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A Comparative Study on the Strength Variation of Aggregate from a Selected Section of the Babai River

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Abstract

Large quantities of construction materials are extracted from the Babai River to meet construction needs in the Bardiya District. The primary objective of this study was to examine the various properties of riverbed aggregates and to investigate the effects of coarse aggregates and their sources on the compressive strength of concrete. For this purpose, five different sites along a 15.5 km stretch of the Babai River within the Barbardiya municipality were selected based on accessibility, extraction area, and deposition. The sample aggregates were collected following the procedure specified in IS 2430-1986, Section 3. Laboratory tests were conducted to determine the physical properties, namely specific gravity and water absorption. The results for these were in the ranges of 2.540–2.601 and 0.449–0.799%, respectively. Similarly, the Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), and Los Angeles Abrasion (LAA) values were found to be in the ranges of 6.52–10.74%, 13.45–16.24%, and 11.82–16.78%, respectively. M20 grade concrete cubes were cast using a nominal volumetric mix. The coarse aggregate source was varied, while the proportions of fine aggregate, cement, and the water-cement (w/c) ratio were held constant. The test results showed that the concrete cubes made with aggregates from the Lathuwaghat source achieved relatively higher compressive strengths, while those made with aggregates from the Babai Bridge site (near the Babai Irrigation Headworks) showed lower values at both 7 and 28 days. The findings of this study aim to provide valuable information on riverbed aggregates to local and public bodies within the construction industry.

Keywords: Babai River, Concrete, Riverbed Aggregates, AIV, ACV, LAA, Compressive strength

1. Introduction

Concrete is a composite material composed of fine and coarse aggregates bonded together by a cement paste, which hardens (Shetty, 2009). It is a fundamental construction material, derives its strength and durability from a combination of various components with coarse aggregate playing vital role (Lamichhane et al., 2023). The strength of concrete is influenced by the water-cement ratio, the concrete grade, the bond between the mortar and coarse aggregate, and the aggregate properties—specifically its size, grading, shape, and strength (Haach et al., 2011). These factors also determine the concrete's durability, density, and chemical and thermal resistance. Furthermore, using a well-graded variety of aggregate sizes improves the packing density, which enhances strength and reduces cost by requiring less cement. Therefore, the size, grading, and quality of the aggregate directly influence both the final cost and the structural performance of the concrete.

The Babai River is a major perennial river in Nepal, one of over 6,000 rivers in the country. It is a significant second-class river for Bardiya District, flowing south from the Siwalik Hills. Originating from the eastern end of the Dang Valley at coordinates 27°58'27" N and 82°34'06" E, the Babai travels approximately 400 km before converging with the Ghanghara River in Bahraich, India. Its estimated terrain elevation near the source

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is 118 meters above sea level(Department of Information and Broadcasting, 2025). The river is also known by variant names such as Babai Nadi, Babai Khola, and Barka Ladiya in the local Tharu language.

Large quantities of construction materials, specifically fine and coarse aggregates, are extracted from the Babai River's deposits to support both private and public infrastructure development in the Bardiya district. Major projects—including roads, buildings, irrigation systems, urban development, and water supply schemes—demand vast amounts of these materials, making their quality a primary concern. To ensure the strength and durability of this infrastructure, all constituent materials must fulfill standard requirements. Therefore, aggregates for the construction industry must be rigorously tested and comply with prevailing standard specifications and codes.

In Nepal, the Himalayas are a primary source of sediments, which are transported downstream by river surges and deposited in the piedmont zone. Consequently, the immediate Himalayan piedmont has become an area of intensive riverbed sediment extraction. As a result, these rivers, laden with sediment, serve as a major source of construction materials for various infrastructure development projects in Nepal (Adhikari et al., 2022). Large quantities of these materials are transported from the upper to the lower zones due to the aggradation and degradation processes of the rivers. The sediments deposited along the riverbanks are often of high strength, a result of the natural sorting and compaction from regular hydraulic action, including wear and tear and the impact of water force.

This study determines the suitability of Babai River aggregates for various construction purposes by evaluating their physical and mechanical properties. The findings will aid government bodies, private owners, contractors, consultants, and suppliers by providing critical data on the variation of these aggregate properties along the river.

