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Experimental Analysis on Quality of Coarse and Fine Aggregate Produce from Crusher Plants of Syangja District of Nepal

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Abstract

Does quality address grade? No, quality standards do not demand the best quality. However, they establish the minimum requirements for engineering uses or conformance with the code provisions or standards, free from faults and defects. Quality control by detection, quality assurance by prevention, and total quality by improving the quality of materials using quality policy and quality planning are necessary for any crusher plant or entrepreneur to achieve customer and society satisfaction. Aggregate must meet specific standards or code provisions for optimum engineering use to get better quality and higher strength concrete. The aggregates' types and quality significantly influence the concrete's properties; hence, the aggregates used to produce concrete that meets the required specifications are a prime concern. The aggregates' quality is significantly related to the concrete's strength, workability, and durability. The physical and mechanical properties of coarse and fine aggregate were analyzed in this research. The test results found that the P1, P3, and P4 crusher plants comply with all physical and mechanical parameters of the IS 383:2016 code provision. In contrast, the crusher plant of P2 does not comply with IS 383:2016 standard on optimizing the coarse and fine aggregate proportion in all-in-aggregate analysis. The Gradation of fine aggregates of all the crusher plants does not lie in the grading zone as classified by IS code 383:2016. The inert material satisfying code provisions and standards helps to gain strength, durability, and other concrete parameters during mixed design for concrete production.

Keywords: *All-in-Aggregate, Mechanical and Physical Properties, Quality, Specification.*

1. Introduction

With rapid urbanization, the nation's infrastructure growth is being increased; hence, durability and quality of the construction material are prime concerns for government institutions and agencies, but in private construction, the testing and analysis of the material is optional in Nepal. The suppliers or manufacturers of building materials do not consider the quality of material standards. The quality of the material must fulfill the national code's provisions and specifications. Each department has different specifications and guidelines for quality control in Nepal. Thus, researchers consider IS code 383:2016 provisions for comparing test results with standard Values. The required quality of concrete is usually stated in the specification, which includes standards of ingredient materials (Fine and Coarse aggregate), workmanship, and construction method. There is a direct correlation between the quality of any construction materials and the success of its producers or suppliers (Soni, 2016).

The aggregate to prepare cement concrete should be rugged, durable, clean, and utterly free from lumps of clay, fine dust, and organic and vegetable matter. Thus, the concrete produced should be the strongest, densest, and most workable for which it is prepared for construction. The presence of such debris and foreign matters prevents the adhesion of aggregates and finally reduces the strength of concrete. The compaction of concrete, air bubbles and voids in concrete, and interlocking of aggregates depends on the quality of fine and coarse aggregates for which concrete is prepared. The amount of aggregates used in producing concrete occupies 60% to 80% of the total volume of concrete (Andres & Smith, 2001). It is therefore important to carry out tests on aggregates to ensure soundness, cleanliness, and proper gradation and to determine specific gravity, moisture content, particle shape, and surface texture and whether such aggregates produce better quality concrete or not (Rangwala & Rangwala, 1997).

Concrete is cementitious paste mixed with aggregate, i.e., coarse and fine aggregates, which is very strong in compression but weak in tension and shear. Steel reinforcing bars are necessary to ensure the concrete members' for structural integrity, such as footings, foundations, walls, columns, slabs, beams, etc. The required strength can be obtained by varying the proportions of the ingredient material. The grades of concrete can be by varying the proportions of the ingredient materials varied from M10 to M80, in the designation of concrete mix 'M' defines the mix, and the number indicates the specified compressive strength of that mix of 150 mm size cube at 28 days expressed in N/mm2 (IS 456:2000). Cement concretes of different grades are widely used in infrastructure construction for development activities as they can be molded into any desirable shapes and sizes, and durable structure, possess adequate strength and plasticity for mechanical working, and most of the properties can be easily varied by varying the proportion of the ingredients materials. Concrete strength and other properties depend on the quality of inert materials, i.e., fine and coarse aggregates, their handling practices, and local conditions. Thus, it is a prime concern to remember that today's success results from yesterday's preparation or planning for quality standards (Kosmatka et al., 2002).

