Universal Technical Journal of Lumbini International academy of Science and Technology
ISSN: [3059-9768] (Print)
(Volume-1, Issue I)

Comparative study of Coarse Aggregate Properties along the Longitudinal Sections of Kaligandaki River in Mustang

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Received: 21-July-2025; Revised: 11-September-2025; Accepted:17- September-2025

Abstract

The most significant component of concrete is aggregate. The demand for aggregates is quite high in Nepal's construction sector for road construction and concrete works. River-borne aggregate material still meets a large portion of the need. The Kaligandaki river is one of most prominent among others for extraction of riverbed material in Gandaki Provine and it is the most economic supplier for aggregates in Mustang district. The quantity of sediments attracts construction stakeholders for use of locally available materials. This study's goal was to analyse the properties of aggregates and variation in aggregate strength at a particular stretch of the Kaligandaki river basin in Mustang district. On the basis of accessibility and deposition, representative samples were taken for study purposes from five carefully chosen riverbank locations. Lab tests for physical properties (FM, specific gravity, water absorption, combined FI and EI) and mechanical properties (LAA, AIV and ACV) were conducted on the samples to evaluate their quality and strength for the construction works. Suitability of aggregates based on strength assessment samples was assured by compliance test to limits specified in DOR specification.

FM, specific gravity, water absorption, combined FI and EI were found in range of (6.57-7.05), (2.62-2.71), (0.485-0.723)% and (33.14-42.29)% respectively. It was concluded that aggregates from all the sources are suitable in their hardness, toughness and compressive strength. A linear relationship between the combined flakiness and elongation index, LAA, AIV and ACV values with longitudinal variation of Kaligandaki river was established.

Keywords: Concrete materials, aggregate sources, properties of aggregates, quality assessment, aggregate strength, longitudinal variation.

Introduction

Concrete is a widely used construction material known for its durability, versatility, and strength. It is composed of a mixture of several key ingredients, each playing a crucial role in the overall performance and properties of the finished product. The main ingredients of concrete include cement, aggregates, water, and sometimes admixtures. The amount of binder required is determined on the size distribution of the aggregate. The largest gaps are found in aggregate with a relatively equal size distribution, but adding aggregate with smaller particles tends to fill these gaps. The binder, which must fill the spaces between the aggregate as well as paste the aggregate surfaces together, is usually the most expensive component. As a result, the size and quality of the aggregate have a direct impact on its economy and strength. The most significant component of concrete is aggregate. They provide the concrete body, minimize shrinkage, and have an economic impact. Natural aggregates are inert granular components such as sand, gravel stone or crushed stone that are mixed with the binding mediums such as water, bitumen, portland cement, lime or other materials to produce compound materials such as asphalt concrete and cement concrete.

Huge amounts of construction materials are required to fulfil demand of construction works, which are being done by private and Government sectors and searching for good quality construction materials is a tough job **(Nayaju & Tamrakar, 2019)**. Water resources not only generate many forms of energy but also transport massive sediments from the lower and Sub-Himalayan Himalayas to the Terai region. The river sediments are mostly gravel, with a little sand and muck. During each flood season, gravel can be easily recovered from the river area following deposition. As a result, the river is a consistent supplier of coarse sediments. Because of the strong need for construction materials, coarse aggregate extracted from rivers has been widely used as a construction material.

The Kaligandaki River, originating from the Tibetan plateau and winding its way through the arid landscapes of Mustang, carries with it a diverse array of sediments. Among these, aggregates, comprised of various-sized particles such as gravel and pebbles, form a crucial component. These aggregates are transported by the river's currents, sculpting the riverbed and contributing to the dynamic nature of the watercourse. The geological diversity of the region influences the types and sizes of aggregates, giving rise to a distinctive mix that shapes the river's morphology.

The construction industry in the Mustang region relies on local materials for infrastructure development. Large amount of construction materials is required for Mustang district in the form of fine and coarse aggregates for development of infrastructure which can be extracted from the deposition of Kaligandaki River. The major infrastructure such as irrigation, roads, urban development, water supply scheme, hydroelectric projects that can be developed within the Kaligandaki basin also demands huge amount of construction materials whose quality is of great concern.