2. Objective of the study

The general objective of this research was to conduct a comparative study on the quality of riverbed aggregates collected from different quarry sites along the Babai River in the Bardiya district.

The specific objectives of this research were summarized as;

1) To determine the physical and mechanical characteristics of riverbed aggregates from different quarry sites of Babai River and comparing the test results with prevailing NS codes.
2) To identify and compare the compressive strength of concrete M20 (nominal mix by volume) prepared from the aggregates of quarry sites of the Babai River basin.

3. Literature Review

Various studies have been done on the properties of aggregate and their effect on the compressive strength of concrete. The study done by (Chhetri et al., 2021) showed that the physical and mechanical properties of coarse aggregate of Seti river decreases from upstream to downstream as gravel carried by the action of flowing water encounters different geological boundaries causing its surface wear and tear also the strength of cube obtained from the lower portion of Seti river is better than that of upper portion. The different physical and mechanical properties of coarse aggregates and strength of concrete cube (M20) made from the different class of aggregates obtained various section of Kaligandaki River found in improving order from the upstream to downstream (Lamichhane et al., 2023).

The aggregate type has effect on the compressive strength of normal concrete. Highest compressive strength was achieved from concrete containing crushed quartzite, followed by concrete containing river gravel and concrete containing crushed granite shows the least strength development at all ages (Abdullahi, 2012). The fineness modulus of aggregate is an indicator of its average particle size, with a higher value representing coarser aggregates. Since the compressive strength of concrete is influenced by both aggregate grading and size, it generally increases with a higher fineness modulus and larger aggregate size.(Haque et al., 2012).

A study by (Adhikari et al., 2022) on aggregates from six sources along a 19 km stretch of the Biring River basin revealed a clear trend. The researchers found that key physical properties (specific gravity, water absorption) and mechanical properties (aggregate impact value, aggregate crushing value, Los Angeles abrasion value), as well as the compressive strength of the resulting concrete, all showed a progressive improvement from upstream to downstream sources.

Three different batches using well graded, uniformly graded & gap graded aggregate for M20 grade of concrete were casted and result showed that gap graded aggregate have better performance than well graded and uniformly graded aggregate (Malewar et al., 2017). The effect of aggregate size 9.5mm, 13.2mm, 19mm & control on compressive strength was studied and concluded that with the increase in aggregate size up to 19mm both concrete compressive strength and workability increased (Vilane and Sabelo, 2016).

Research by (Ogundipe et al., 2018) revealed that the compressive strength of concrete increased with larger coarse aggregate sizes up to 20mm. Similarly,(Ndon and Ikpe, 2021) demonstrated that increasing the size of coarse aggregates leads to a corresponding increase in the compressive strength of concrete. Existing studies on the relationship between coarse aggregate size and concrete compressive strength are generalized and may not account for the specific geological and environmental conditions along the Babai River. Therefore, there is need of study that specifically tailor the investigations about the physical and mechanical characteristics the riverbed materials from the Babai River.

4. Methodology

4.1 Research Design

This study follows an experimental and comparative research design to evaluate the variation in strength properties of aggregates collected from five different selected section of the Babai River. The research focuses on determining mechanical and physical differences in aggregate sources affect their mechanical strength and suitability for construction purposes.

4.2 Study Area

The five different sites along a 15.5 km stretch of the Babai River within the Barbardiya municipality were selected based on accessibility, extraction area, and deposition. The riverbed provides natural aggregates of varying composition due to differences in geological formations and sediment transport processes.

Table 1. Sample Collection Location along Babai River

S. N	Spots (source)	Latitude	Longitude	Distance from U/S Quarry
1	Babai Bridge (Babai Irrigation Headworks)	28° 25'7" N	81°21'44" E	-
2	Chandanghat	28° 22'53" N	81°19'2" E	6.30 km
3	Dhungrahighat	28°22'11" N	81°18'38" E	9.2 km
4	Kumraghat	28°20'44" N	81°18'27" E	12 km
5	Lathuwaghat	28°19'17" N	81°18'18" E	15.5 km

The quarry sources Babai Bridge (near Babai Irrigation Headworks) and Chandanghat are situated at Barbardiya municipality ward no. 1 and sources Dhungrahighat, Kumraghat and Lathuwaghat are situated at Barbardiya municipality ward no. 2. The permission for the collection of river bed aggregate sample was taken from both the ward no. 1 and 2 offices and the Barbardiya municipality office.