Aggregates are a locally available resource for concrete preparation. However, its properties vary from one location to another, where it is taken for further processing or without processing. The strength of concrete can be improved not only with increased cement proportion but also by using better quality aggregates, which are possible solutions (Khanna & Justo, 1999). Aggregates can be classified into three groups: fine aggregate, coarse aggregate, and all-in-aggregate. Fine aggregate is characterized by its passage through a 4.75 mm IS sieve. Coarse aggregate is symbolized based on its particle size and shape, which may be uncrushed, crushed, or partially crushed gravel or stone. The grading of coarse aggregate is determined by the proportion of material that passes through a specific sieve size. All-in-aggregate means aggregate containing a mixture or proportion of material of all sizes, such as a pit, river bed, crushing plant, or other source. The requirements for all-in-aggregates are the same as for fine and coarse aggregates separately except for grading. Also, it is known as ballast (Kosmatka et al., 2002). All-in-aggregates are not preferred for making high-quality concrete. In most cases, fine and coarse aggregate adjustment is necessary to supplement the grading by adding respective size fractions, which may be deficient in the aggregate as found in the gradation analysis (Gambhir, 2006). The fineness modulus varies from 3.5 to 6.5 for all-in-aggregate. Crushed aggregate is generated by crushing quarry rocks, boulders, cobbles, or large-size gravel. Crushed aggregate passes several processing units such as crushing, screening, and washing to obtain proper gradation, and free from dust particles. Thus, the aggregates should be handled and stored to minimize segregation and degradation and prevent contamination in the aggregate stockpile during construction. The cone crusher grinds the flaky and elongated aggregates, giving the shape of sharp corners and reducing flakiness and elongation index; such aggregates enhance the strength of the concrete in the production of high-grade concrete, reducing consumption of concrete quantities and resulting, to some extent, economizing the cost. Suppose the aggregate is more or less cubical; the strength of the concrete increases. There needs to be more clarity or a question mark when using natural or crushed aggregate for better strength. It is clear that for grades above M15, the failure is due to the shear failure of aggregate and not bond failure, so the natural aggregate is better as it has strength even though the surface is smooth. The color of aggregates, whether white or yellowish, does not affect the strength of the aggregate (Shrestha, 2018).

Construction materials are the purchase's items and consumed at the construction site. Planning construction materials at the site means identifying materials, estimating quantities, defining specifications, forecasting requirements, locating procurement sources, and getting materials samples approved until the construction is completed. Assuring the right quality in right quantity at the correct prices from the right sources at the right time is necessary for efficient and effective engineering and economical utilization (Chitkara, 2015).

Jimoh et al. studied the influence of aggregate types and size on compressive strength. The 1:2:4 sample was cast using sand and quarry dust as fine aggregate, whereas granite and gravel were used as coarse aggregates of 20 mm and 28 mm in size. It was found that the mix cast with quarry dust and granite of 20 mm size coarse aggregate gave the best results. It was concluded that with the increase in size of coarse aggregate, its compressive strength reduced (Jimoh et al., 2007). The effect of using igneous, sedimentary, and metamorphic rock as aggregate in normal-strength concrete was carried out, and the aggregates used from each category were granite, limestone, and marble. During the testing, it was observed that granite concrete showed the best performance. In contrast, marble aggregate concrete showed the least strength, owing to the weakness in inherent properties of the metamorphic rock as compared to igneous and sedimentary rocks used for coarse aggregate (Tsado, 2013). The aggregate material becomes more suitable in its hardness, toughness, and strength when moving upstream towards downstream along the Bering River of Nepal. The lower part of the stream was assessed to have somewhat better-quality coarse aggregates (Adhikari et al., 2022).

Suppliers of construction materials and investors of quarry sites where construction material is extracted should be aware that anything less than the specifications will not be acceptable to the client. Therefore, the quarry site investor should be aware of, understand, and implement the total quality management technique, clarify their understanding of the quality issue, and move forward to achieving total quality (Banstola et al., 2023).