Research objectives

The main objective of the research is to analyze the properties of coarse aggregate along the different selected sections of Kaligandaki River. The specific objectives of the study are:

1. To determine the physical properties (FM, Specific gravity and water absorption) and mechanical properties (LAA, AIV and ACV) of coarse aggregate at the different selected sections along the longitudinal profile of Kaligandaki River.
2. To assure the suitability of aggregates based on strength assessment of specimens prepared from selected sections of Kaligandaki River.
3. To Compare the physical and mechanical properties of coarse aggregate along the selected sections of Kaligandaki River.

Literature Review

Concrete is one of the well-known as well as pioneer and most common construction materials used globally, mainly because of its availability, convenience, low cost, long durability, versatility and ability to sustain extreme weather environments. Although aggregate is considered as an inert filler material, it is a necessary component of concrete that occupies most volume and it defines thermal and elastic properties and dimensional stability of concrete **(Kalra & Mehmood, 2018)**. Aggregates have different physical, mechanical, chemical and thermal properties which directly affect the strength and durability of concrete product **(Zega, et al., 2010)**. The compressive strength of aggregate is an important factor in the selection of aggregate from any source. The compressive strength of concrete depends on the water to cement ratio, ratio of cement to aggregate, degree of compaction, bond between mortar and aggregate as well as size, grading, shape and strength of the aggregate **(Abdullahi, 2012)**. Despite researches have shown reluctance to utilize gravel in the production of concrete, the use of locally sourced coarse aggregate materials cannot be prohibited once all their engineering properties are known **(Nduka, et**

al., 2018). Physical and mechanical properties of aggregate must be known before the production to make a desirable mix and desired strength of concrete. These properties include shape, size, texture, gradation, moisture content, specific gravity, water absorption, soundness and bulk unit weight etc. These properties aggregates determine the strength, workability, and durability of concrete. Aggregates strongly influence freshly mixed and hardened properties, mixture proportions, and economy of concrete. Aggregates from different sections of the same river basin vary along longitudinal profile. The variation affects the quality and strength of road and concrete structures So, selection of good quality aggregates is an important process in accessing local material for construction.

Study conducted by **(Maharjan & Tamrakar, 2007)** in Rapti River, Central Nepal Sub-Himalaya to evaluate the quality of gravel for concrete and road aggregates to discover their suitability for construction purposes, different properties such as petrographic, physical, mechanical and chemical properties were analysed and it was found that sample were mostly subrounded, oblate triaxial ellipsoid with high sphericity, rough to smooth surface texture, the water absorption value from 0.69 to 1.12% which is <3%, dry density ranged from 2460 to 2680 kg/m3 which means normal density aggregates, aggregates impact values of samples ranged from 14.10 to 16.10%, Los Angeles Abrasion value 29.83% which is<30% and sodium sulphate soundness values ranged from 4.46 to 7.19% which is <10%. All the tested results are complied with the exiting Nepal Standard, British Standard and American Standard and it showed that the samples are suitable for road aggregates and concrete works.

Study done by **(Madai, et al., 2019)** to find the suitability of aggregates of Kavre and Sindhuli district quarries for different layers of Flexible Pavement using the standard material test procedures, they discovered that the aggregates from the three quarries included in the study, Challal Ganesh- Kavre, Aapghari- Ghampyakhola, and Bhyakurkhola, met the specifications needed to be used for various layers of flexible pavement.

Similarly, a study done by **(Adhikari, et al., 2022)** to analysis of aggregate strength variation at selected section of Biring river basin concluded after conducting the lab test of physical properties of aggregate, Fineness Modulus, Water Absorption and Specific Gravity were found in the range of (7.16-7.49), (0.72-1.15) % and (2.616-2.712). The linear equations for the longitudinal variation of LAA, AIV and ACV value along the river profile were established. For a longitudinal variation equation for LAA value $y=-0.352x+37.41$, AIV value an equation $y=-0.0189x+27.15$ and ACV value an equation $y=-0.212x+29.88$ where y = Value of LAA, AIV and ACV value and x = distance in km from upstream origin point. They found the average compressive strength M20 grade concrete cubes for 7 and 28 days to be within standard required and that of 28 days above 20Mpa.

Research Methodology

Study Area

The study area is geographically located in Mustang district. Kaligandaki River flows in south-west direction through enchanting landscape of Varagung Muktichhetra RM, Gharapjhong RM and Thasang RM including major cities closer to river bank. There are some major flood plains from which riverbed materials can be extracted. Different five sites are identified for sample collections on the basis of deposition of materials, residential area for the consumption and accessibility to site.