4.3 Sampling Procedure

Aggregate materials were collected from the Babai River's five quarry sites following the procedure prescribed in the IS 2430-1986 Code section 3 (Bureau of Indian Standards, 1986).

4.4 Laboratory Testing

The lab test for the collected aggregate materials was done at Lab Unit of Road Division Nepalgunj. All tests were conducted following the relevant Indian Standards (IS):

- Specific Gravity and Water Absorption: IS 2386 (III), section 2.3 (Bureau of Indian Standards, 1963a)
- Aggregate Impact Value: IS 2386 (IV), section 4 (Bureau of Indian Standards, 1963b)
- Aggregate Crushing Value: IS 2386 (IV), section 2 (Bureau of Indian Standards, 1963b)
- Los Angeles Abrasion Value: IS 2386 (IV), section 5.3 (Bureau of Indian Standards, 1963b)
- Compressive Strength of Concrete: IS 516, sections 2 & 5 (Bureau of Indian Standards, 1959)

4.5 Data Analysis

Data obtained from laboratory experiments were analyzed with the statistical tool as comparative analysis such as table, charts & diagrams and statistical significance analysis such as regression and excel solver. The analysis was carried out using the MS-Excel 2016.

5. Result and discussion

5.1 Physical properties

The specific gravity and water absorption of aggregates from various sources were determined through laboratory testing, and the results are shown in below Table 2;

Table 2. Specific Gravity and Water Absorption Value obtained from lab test

S. N	Spots (source)	Specific Gravity	Water Absorption %
1	Babai Bridge (Babai Irrigation Headworks)	2.54	0.799
2	Chandanghat	2.551	0.626
3	Dhungragighat	2.565	0.572
4	Kumraghat	2.574	0.521
5	Lathuwaghat	2.601	0.499

The obtained values of specific gravity and water absorption value can be compared as;

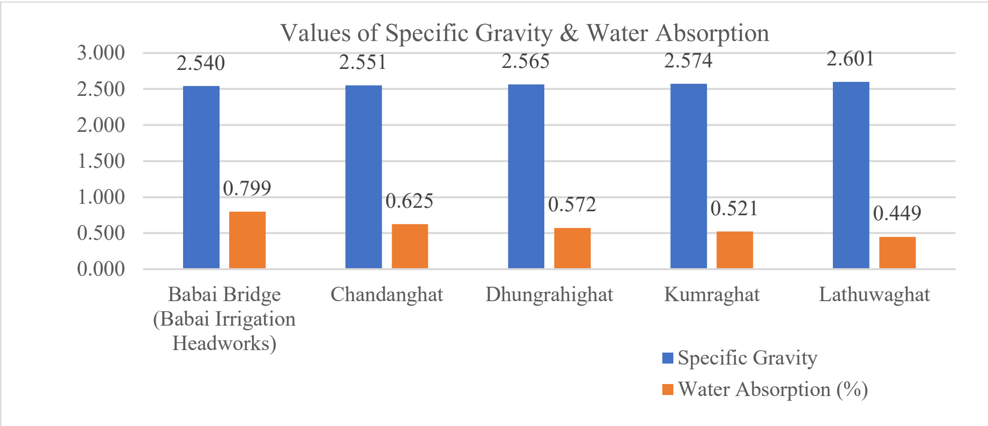

Figure 1. Values of Specific Gravity and Water Absorption of aggregates

Based on the observed results, the physical properties of the riverbed aggregate samples satisfy the requirements for construction materials as specified in the *Standard Specification for Roads and Bridge Works, 2073 (with Amendment 2082)*(Department of Roads, 2073). All sampling sources exhibited specific gravity values greater than 2.5 and water absorption values below 5%, thereby meeting the prescribed standards. The specific gravity values ranged from 2.54 to 2.601, while the water absorption values varied between 0.799% and 0.449%. A gradual increase in specific gravity was observed from the upstream site (Babai Bridge) to the downstream site (Lathuwaghat). Conversely, the water absorption values showed a decreasing trend, with the highest value (0.799%) recorded at Babai Bridge and the lowest (0.449%) at Lathuwaghat.