This study is only concerned with the quality of crushed inert material for concrete production in Syangja district of Nepal. According to the latest census of 2021, more than 66 percent of Nepal's population lives in the municipalities. In Nepal, there are 293 municipalities and 753 local units. People are migrating to urban areas for better education, health, and job opportunities, leading to a rise in the urban population, which is also reflected in Syangja district of Nepal. During the construction of infrastructures in Syangja district, conflicts arise when selecting the required quality of material produced by the crusher plants of Syangja district. Most people use construction materials thinking that supplied inert materials are suitable for construction activities, but these local people do not know their quality and standards. It has yet to be determined what kind of quality and standards would work in this locality to promote quality construction in the future. This study aims to discuss whether inert materials produced from crusher plants as construction materials in Syangja district of Nepal satisfy the quality standard and explore the parameters of their lack of quality, if any. Thus, the test results discuss and reflect the present issue about the quality of inert construction materials for concrete preparation and, finally, suggest to local people, construction entrepreneurs, and investors of the crusher plants about the current status, practices, and potential future corrective action for any deviation from standards. Some fundamental questions must be answered regarding the aggregate quality of concrete preparation: Does it satisfy or focus on customer needs? Does it meet the standards without sacrificing material quality or compromising industry standards? Does the industry stay with advancements in producing ingredient materials of concrete? Therefore, today's quality does not remain for tomorrow, so continual improvement is needed by introducing or implementing total quality business or organization to maintain quality standards in the future. Today, customers in the global market want assurance that they will get reliable quality for their investments, money, or monetary value.

2. Material and Methodology

The study area comprises a crusher plant in the Syangja district of Nepal, where coarse and fine aggregate production occurs and is used as a construction material. Literature review, field observation, key informant interviews with construction entrepreneurs, material suppliers, chairperson of the district coordination committee of Syangja district, and consultative meetings with representatives of local government institutions were held to find the number of crusher plants, name of crusher plants, their production capacities, and number of crusher plants that produced inert materials used only in Syangja district.

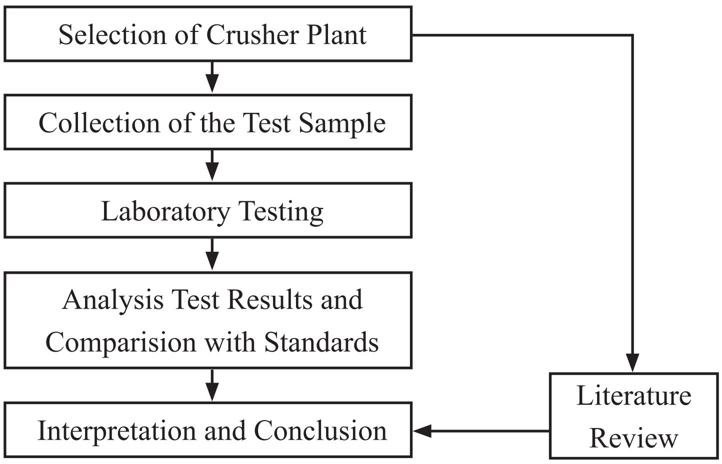

Fig. 1: Flow Chart of the study for methodology.

Four crusher plants are registered in the Syangja district of Nepal to extract coarse and fine aggregate from Aandhikhola as a source. All the crusher plants were considered population size for research. Experimental data was analyzed and compared with Indian Standard Code provisions, and test procedures were used IS 383:2016. Three samples were collected from each crusher plant by quartering, and sample screening was done to test the physical and mechanical properties of four crusher plants, whose material is used for infrastructure construction within the Syangja district of Nepal. The average value obtained from the three samples was calculated and compared with the standard value given in the code IS 383:2016. All the laboratory tests were conducted in Barahi Technical Solutions Pvt Ltd., certified and calibrated by the Government of Nepal, Nepal Bureau of Standards for material testing. The methodological flow chart applied in this study is shown in Figure 1.

The laboratory test for physical properties of the sample, such as sieve analysis of fine and coarse aggregate, particles finer than 75 microns of coarse and fine aggregate, specific gravity and water absorption of fine and coarse aggregate, and flakiness index of coarse aggregate, were carried out as per the procedure specified in the IS code 383:2016. The laboratory tests for mechanical properties of the sample, such as Los Angeles Abrasions Value, Aggregate Impact Value, and Aggregate Crushing Value of coarse aggregate, were carried out as per the method and procedures specified in the IS code 383:2016. Samples from each crusher plant were indicated randomly as P1, P2, P3, and P4 for ethical research and confidentiality of test results of each crusher plant obtained from the laboratory testing. The researcher team only knows which crusher plant has which test results. The indication of symbol P1 represents Gharau Kalika Crusher Udhyog, Dauna, Galyang-08, Syangja; P2 represents Aadhikhola Rodha Udhyog, Gahakhola, Walling-13, Syangja; P3 represents Chhangchhangdi Crusher Udhyog, Amala, Walling-11, Syangja; and P4 represents Bhirkot Prasodhan Kendra, Bayarghari, Bhirkot-1, Syangja. The specified laboratory test was conducted under normal temperature and pressure of the laboratory as is condition, and seasonal variation on the sample's properties and the geological properties of the aggregate sample was not considered.