Data Collection

Primary data which were collected through the lab test by the means of observation, recording, testing and measuring. Lab experiment reports of aggregates form different sources made adequate primary data for the study purpose. Secondary source of information was collected from the different source such as documents, data from government office, various standard codes, international journals, newspapers, books, national and international research articles, different web sites.

Results and Discussion

Gradation analysis for gravel (Granular Sub base)

The particle size distribution curve of gravel of all the different sources are as follows:

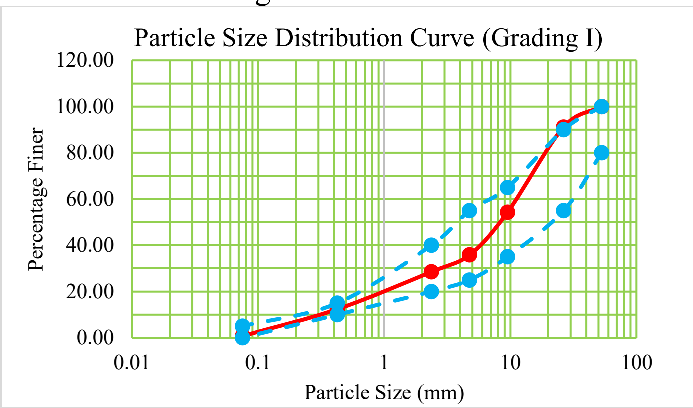

Fig. 4.1. Particle size distribution of gravel from Kagbeni Source

From above Fig. 4.1, it was found that Gravel from Kagbeni Source did confirm grading envelop as per DOR standard specification.

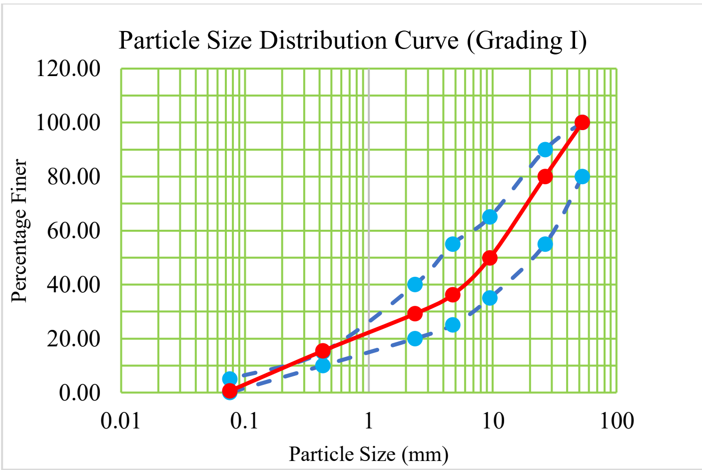

Fig. 4.2. Particle size distribution of gravel from Jomsom Source

From above Fig. 4.2, it was found that Gravel from Jomsom Source did confirm grading envelop as per DOR standard specification.

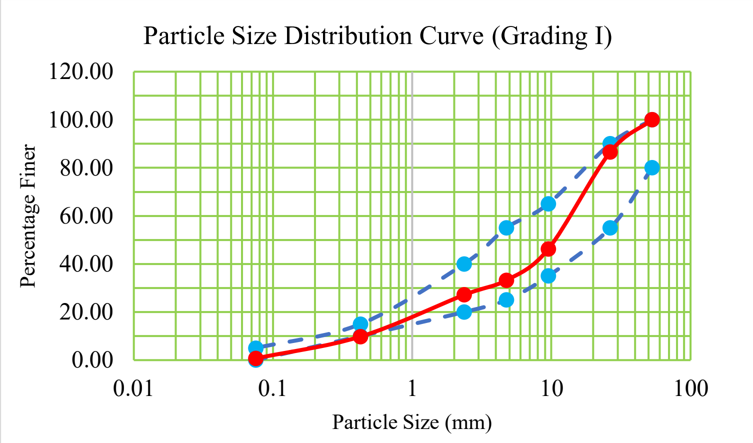

Fig. 4.3. Particle size distribution of gravel from Marpha Source

From above Fig. 4.3, it was found that Gravel from Marpha Source did confirm grading envelop as per DOR standard specification.