5.2 Mechanical properties

The mechanical properties (aggregate impact value, aggregate crushing value and Los Angeles Abrasion value) of the aggregates of different selected sources were tested in Laboratory. The test procedure was done by following the test method specified in IS 2386 – 1963 part 4. The values obtained from the lab test are represented as

Table 3. Value of AIV, ACV & LAA obtained from lab test

S. N	Spots (source)	AIV %	ACV%	LAA %
1	Babai Bridge (Babai Irrigation Headworks)	10.74	16.24	16.78
2	Chandanghat	10.34	16.06	16.26
3	Dhungragighat	9.30	15.20	15.44
4	Kumraghat	8.38	15.35	13.04
5	Lathuwaghat	6.52	13.45	11.82

5.2.1 Aggregate Impact Value

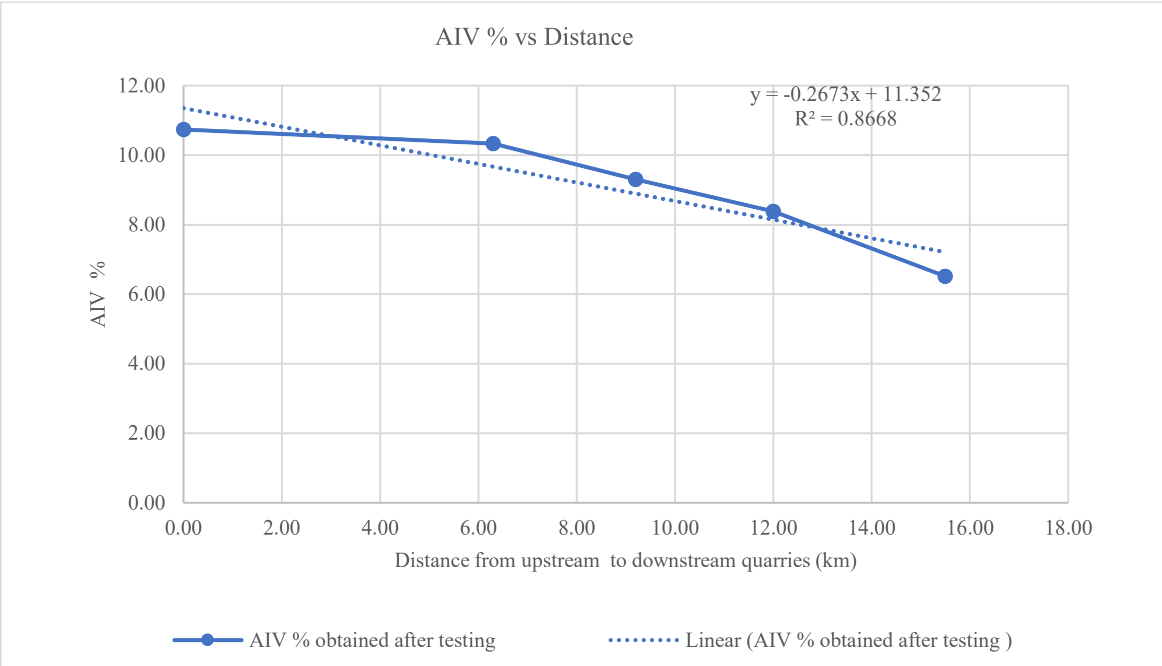

Figure 2. Graphical representation of AIV and distance from upstream to downstream (km)

From Figure 2 It is evident that the aggregate impact values (AIV) of the riverbed aggregate samples comply with the requirements specified in the *Standard Specification for Roads and Bridge Works, 2073 (with Amendment 2082)*. The maximum AIV was obtained at the Babai Bridge site, while the minimum value was recorded at Lathuwaghat. The results indicate a decreasing trend in aggregate impact values (AIV) from the upstream to the downstream sites. Based on the observed data, a linear relationship was established between the AIV and the longitudinal distance along the river. The derived regression equation representing this variation is $y=-0.2673x+11.352$. where y = Value of AIV and x = distance from upstream quarry site.

