riverbed Quarry as Construction Material Used in Kaski District of Nepal.

[3] Chaudary, U. 2018, M.Sc. nec. Thesis, an Assessment for Suitability of Flexible Pavement Construction Materials from Local Sources of Rupandehi and Nawalparasi Districts, Nepal.

[4] DoR, 2016, Manual of Standard Tests.

[5] Kalaunee G. P, 2019. M.Sc. nec. Thesis, Relationship between Impact Value and Los Angeles Abrasion Value of Aggregates. Nepal Engineering College-Center for Postgraduate Studies (nec-CPS), Pokhara University.

[6] Khanal, R. 2013 "Suitability test of coarse Aggregates for pavement construction from twenty-five quarries of central region of Nepal."

[7] Malepati, R. K, 2024. M.Sc. nec. Determination of Los Angeles Abrasion Value and California Bearing Ratio Value using Aggregate Crushing Value of Base Course Aggregate from Different Sources in Madhesh Province.

[8] Rawal, L. B 2022. M.Sc. nec Thesis, Evaluation of Suitability of Road Aggregates for Base and Surface Courses of Flexible Pavement from Different Sources: A Case Study of Sudurpashchim Province.

[9] Singh, R. K, 2021 M.Sc. nec Thesis, Comparative Study on the Physical Properties of Riverbed, Crushed and Mixture of Riverbed and Crushed Aggregate for Road Sub-Base.

[10] Sharma, K. A, 2022, M.Sc. nec Thesis, Impact Value using Modified Compaction Test of Different Aggregates Sources of Bagmati Province.

[11] Standard Specifications for Road and Bridge Works, 2016. Department of Roads, Nepal.

[12] Uprety, S. and Tamarakar G. B. S., 2017. The relationship between Los Angeles Abrasion Value and Thickness of Base Course of different aggregates samples of Nepal. Proceedings of IOE Graduate Conference, 2017.