3. Results and Discussions

3.1 Physical Properties of fine & coarse aggregate

The properties that can be appreciated by physical examination of fine and coarse aggregate are:

a. Gradation

The distribution of the coarse and fine aggregate particles obtained by sieve analysis, in which particles of various sizes were distributed into various sizes by standard IS sieve, is termed as grading of the aggregate. Sieve analysis defines the particle size distribution of fine, coarse, and all-in aggregates by sieving or screening.

i. Fine Aggregate

As per IS 383:2016, the grading envelope aggregate size lies between 10 mm and 0.15 mm, and the sieves are fine aggregates. The gradation of fine aggregate is given below.

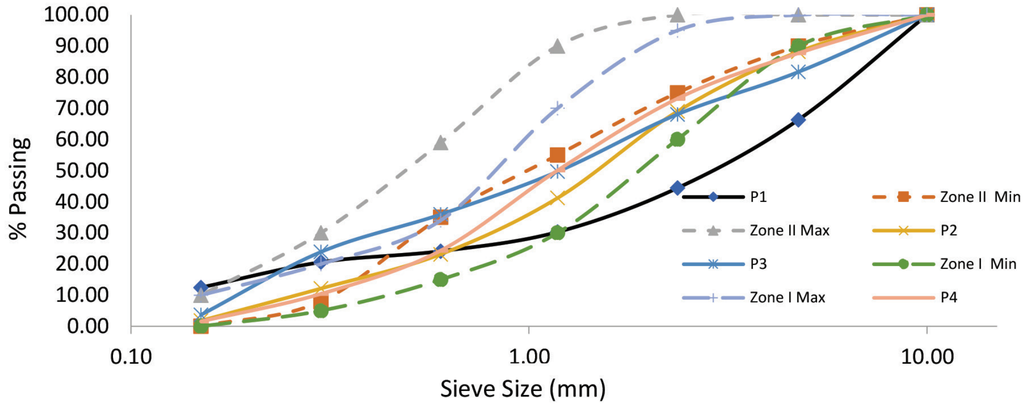

Fig. 2: Gradation of fine aggregate of sample crusher plant.

The sieve analysis shows that the fine aggregate of crusher plants P1, P2, and P3 does not match the limit prescribed by IS code 383:2016, whereas the crusher plant of P4 lies within zone I as per IS code 383:2016.

ii. Coarse Aggregate

As per IS 383:2016, coarse aggregate is defined as a grading envelope indicating aggregate size between 20 mm and 4.75 mm sieve, and it is used in structural concrete. The gradation curve of coarse aggregate is given below.

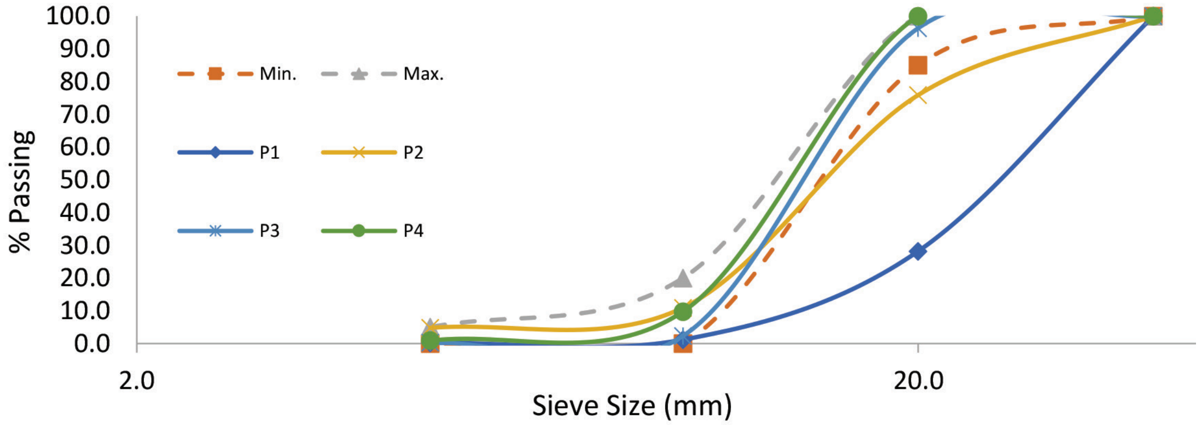

Fig. 3: Gradation of coarse aggregate of sample crusher plant.