5.2.2 Aggregate Crushing Value

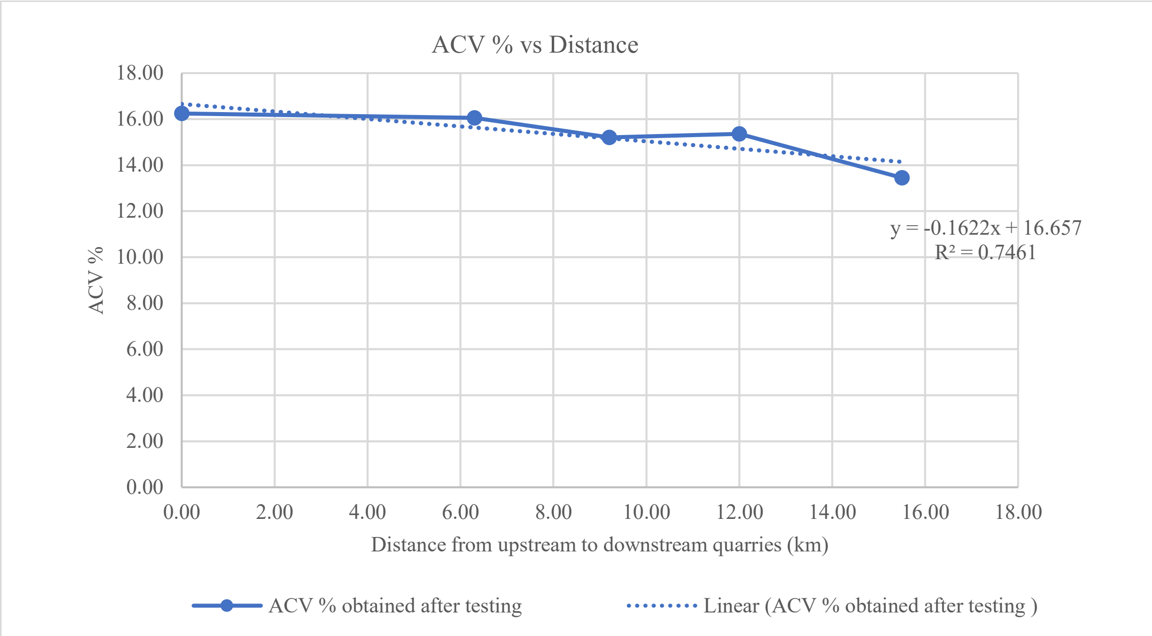

Figure 3. Graphical representation of ACV and distance from upstream to downstream (km)

Figure 3 shows that the aggregate crushing values (ACV) of the sampled aggregates conform to the criteria specified in the *Standard Specification for Roads and Bridge Works, 2073 (with Amendment 2082)* The highest aggregate crushing value (ACV) was recorded at the Babai Bridge site, while the lowest was observed at Lathuwaghat. Although the value obtained at Kumraghat was slightly higher than that at Dhungrahighat, the overall results indicate a decreasing trend in ACV from the upstream to the downstream sites. Based on the observed data, a linear regression analysis revealed a negative correlation between the aggregate crushing value (ACV) and the longitudinal distance along the river. The resulting regression equation, $y=-0.1622x+16.657$, indicates a gradual decrease in ACV values with increasing distance from the upstream quarry site.

