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# An assessment of aggregate quality from crusher plant as construction material used in Kaski district of Nepal

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## Abstract

Quality refers to the minimum acceptable physical dimensional characteristics as specified in the form of a specification. Quality improvements are essential for any crusher plant or entrepreneur to stay in operation in a competitive business. Aggregates have a significant relation with the strength of the various grades of concrete to optimize the quality and obtain the specific result on the strength of concrete. The aggregate properties play significant role to enhance quality of concrete and its durability. Among various properties of the aggregate, only physical and mechanical properties of coarse and fine aggregates were tested and evaluated. Results showed that coarse and fine aggregates of the crusher plants A, B, and C lie within the specifications defined by standard specifications for road and bridge works - 2073 (with second amendment 2078) of Department of Roads (DoR), Nepal, and the plants of D, E, F, G, H, I, and J does not comply with the standard. The physical and mechanical properties of aggregates complying with the standard help gain strength, durability, and other properties of concrete in concrete mix design.

***Keywords***: *mechanical and physical properties, quality assurance, specification, total quality management, well-graded aggregate*

## 1. Introduction

Concrete is a composite material that is widely used in the construction of infrastructure. Materials used for the preparation of concrete must meet the minimum requirement prescribed in standard, or specifications, or code provision to obtain desired strength. The properties of coarse and fine aggregates must also fulfill the required specification prescribed in the code provision. Aggregates occupy about three-quarters of the total volume of concrete in concrete preparation; therefore, the properties of aggregate affect the durability and performance of the concrete structure. Inert material known as aggregate is not truly inserted because its properties influence the performance of concrete (Neville & Brooks, 2010). The amount of the aggregates used in making concrete usually occupies 60% to 80% of the total volume of concrete; the type and quality of the aggregates decide and affect the properties of concrete. Particles size with a diameter greater than 4.75

mm are usually named as coarse aggregate, and smaller particles are known as fine aggregate (McNally, 1998). The aggregates being used during concrete preparation should have required specification. The quality of the concrete depends upon the quality of the paste and aggregate and the bonding between the aggregate and paste. The presence of different aggregates types on concrete influences compressive strength: with stronger aggregate types increasing the overall strength of the concrete (Larrard & Belloc, 1997). The quality of aggregate determines the performance of concrete. The variation on aggregate properties (mechanical and physical) also influences the property of concrete strength, workability and durability (Prajapati and Karanjit, 2019). The shape of the aggregate particles and its quality, including grading as well-graded aggregate play more vital role on the compressive strength of concrete mixture resulting minimum voids, are important to ensure expected strength of the concrete (Mohammed et al., 2010). Aggregate bearing sound characteristics such as shape, texture, and grading have a significant control on the properties of aggregate and the strength of concrete (Naville and Brooks, 2010; Donza et al., 2002).

For construction of concrete infrastructure, inert materials are obtained mainly in two forms: natural and artificial. This paper focuses on quality of crushed or artificial material only. The manufacturer of crusher plant did not concern about such standards mentioned in the code provisions or specification; ultimately construction activities are delayed due to a conflict in the selection of the required quality of material. This research discusses and pin points on those parameters mentioned in the code and availability of the quality of material in the market. For the research, materials from crusher plant were taken which is used in Kaski district of Gandaki Province, Nepal. Crusher plants were selected on the basis of production capacity greater than 0.5 million cubic meters in each fiscal year and extracted only from the Seti river.

This research is carried out to characterize current quality standards and improvements required, if any, to aware local people, construction entrepreneur and investors of crusher plant on current practices and potential future directions. In Kaski district, concrete is the most commonly used construction material within urban areas for civil construction works such as hydropower dams, buildings, bridges, highways, multistoried buildings and infrastructure development activities. The construction works are carried out by different grade of concrete consuming various types of aggregates. The aggregate properties have influential impact on the fresh and hardened concrete for its performance. The purpose of this study is to find whether coarse and fine aggregates produced from crusher plant as construction material used in Kaski district of Nepal comply with the quality standard and to explore their lacking parameters on quality, if any. The stakeholders of construction team familiar with quality may cost more, but lack of quality costs evens higher. Then it further argues on the need of total quality management in crusher industries.