The gradation of a coarse aggregate of crusher plants P3 and P4 lies on the single size 20 mm down aggregate of IS: 383:2016, but crusher plants of P1 andP2 do not lie on any size like 20mm down, 40 mm down, 16 mm down and 10 mm down as specified by IS: 383:2016. The coarse aggregate should have a limit of 20 mm down for structural concrete.

iii. Combined Gradation of coarse and fine aggregate as per IS 383:2016

As the aggregates are used with the combination of fine and coarse for any concrete works, it is called all-in-aggregate. The analysis was carried out for the optimization of coarse and fine aggregate ratios for concrete works, which is shown graphically below.

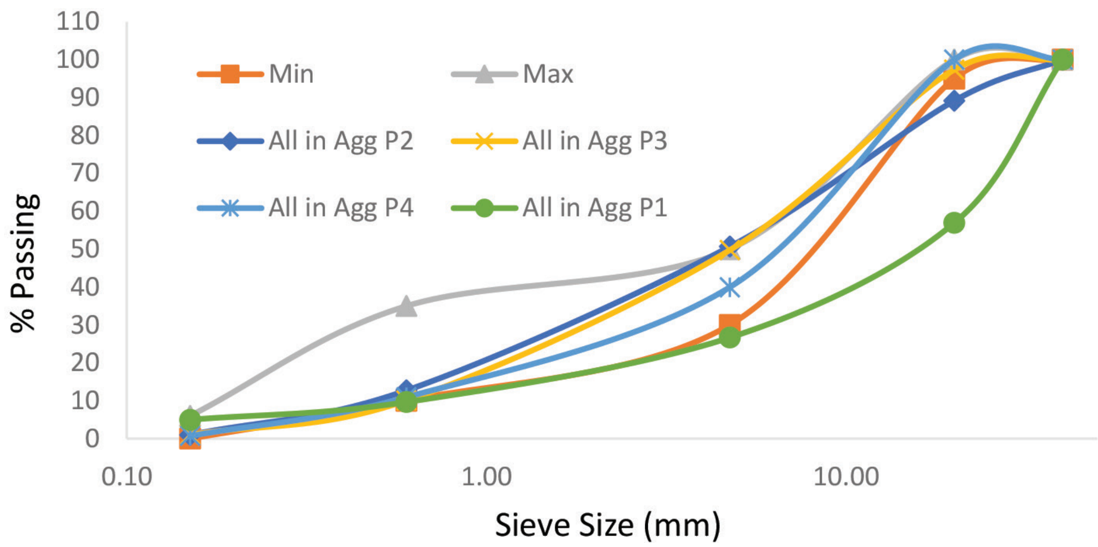

Fig. 4: Gradation of all in aggregate of sample crusher plant.

From the above graph, the crusher plant of the P1 source lies in the 40 mm down all-in-aggregate with the proportion of 60% coarse aggregate and 40% fine aggregate; the crusher plant of P2 does not lie in 20 mm and 40 mm down all-in-aggregate none of any proportion, crusher plant of P3 lies 20 mm down all-in-aggregate with proportion of 72% coarse aggregate and 28% fine aggregate, and crusher plant of P4 lies 20 mm down all-in-aggregate with proportion of 55% coarse aggregate and 45% fine aggregate. Well-graded aggregates enhance those determinants, resulting in more excellent workability and durability of concrete. The well-graded aggregates fill voids together competently, thus decreasing the volume between aggregate elements occupied by cement paste.

b. Materials finer than 75 microns of coarse and fine aggregate

The material passing the 75-micron IS sieve usually contains clay and silt particles. Because of their fineness and other physical characteristics, materials finer than 75 microns are treated with undesirable materials in aggregates. These characteristics disturb strength, workability, concrete durability, water demand, and shrinkage in concrete, negatively impacting its quality.

i. Coarse Aggregate

The average value in coarse aggregate finer than 75 microns of each sample is tabulated as:

Table 1: Coarse aggregate finer than 75 microns of sample crusher plant

Description	Particles finer than 75 micron of coarse aggregate			
Code No.	P1	P2	P3	P4
Average Value (%)	2.76	0.6	0.48	1.0
Standard Value (%)	Less than 3			

Coarse aggregate from all the crusher plants lies within the limit of particles finer than 75 microns. The standard value of coarse aggregate finer than 75 microns is 3 % maximum as per code provisions.

ii. Fine Aggregate

The average value of fine aggregate finer than 75 microns of each sample is presented below:

Table 2: Fine aggregate finer than 75 micron of sample crusher plant

Description	Particles finer than 75 micron of fine aggregate			
Code No.	P1	P2	P3	P4
Average Value (%)	10.8	1.6	1.15	1.10
Standard Value (%)	Less than 15			

Fine aggregate from all the crusher plants lies within the limit of particles finer than 75 microns. The standard value of fine aggregate finer than 75 microns is 15% maximum per code provision.

c. Specific gravity and water absorption of coarse and fine aggregate

Specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. This parameter is a reliable indicator of the strength and quality of a particular material. In essence, it helps to determine how robust and resilient the material is. Generally, aggregates with lower specific gravity values tend to be weaker than those with higher. This teaches that specific gravity is essential when selecting aggregates for construction purposes.

Water absorption of coarse and fine aggregate defines the percentage of porosity by both weight and volume. The percentage between dry and saturated aggregate declares the water absorption value for aggregate and water holding capacities. Water absorbed by an aggregate when immersed in water and expressed in percentage is termed water absorption of aggregate. The average value of specific gravity and coarse and fine aggregate water absorption is below.

Table 3: Specific gravity and water absorption of coarse aggregate

Description	**Specific gravity and water absorption of coarse aggregate**				**Standard Value**
Code No.	P1	P2	P3	P4	
Specific Gravity	2.57	2.53	2.58	2.62	2.5 to 3
Water Absorption (%)	0.97	1.73	1.04	0.82	2

The table shows that water absorption and specific gravity of coarse aggregate from all the crusher plants lie within the limit as per IS 383:2016. The standard value of specific gravity is 2.5 to 3, and water absorption is 2% maximum.

Table 4: Specific gravity and water absorption of fine aggregate

Description	**Specific gravity and water absorption of fine aggregate**				**Standard Value**
Code No.	P1	P2	P3	P4	
Specific Gravity	2.57	2.54	2.45	2.57	2.5 to 3
Water Absorption (%)	1.42	1.01	3.2	1.42	5

This table shows that the water absorption and specific gravity of fine aggregates from all crusher plants lie within the limit as per IS 383:2016. The standard values given for specific gravity and water absorption of fine aggregate are 2.5 to 3 and 5% maximum respectively.

d. Flakiness Index of Coarse aggregate

When an aggregate's least dimension is less than 60% of its mean dimension, it is called a flakey aggregate; the average Value of the flakiness index for a coarse aggregate is shown below.

Table 5: Flakiness index of coarse aggregate

Description	**Flakiness index of coarse aggregate**			
Code No.	P1	P2	P3	P4
Flakiness Index Average Value (%)	12.9	25.1	24.3	21.7
Standard Value (%)	25 %			

The flakiness index of coarse aggregate from P1, P3, and P4 crusher plants lies within the limit of IS 383:2016, but the crusher plant of P2 does not lie within the limit. The standard Value of the Flakiness Index of coarse aggregate is 25% maximum.

3.2 Mechanical Properties of Coarse Aggregate

These properties govern the behavior or attributes of coarse aggregate when external forces are applied. The coarse aggregate indexes, which attribute a construction material's resistance to a load acting on it during the failure process, indicate the degree to which it may deform under the load and its behavior. The rate at which the failure process development occurs may be under a static or repeated load. The mechanical properties of coarse aggregate are determined by making representative specimens of various shapes in mechanical tests. Los Angeles Abrasion Value, Impact Value, and Crushing Value are the mechanical properties of coarse aggregates. The aggregate crushing value defines a relative measure of the resistance of an aggregate in bulk to crushing a gradually applied load in compression. The impact value of bulk aggregates measures the extent of the formation of smaller particles by the resistance of bulk aggregates under impact loading conditions. Los Angeles Abrasion Value specifies resistance to wear or hardness or to resist the abrasing action due to traffic loads. An aggregate sample indicating a low loss in testing value gives tough, hard, and strong (Kukreja et al., 1996). The mechanical properties of coarse aggregate are tabulated below.