5.2.3 Los Angeles Abrasion Value

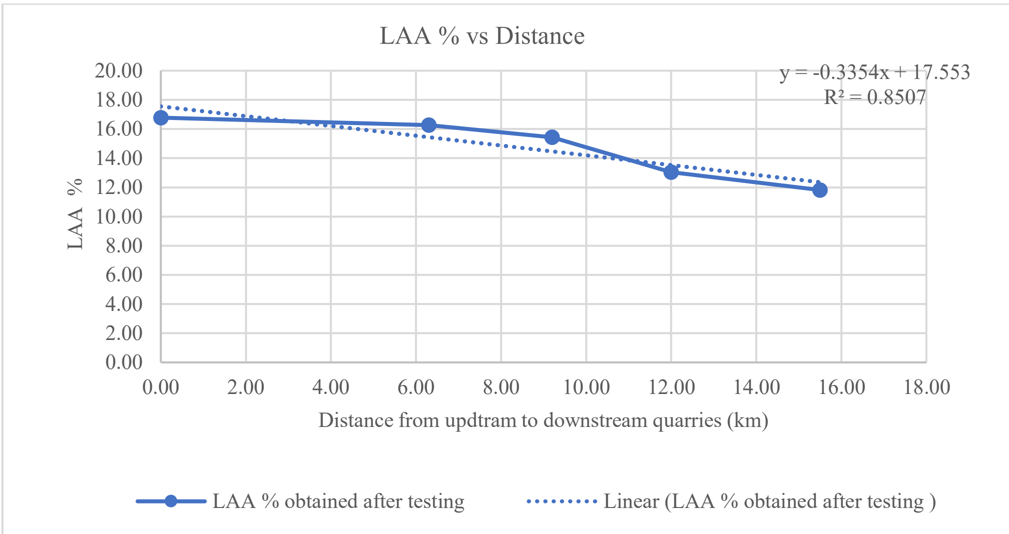

Figure 4. Graphical representation of LAA value and distance from upstream to downstream (km)

The Los Angeles Abrasion (LAA) values for all sampled aggregates met the specified construction criteria, decreasing from upstream (Babai Bridge) to downstream (Lathuwaghat). This longitudinal trend is modeled by the linear equation $y = -0.3354x + 17.553$ (where y = LAA, x = distance from upstream), indicating a consistent improvement in aggregate abrasion resistance downstream.

5.3 Compressive Strength

Following IS 516:1959, six concrete cubes were cast for each of the five aggregate sources using a standard M20 nominal mix. The compressive strength was determined at 7 and 28 days, revealing distinct strength development trends correlated with the aggregate source location.

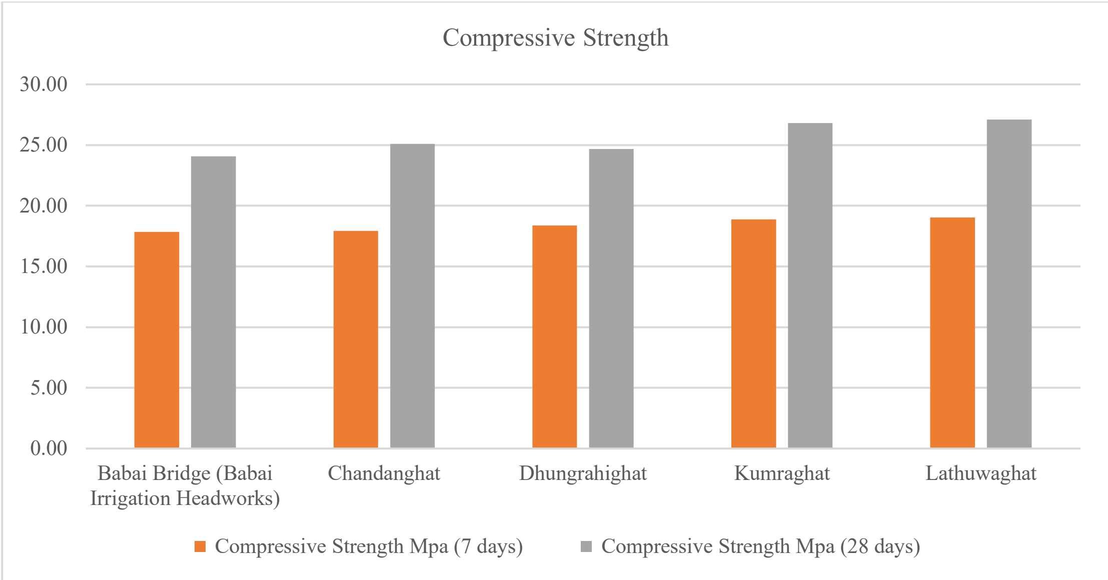

Figure 5. Bar Chart for compressive strength of 7- & 28-days concrete cube

The observed results indicate that the 7-day and 28-day compressive strengths of concrete cubes meet the requirements specified in the *Standard Specification for Roads and Bridge Works, 2073 (with Amendment 2082)*. All sources exhibited compressive strengths exceeding 16.08 MPa at 7 days and 24 MPa at 28 days. Although the compressive strength at Dhungrahighat was slightly lower than that at Chandanghat, the lowest strength was recorded at Babai Bridge, while the highest was observed at Lathuwaghat for both 7-day and 28-day tests.