## 2. Materials and Methods

Kaski district, where coarse and fine aggregates are produced from crusher plants were used as a construction material, has been chosen as study area. The field enquiry and questionnaire survey were done with local contractors, material suppliers and chairman of Crusher Industry Business Operation Committee of Gandaki Province to know about number of crusher plants, name of crusher plants, their production capacities and crushed coarse and fine aggregates being used in Kaski district. The crushed coarse and fine aggregates being used in Kaski district were found to be only from ten crusher plants and are extracted from the Seti river and remaining five crusher plant are supplying their materials only in Tanahun district and are extracted from sources other than the Seti river. There are a total of 15 crusher plants located in Kaski and Tanahun districts of Nepal. Only ten crusher plants were selected which supply construction material in study area on the basis of production capacity of fine and coarse aggregates having production more than 0.5 million cubic meter in each fiscal year extracting from the Seti river.

The overall methodological flow chart adopted in this study is provided in **Figure 1**. Three samples for each test for physical and mechanical properties were collected from ten different crusher plants. Samples were placed in a sealed container to retain moisture until testing. Laboratory tests for the physical and mechanical properties of each sample were carried out in laboratory which is calibrated and certified by the Government of Nepal, Nepal Bureau of Standards for material testing. In this study, the physical and mechanical properties of coarse and fine aggregates of sampled crusher plants were tested, the average value as obtained from three samples was calculated, and compared with the standard value provided on code or standard specifications for road and bridge works - 2073 (with second amendment 2078) of the Department of Roads (DoR), Nepal.