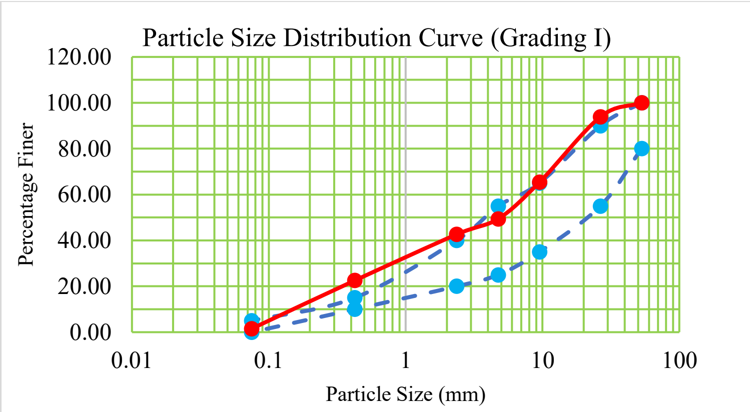

Fig.4.4. Particle size distribution of gravel from Tukuche Source

From above Fig. 4.4, it was found that Gravel from Tukuche Source did not confirm grading envelop as per DOR standard specification having slightly fine particles.

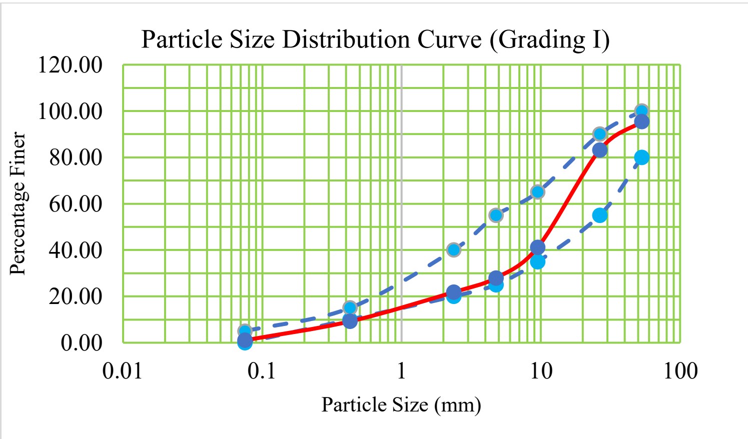

Fig. 4.5. Particle size distribution of gravel from Dhampu Source

From above Fig.4.5, it was found that Gravel from Dhampu Source did confirm grading envelop as per DOR standard specification.

Physical Properties of coarse aggregates

Lab tests of the aggregates from the different sources were carried out using standard test procedures and after calculation following values of physical properties were obtained. These values of fineness modulus, specific gravity, water absorption, flakiness and elongation indices were presented in the table as follows.