Table 6 : Mechanical properties of coarse aggregate

Description	Mechanical properties of coarse aggregate				Standard Value
	P1	P2	P3	P4	
Los Angles Abrasion Value	37.16	41.92	42.58	40.55	30% - 50% Maximum
Aggregate Impact Value	25.28	26.39	28	23.27	30% Maximum
Aggregate Crushing Value	27.78	28.79	29.3	26.94	30% Maximum

This table indicates that the Los Angeles abrasion value of coarse aggregate from all the sampled crusher plants lies within the limit of IS 383:2016. The standard value defined by IS 383:2016 as the aggregate shall have a Los Angeles abrasion value of not more than 50% in ordinary concrete and 30% in high-strength concrete. Also, it assigned that the aggregate impact value of coarse aggregate from all the sampled crusher plants lies within the limit defined by IS 383:2016. The standard value defined by IS 383:2016 is that the aggregate shall have an aggregate impact value of less than 30%. Similarly, the aggregate crushing value of coarse aggregate from all the sampled crusher plants is within the limit defined by IS 383:2016. The standard value defined by IS 383:2016 is that the aggregate shall have an aggregate impact value of less than 30%.

4. Conclusions

From these test results, it is concluded that the crusher plant running in Syangja district which supplies aggregate from the Aandhikhola source; the gradation of a fine aggregate of all the crusher plants does not lie in the grading zone defined by the IS code. In contrast, the coarse aggregate sample of P1 lies in a 40 mm down envelope, P3 and P4 lie within a 20 mm down single-size envelope, and P2 does not lie in any envelope. Except for particle size distribution, all the physical properties of a fine and coarse aggregate of all the crusher plants lie within the limit of IS 383:2016. In contrast, coarse aggregate crusher plant P2 does not comply with the flakiness and elongation index. The mechanical properties of all the sampled plants comply with the standard value defined by IS 383:2016 The concretes are prepared with coarse and fine aggregate, known as all-in-aggregate. In the case of all-in-aggregate gradation analysis, the material of the P1 crusher plant lies in the 40 mm down all-in-aggregate with the proportion of 60% coarse aggregate and 40% fine aggregate, crusher plant of P2 does not lie in 20 mm and 40 mm down all-in-aggregate with none proportion, crusher plant of P3 lies 20 mm down all-in-aggregate with the proportion of 72% coarse aggregate and 28% fine aggregate, and crusher plant of P4 lies 20 mm down all- in-aggregate with proportion of 55% coarse aggregate and 45% fine aggregate.

5. Recommendations

Conclusively, it is significant to test aggregates to know the quality of their engineering design and economic utilization. The economy of concrete in construction depends upon whether local materials are used or not in maximum quantities. Classification and determination of the quality of aggregates of different sources depend upon their physical, mechanical, strength, or stability characteristics, knowing to which characteristics and types of construction materials to use can be suggested. Also, the findings show that business entrepreneurs should be familiar with the quality of construction materials and whether they meet code provisions or not. For the well-grading of fine and coarse aggregate, they should regulate the average fineness modulus by modifying its gradation. The coarse aggregate of the crusher plant of P2 does not meet the flakiness index as it needs to be 383:2016; proper shaping, sizing, and sieving of coarse aggregate in the cone crusher must be done. In case of grading deficiencies in all-in-aggregate, the necessary adjustments should be made to the grading by adding a single-size aggregate without separating it into fine and coarse aggregates.

In the case of all-in-aggregate, crusher plants of P1, P3, and P4 do not need plant improvement; the coarse aggregate of P2 crusher plants should be suggested to produce less than 40 mm down to meet IS code provision. To use fine aggregate in concrete production, all the crusher plants are suggested to produce finer materials than they are producing these days in such a way that fine aggregates of all the crusher plants must pass from a sieve 4.75 mm retaining maximum of 10% of original weight; sieve of 2.36 mm retaining maximum of 25% of original weight; sieve of 1.18 mm retaining maximum of 35% of original weight, and sieve of 0.60 mm retaining maximum of 24% of original weight in sieve analysis.

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Declaration of Competing Interest

The authors assert that they have no known competing financial attention or personal relationships that could have appeared to compel the work reported in this paper.

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