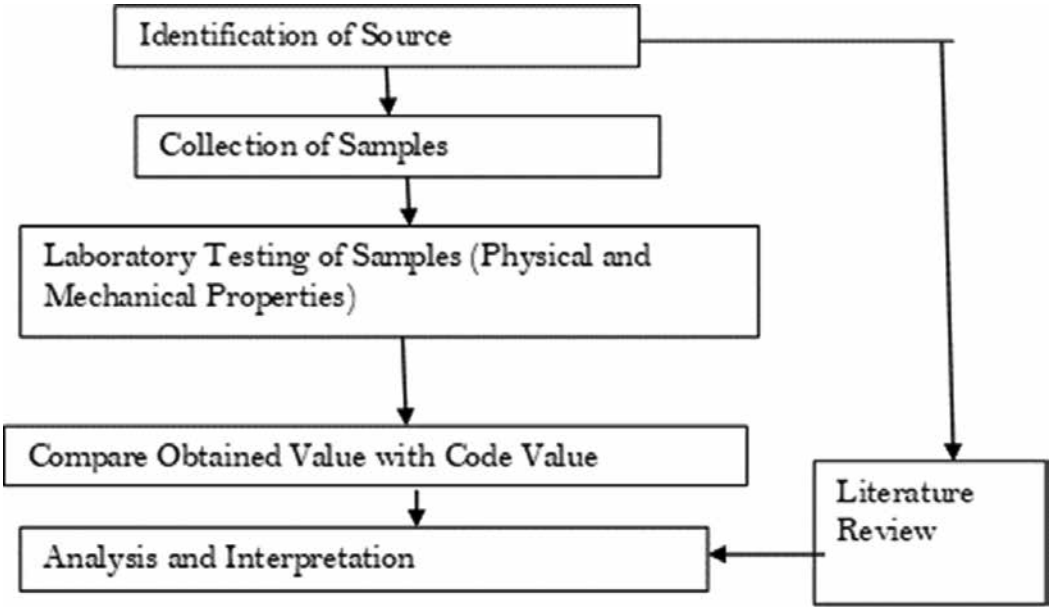


**Figure 1:** Methodological flowchart of this study

Quantitative approach was applied in laboratory tests carried to evaluate and examine the physical properties of fine and coarse aggregates and mechanical properties of coarse aggregates. Fine and coarse aggregates' samples were collected as per IS:383-1970 specification for coarse and fine aggregates from natural sources of concrete as defined in Manual for Standard Tests - 2016 of Department of Roads, Nepal. The laboratory test for physical properties of the sample such as gradation of fine and coarse aggregates, clay lumps of fine and coarse aggregates, finer than 75 microns of coarse and fine aggregate, specific gravity and water absorption of fine and coarse aggregates, and flakiness index of coarse aggregates were carried out as per test procedure specified in the Manual for Standard Tests - 2016 of Department of Roads. The laboratory tests for mechanical properties of sample such as Los Angles Abrasions Test, aggregate impact test, and aggregate crushing test of coarse aggregate were carried out as per the method and test procedures specified in the Manual. Samples from each crusher plant were coded as A - Dhorbarahi Crusher Plant, B - Faurish Crusher Plant, C - Akala Crusher Plant, D - Shiva Shanti Crusher Plant, E - Shiva Shakti Crusher Plant, F - Khanal Crusher Plant, G - Harati Crusher Plant, H - Kharel Crusher Plant, I - Quality Crusher Plant, and J - Barahi Crusher Plant for ethical research and confidentiality of data obtained from the laboratory testing. All the laboratory testing was conducted under normal temperature and pressure of laboratory and seasonal variation on properties. The geological properties of aggregate sample was not taken into consideration.

## 3. Results and Discussion

### 3.1 Physical properties of fine and coarse aggregate

*3.1.1 Gradation*

Grading of aggregates means particle size distribution of an aggregate as determined by sieve analysis in which the particles are divided into their various sizes by standard sieves is termed as grading of the aggregate. Basic reasons for grading of aggregate is that small size particles fill up the voids left or made by the larger size aggregates.

According to Standard Specifications for Road and Bridge Works - 2073 (with second amendment - 2078), grading requirement for fine aggregate size lies between 10 mm to 0.15 mm sieve. The gradation of fine aggregate is depicted in Figure 2. The gradation of fine aggregate of crusher plants A, B, C, and D are within the limit as prescribed by the Standard and that of E, F, G, H, I, and J do not comply with the Standard. The specification (with amendment) specified that fine aggregate should be in limit zone II of IS code 383-1970 specifications for coarse and fine aggregates from natural sources for concrete (second revision).

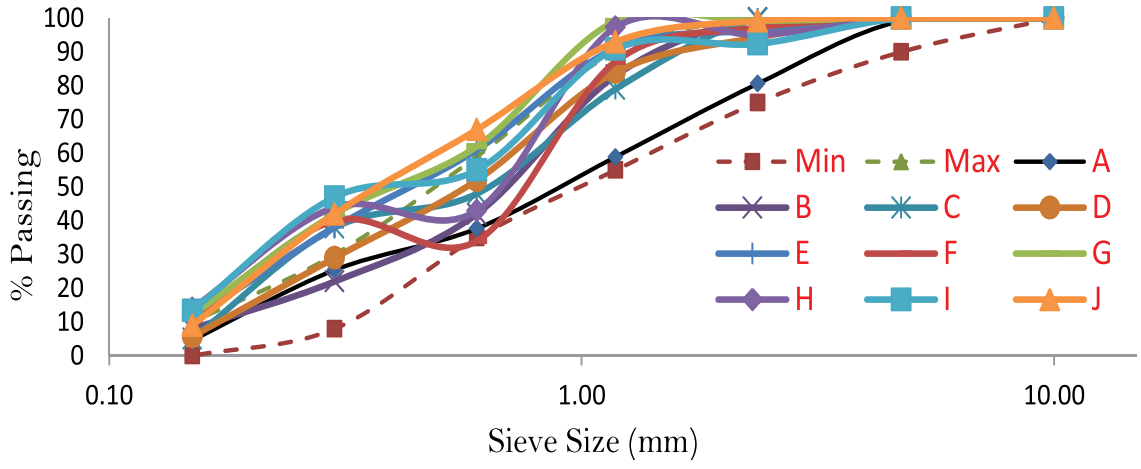


**Figure 2:** Gradation of fine aggregates of sample crusher plant

Aggregate size that lies between 20 mm to 4.75 mm sieve is coarse aggregate. It is used in structural concrete. The gradation of coarse aggregate in this study is provided in Figure 3. It shows that plants A, B, C, and F comply with the Standard (i.e., lie on the 20 mm down aggregate) but the plant of D, E, G, H, I, and J do not comply. The Standard Specifications for Road and Bridge Works-2073 (with second amendment - 2078) specified that the coarse aggregate should be in limit of 20 mm down for structural concrete. Well-graded aggregates enhance better result in greater workability and durability of concrete. In concrete mix proportions, the well-graded aggregates pack together efficiently, thus reducing the volume between aggregates particles that must be filled by cement paste.