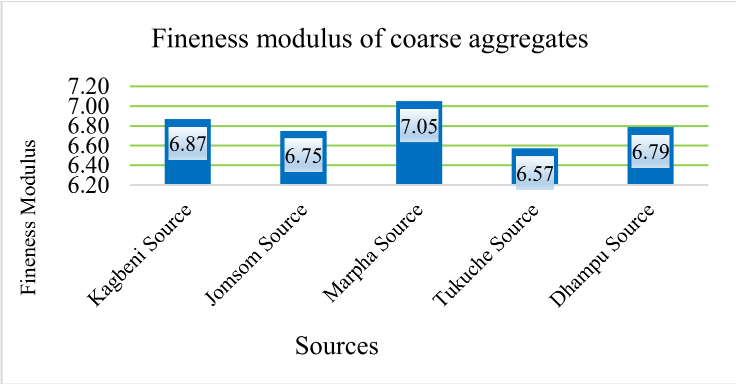

Fig. 4.6. Fineness Modulus of aggregates from different sources

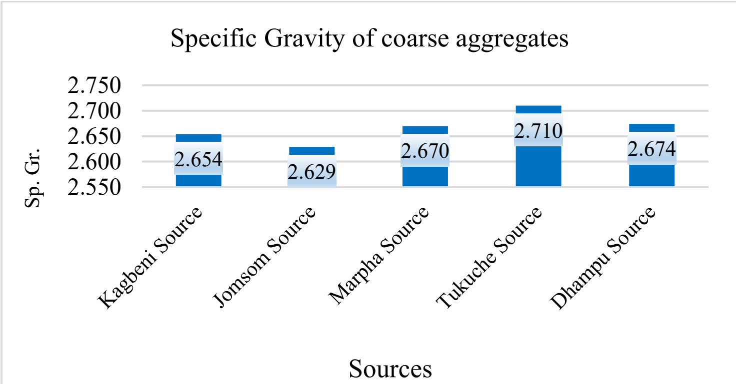

Fig. 4.7. Specific Gravity of aggregates from different sources

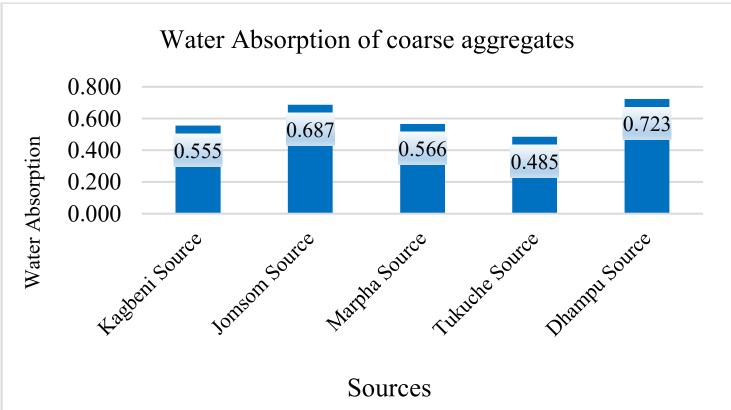

Fig. 4.8. Water Absorption of aggregates from different sources

The highest value of fineness modulus was found on Marpha source as 7.05 which represents average particle size is coarser than 10mm sieve size (index number 7) and the lowest value of fineness modulus was found in Tukuche source as 6.57 which represents average particle size is finer than other sources. The highest value for the specific gravity was found to be 2.710 that of Tukuche source and lowest value of specific gravity was 2.629 that of Jomsom source aggregates. The lowest value of water absorption was found on Tukuche source aggregates as 0.485% and the highest value of water absorption was found on Dhampu Source aggregates as 0.723%. High value of specific gravity and low value of water absorption represents higher quality aggregates. The combined flakiness and elongation index seemed in gradually decreasing order along downstream sections ranging from 42.29% at the first source to 33.14% at the last source of material.

Comparative analysis of Physical Properties of aggregates

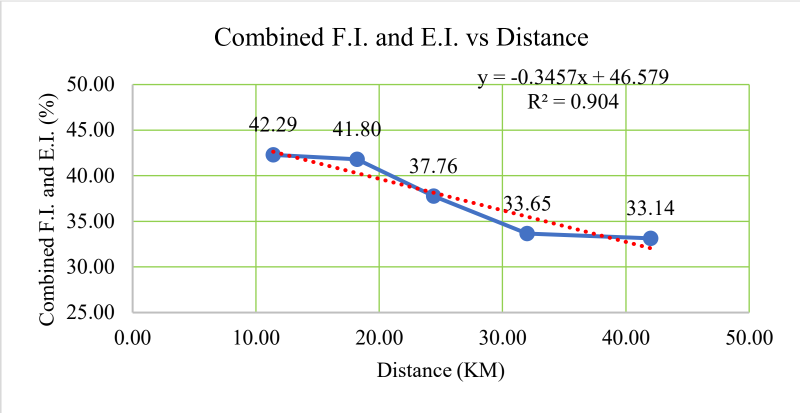

Fig. 4.9. Variation of Combined F.I. and E.I. along longitudinal profile of river

It was clearly observed that aggregates from lower sections had lesser values of combined flakiness and elongation index which means better quality aggregates found in lower portion of Kaligandaki river in Mustang. Aggregates from Kagbeni source had highest combined flakiness and elongation index as 42.29% and Dhampu source had the same lowest as 33.14%. Combined flakiness and elongation index followed down trendline as the distance from the origin source was increased. The linear equation developed for combined flakiness and elongation index was:

$y = -0.3457x + 46.579$ …………………Eq. (1)

where x = distance from the origin source.