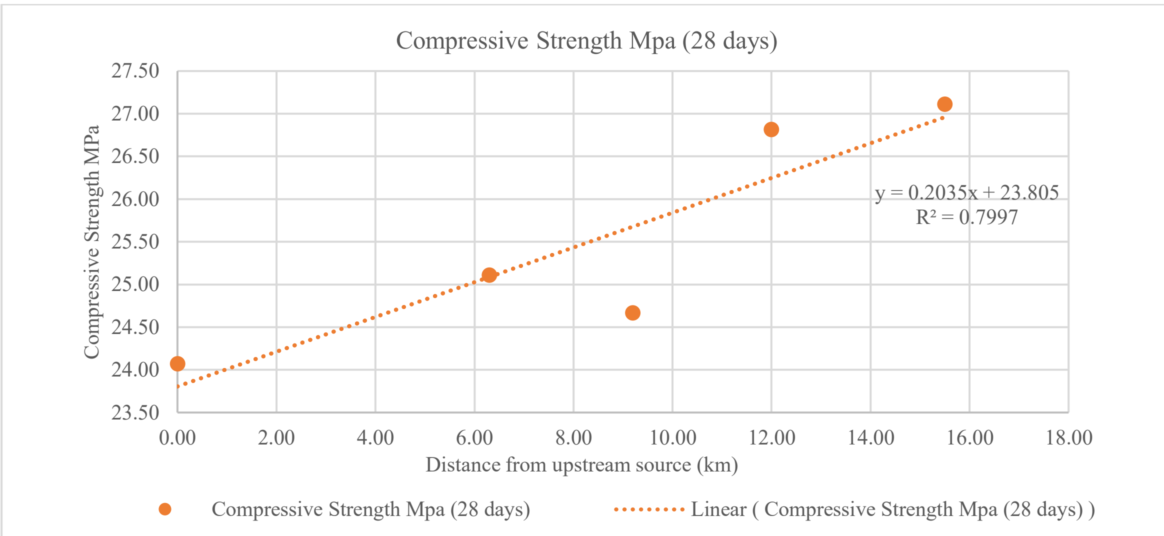

Figure 6. Graphical representation of compressive strength (MPa) and distance (km)

The 28-day compressive strength of concrete, utilizing riverbed aggregates, exhibited a positive linear correlation with distance downstream from the Babai Bridge site (Figure 6). This trend is quantified by the equation y=0.2035x+23.805, where y is compressive strength and x is the longitudinal distance, indicating a consistent increase in concrete strength downstream.

Overall, this study corroborates the findings of earlier research that highlight the critical role of aggregate source and river morphology in determining aggregate quality. The observed longitudinal improvement in aggregate properties along the Babai River reinforces the importance of selective extraction and source-based quality control, as emphasized by (Adhikari et al., 2022) and (Chhetri et al., 2021). The conformity of all tested aggregates with the Standard Specification for Roads and Bridge Works, 2073 (Amendment 2082) further validates their suitability for structural concrete applications.

6. Conclusion and recommendation

This study demonstrates that aggregates from the Babai River are suitable for construction, as all tested properties meet the requirements of the *Standard Specification for Roads and Bridge Works, 2073 (with Amendment 2082)*. Specific gravity values increase and water absorption decreases from upstream (Babai Bridge) to downstream (Lathuwaghat), indicating denser and less porous aggregates downstream. Correspondingly, AIV, ACV, and LAA values decrease downstream, reflecting improved impact resistance, crushing strength, and abrasion resistance. Concrete made from these aggregates achieved compressive strengths above the required limits, with downstream sources producing higher strengths, confirming the positive influence of aggregate quality on concrete performance. Overall, the results highlight a clear longitudinal improvement in aggregate properties along the river, emphasizing the importance of source selection for optimal concrete durability and strength.

It is recommended to study the relationship between the physical and mechanical properties of Babai River aggregates, as well as to investigate their chemical properties.

7. Limitations

This study focuses on selected physical and mechanical properties of aggregates from five sources along a 15.5 km stretch of the Babai River (Babai Irrigation Headworks to Lathuwaghat). M20 concrete cubes were prepared by varying coarse aggregates while keeping fine aggregates, cement and water cement ratio constant.

8. Acknowledgement

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