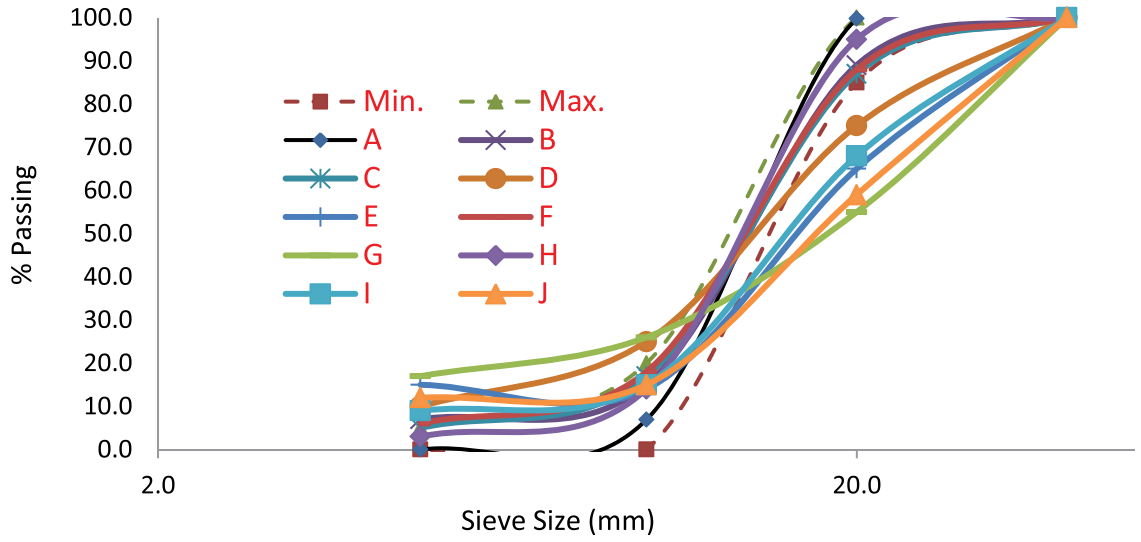


**Figure 3:** Gradation of coarse aggregate of sample crusher plant.

*3.1.2 Clay lumps in coarse and fine aggregate*

Clay lumps in aggregates are any particles or aggregate which can be broken into finely divided particles with the fingers is termed as clay lumps. These particles when immersed in water for a short time period can be distorted when squeezed between the thumb and forefinger or may disintegrate into individual grain sizes.

The average value of clay lumps in coarse aggregate of each sample is given in Table 1. The average value of clay lumps of the coarse aggregate of all crusher plants lies within the limit as defined in the Standard, i.e., less than 1%.

**Table 1:** Clay lumps in coarse aggregate of sample crusher plants

| **Description** | **Clay Lumps in Coarse Aggregate** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J |
| Average Value (%) | 0.38 | 0.26 | 0.21 | 0.25 | 0.34 | 0.33 | 0.31 | 0.29 | 0.25 | 0.20 |
| Standard Value (%) | Less than 1 | | | | | | | | | |

The average value of clay lumps in fine aggregate of each sample is provided in Table 2. The average values of clay lumps of the fine aggregate of crusher plant of A, B, C, D, E, F, G, and H lie within the limit whereas samples of the crusher plant I and J do not lie within the limit as specified by the Standard, that is less than 1%.

**Table 2:** Clay lumps in fine aggregate of sample crusher plant

| **Description** | **Clay Lumps in Fine Aggregate** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J |
| Average Value (%) | 0.88 | 0.81 | 0.88 | 0.80 | 0.79 | 0.77 | 0.84 | 0.82 | 1.2 | 1.29 |
| Standard Value (%) | Less than 1 | | | | | | | | | |

*3.1.3 Materials finer than 75 microns of coarse and fine aggregates*

The material passing the 75-micron IS sieve constitutes clay and silt particles in most cases. The size of silt lies between 0.06 mm to 0.002 mm whereas that of size of the clay smaller than 0.002 mm. Those materials finer than 75 microns are considered undesirable as constituents in aggregates because of their fineness and other physical characteristics which affect strength, workability, concrete durability, water demand and shrinkage in concrete. It also promotes negative impacts on quality of concrete.