Comparative analysis of Mechanical Properties of aggregates

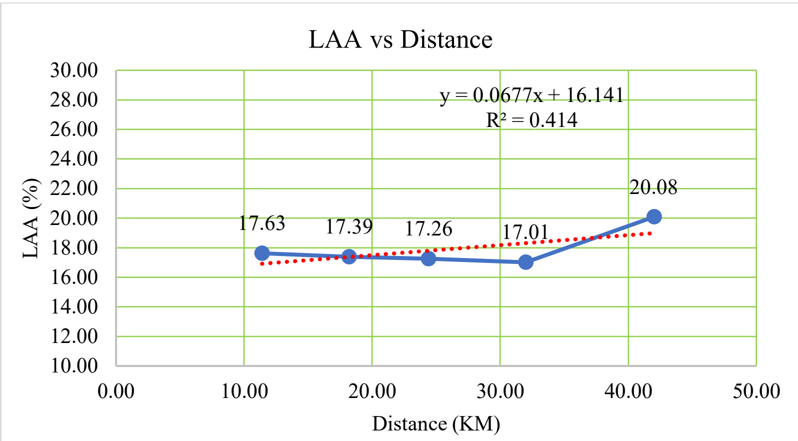

Fig. 4.10. Variation of LAA along longitudinal profile of river

It was observed that Los Angeles Abrasion Values of aggregates of lower sections had lesser values from Kagbeni source to Tukuche source representing aggregates with more resistance against wear and tear as distance was increased but the LAA value of aggregates from Dhampu source was found to be highest among all other sources representing aggregates with less resistance against wear and tear. LAA followed up trendline as the distance from the origin source was increased. The linear equation developed for Los Angeles abrasion value was:

$y = 0.0677x + 16.141$ …………………Eq. (2)

where x = distance from the origin source.

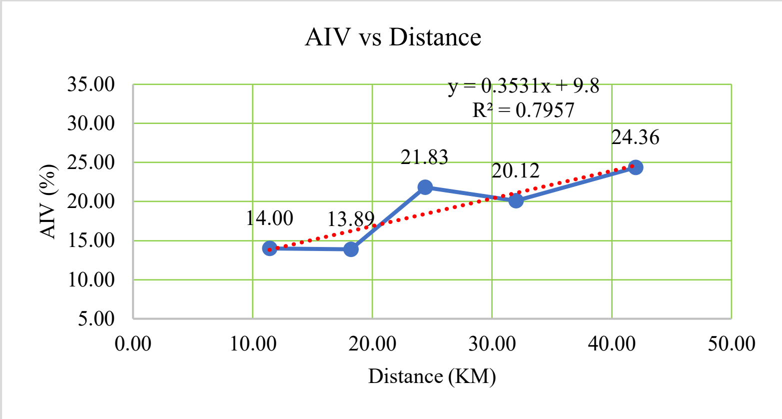

Fig. 4.11. Variation of AIV along longitudinal profile of river

It was observed that Aggregate Impact values of aggregates from Kagbeni and Jomsom source had lesser values representing aggregates with more resistance against impact load. AIV value of aggregates from Dhampu source was found to be highest as 24.36% among all other sources representing aggregates with less resistance against impact. AIV followed up trendline as the distance from the origin source was increased. The linear equation developed for aggregate impact value was:

$y = 0.3531x + 9.8$ …………………Eq. (3)

where x = distance from the origin source.

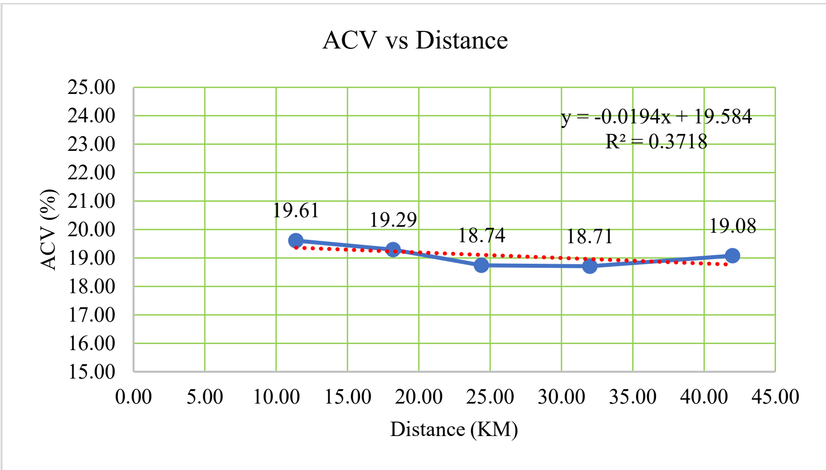

Fig. 4.12. Variation of ACV along longitudinal profile of river

It was observed that Aggregate Crushing values of aggregates of lower sections had lesser values from Kagbeni source to Tukuche source representing aggregates with more resistance against gradually applied compressive load as distance was increased but the LAA value of aggregates from Dhampu source was found to be higher than that of Marpha and Tukuche sources representing aggregates with slightly less resistance against gradually applied compressive load than that of Marpha and Tukuche sources. ACV followed down trendline as the distance from the origin source was increased. The linear equation developed for aggregate crushing value was:

$y = -0.0194x + 19.584$…………………Eq. (4)

where x = distance from the origin source.