The average value of coarse aggregate finer than 75 micron of each sample is tabulated in Table 3. Coarse aggregates from all the crusher plants lie within the limit of finer particles smaller than 75 micron. The standard value of coarse aggregate finer than 75 micron is 3% at maximum.

**Table 3:** Coarse aggregate finer than 75 micron of sample crusher plants

| **Description** | **Coarse Aggregate Finer than 75 Micron** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J |
| Average Value (%) | 1.28 | 1.25 | 1.15 | 1.10 | 1.17 | 1.11 | 1.19 | 1.26 | 1.28 | 1.24 |
| Standard Value (%) | Less than 3 | | | | | | | | | |

The average value of fine aggregate finer than 75 micron of each sample is presented in Table 4. Fine aggregates from all the crusher plants lie within the limit of finer particles smaller than 75 micron. The standard value of fine aggregate finer than 75 micron is 15% at maximum.

**Table 4:** Fine aggregates finer than 75 micron of sample crusher plant

| **Description** | **Fine Aggregate Finer than 75 Micron** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J |
| Average Value (%) | 1.9 | 1.85 | 1.92 | 1.76 | 1.82 | 1.88 | 1.7 | 1.45 | 6.2 | 6.7 |
| Standard Value (%) | Less than 15 | | | | | | | | | |

*3.1.4 Specific gravity and water absorption of coarse and fine aggregates*

The specific gravity of an aggregate is the ratio of the mass or weight of a solid in a given volume of sample to the mass or weight of an equal volume of water at the same temperature. Specific gravity of an aggregate measures the strength or quality of material. Aggregates of low specific gravity are generally weaker than those with higher value of specific gravity. Water absorption of coarse and fine aggregates defines percentage of water absorption by weight as well as by volume. It is also used to define percentage of porosity. The percentage increase in weight between dry aggregate and the saturated aggregate gives water absorption value for aggregates. Therefore, the water absorption value is the amount of water able to be hold by aggregate; that is, water holding capacities of aggregate. The percentage of water absorbed by an aggregate when immersed in water is defined as water absorption of aggregate. The average value of specific gravity and water absorption of coarse and fine aggregates is tabulated in Table 5. It shows that water absorption and specific gravity of coarse aggregates of all the crusher plants lie within the limit as per the Standard, i.e., specific gravity lies within 2.5 - 3 and water absorption have values less than or equal to 2%.

**Table 5:** Specific gravity and water absorption of coarse aggregate

| Description | Average Value of Specific Gravity and Water Absorption of Coarse Aggregate | | | | | | | | | | Standard Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J | |
| Specific Gravity | 2.64 | 2.66 | 2.61 | 2.61 | 2.67 | 2.65 | 2.64 | 2.63 | 2.63 | 2.67 | 2.5-3 |
| Water Absorption (%) | 0.7 | 0.77 | 0.81 | 0.89 | 0.82 | 0.91 | 0.85 | 0.88 | 0.84 | 0.83 | 2 |

Table 6 reveals that water absorption and specific gravity of fine aggregate of all crusher plants lie within the limit as per the Standard, that is, specific gravity lies within 2.5 – 3 %, and water absorption has a maximum value of 5%.

**Table 6:** Specific gravity and water absorption of fine aggregate

| Description | Average Value Specific Gravity and Water Absorption of Fine Aggregate | | | | | | | | | | Standard Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Code No. | A | B | C | D | E | F | G | H | I | J | |
| Specific Gravity | 2.62 | 2.64 | 2.59 | 2.57 | 2.65 | 2.63 | 2.61 | 2.60 | 2.59 | 2.64 | 2.5-3 |
| Water Absorption (%) | 1.26 | 1.3 | 1.29 | 1.25 | 1.24 | 1.36 | 1.15 | 1.28 | 1.26 | 1.28 | 5 |

*3.1.5 Flakiness index of coarse aggregate*

Flaky aggregates are those aggregates whose thickness is small when comparing with width and length of that aggregate. In other words, when the least dimensions of aggregate is less than the 60% of its mean dimension, than it is called flakey aggregate. The average value of flakiness index of coarse aggregate is shown Table 7. The flakiness Index of coarse aggregate from crusher plants A, B, C, F, G, and J lie within the limit, and coarse aggregate from crusher plants D, E, H and I do not lie within the limit as defined by the Standard. The standard value of the Flakiness Index of coarse aggregate is 25% maximum.