Relationship between Physical and Mechanical Properties of aggregates

Among the physical properties under this study, water absorption values showed significant relation with the mechanical properties. As the coarse aggregate material with higher water absorption are considered to be more porous and sustain higher amount of water within it, the strength of such aggregate would be less. Here the water absorption of aggregate from Tukuche source was found to be the least as 0.485% and LAA value of the same source was found to be the least as 17.01% indicating good quality aggregates. Similarly, Dhampu source aggregates had highest value of water absorption as well as LAA as 0.723% and 20.08%. The Pearson's Correlation coefficient is 0.728 (>0.5), which indicated that water absorption has direct correlation with LAA value.

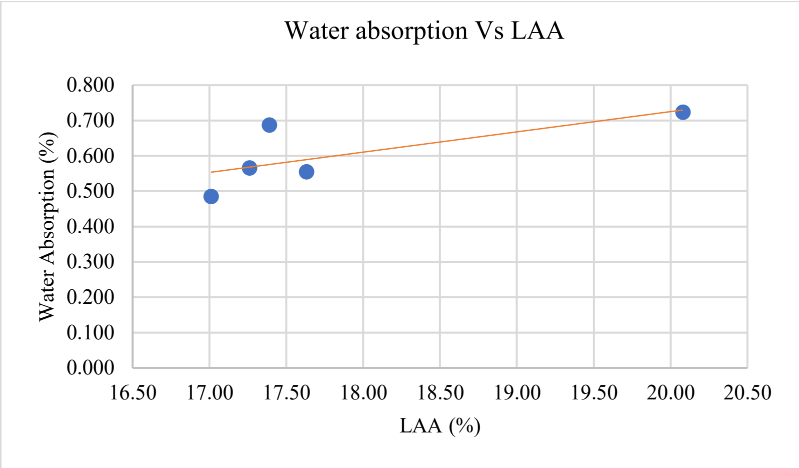

Fig. 4.13. Relationship between Water absorption and LAA

Conclusion And Recommendation

Conclusions

The conclusions of the study regarding the qualitative assessment of aggregates of the Kaligandaki River in Mustang are as follows:

1. Specific gravities of the aggregates sample from all five selected sections have no significant differences along the river length. Water absorption of aggregates from Dhampu source is relatively higher.
2. Except combined flakiness and elongation indices aggregates sample of Kagbeni, Jomsom and Marpha sources, the physical and mechanical properties of riverbed aggregates from all five selected sections of Kaligandaki river basin are satisfactory. Riverbed aggregates of Kaligandaki river in Mustang are flaky and elongated. Combined flakiness and elongation index goes on decreasing at downstream sources of Kaligandaki river.
3. Regarding the mechanical properties of aggregates, LAA and ACV goes on decreasing along lower portion of Kaligandaki river from origin source to Tukuche source, it means lower portion of river have relatively better quality of aggregates. But aggregates from Dhampu source have relatively higher values of LAA, AIV and ACV

than upstream sources, it means aggregates from this source are of low strength. The tributary river sources also effect on strength quality of aggregates.

4. Water absorption has direct correlation with LAA value.

Recommendations

As aggregates from sources of upper portion along Kaligandaki river in Mustang are flaky and elongated, flakiness and elongation may be the major issue in the case of riverbed aggregates from Kaligandaki river. Hence, proper attention should be taken in the collection of riverbed aggregates so that good quality can be achieved in road construction and concrete works.

It was found that the aggregates from every source satisfied the minimal strength requirements for the construction projects covered by this study. Therefore, it is recommended that aggregates from the distinct sources of Kaligandaki river can be used road construction and other concrete works. Among the five sources, aggregates from Tukuche source have highest specific gravity, lowest water absorption, highest mechanical strength, so it is recommended to use aggregates from Tukuche source for pavement works, high strength concrete and wearing course works.

There are enormous amount aggregates present in Kaligandaki river bank in Mustang. From the study conducted, it is found that the aggregates are of very good quality and strength. Therefore, it is recommended to utilize these resources with sustainable management that locally available construction materials contribute for local infrastructure development as Well As Local Source of Income.

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