**Table 7:** Flakiness index of coarse aggregate

| Description | Average Value of Flakiness Index of Coarse aggregate | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Code No | A | B | C | D | E | F | G | H | I | J |
| Average Value (%) | 21 | 21 | 25 | 28 | 27 | 22 | 21 | 29 | 28 | 25 |
| Standard Value (%) | Maximum 25 | | | | | | | | | |

## 3.2 Mechanical properties of coarse aggregate

Those properties which govern the behavior of coarse aggregate when external forces are applied. The indexes of coarse aggregate which attribute the resistance of a construction material to a load acting on it during the process of failure indicates as the degree to which it may deform under the load and its behavior. The rate at which development of the process of failure takes place may be under a static load or repeated load. The mechanical properties of coarse aggregate are determined making representative specimens of required and standard shapes for mechanical test. Los Angeles Abrasion Value, Impact Value, and Crushing Value are the mechanical properties of coarse aggregate. The mechanical properties of coarse aggregate are tabulated in Table 8.

**Table 8:** Mechanical properties of coarse aggregate

| Description | Average Value of Sample Material at Different Crusher Plants | | | | | | | | | | Standard Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| Los Angles Abrasion Value | 27 | 30 | 28 | 25 | 24 | 28 | 29 | 26 | 24 | 28 | 35-45 % Maximum |
| Aggregate Impact Value | 24 | 25 | 25 | 22 | 20 | 24 | 26 | 21 | 21 | 24 | 30-45 % Maximum |
| Aggregate Crushing Value | 23 | 22 | 24 | 20 | 21 | 21 | 22 | 20 | 20 | 22 | 30-45 % Maximum |

This table attributes that Los Angles Abrasion value of coarse aggregate from all the sampled crusher plants lie within the limit defined by the Standard, that is not more than 45% in ordinary concrete, and not more than 35% in high quality concrete. Furthermore, aggregate impact value of coarse aggregate from all the sampled crusher plants lie within the limit defined by the Standard, that is, not more than 30% for pavement structure and not more than 45% for other structures. Similarly, the aggregate crushing values of coarse aggregate from all the sampled crusher plants are found to be within limit defined by the Standard, that is, not more than 30% for pavement structure, and not more than 45% for other structures.

## 4. Conclusions

The business of crusher plants, their survival, and success depends on supplying of quality construction material and their commitment to quality. Today's quality is not quality for tomorrow; so, continual improvement is needed to achieve customer and society satisfaction as a whole. From this study, it can be concluded that out of ten crusher plants of coarse and fine aggregates in the Kaski district, only four (i.e., 40%) comply with the specification (only on gradation) as prescribed by the Standard Specifications for Road and Bridge Works - 2073 (with second amendment - 2078). The fine and coarse aggregates from remaining six (i.e., 60%) crusher plants do not meet the Standard on gradation. Similarly, out of ten crusher plants, only crusher plants A, B, and C (i.e., three or 30%) fulfill quality requirements for all physical and mechanical parameters of fine and coarse aggregate as defined in the Standard but remaining (i.e., 70%) fail in one or more parameters such as on gradation, clay lumps, finer than 75 micron, and flakiness index.

The factual information revealed in this study implies that the implementing agency should be familiar with quality compliance of construction materials. It sets a convincing ground to formulate and implement total quality management framework and associated strategies for ensuring quality of construction materials for accelerated and sustainable infrastructure development in Nepal. Examples of some of the strategies could be internal quality testing, quality surveillance, quality assurance, and quality audit to get total quality management of the products. Requirements may vary among crushers. For example, plants D, E, G, H, I, and J need to add finer materials to obtain desired range described by the Standard for gradation of coarse aggregate. Whereas the fine aggregate from crusher plants E, F, G, H, I, and J need to be washed properly before supplying the material to the customer.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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