Effect of Coarse Aggregate Size Variation on Compressive Strength of Concrete along the Length of Kali Gandaki River

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Abstract

The Kali Gandaki River is renowned for its diverse geological composition, providing a unique opportunity to examine how the inherent characteristics of coarse aggregates impact concrete performance in terms of compressive strength. This research delved into the influence of varying coarse aggregate sizes on the compressive strength of concrete obtained from different points along the Kali Gandaki River. Multiple samples of coarse aggregates were gathered from distinct geological regions along the river. The study adopted a concrete mix design for M20, and concrete cubes were manufactured with coarse aggregate sizes ranging from 10mm-16mm, 16mm-20mm, 20mm-25mm, to 25mm-31.5mm. All sample sets underwent compressive strength testing after 7 and 28 days of curing.The results revealed that, under identical curing conditions and water-cement ratios, the compressive strength of the produced concrete increased with the aggregate size, reaching a peak at 25mm. Additionally, among the surveyed locations, namely Ramdi Ghat, Khada Ghat, Pakhichaur Hungi Ghat, and Belchaur Ghat, Belchaur Ghat exhibited superior performance in compressive strength. The findings of this work aim to contribute valuable insights to the field of concrete technology and construction industry.

Keywords : *Compressive strength, Seive analysis, Specific gravity, Void ratio, Heterogeneity*

Introduction

Concrete, a fundamental construction material, derives its strength and durability from a combination of various components, with coarse aggregates playing a pivotal role. The properties of these aggregates, including size, shape, and geological origin, significantly influence the performance of concrete in terms of compressive strength.The Kali Gandaki River serves as a natural source of coarse aggregates, with gravel, sand, and rocks deposited in its bed over time. This abundance makes it a readily accessible resource for construction purposes. The coarse aggregates extracted from the Kali Gandaki River play a pivotal role in the development of major infrastructure projects within the region. The Kali Gandaki River flows through diverse geological terrains, presenting a unique opportunity to explore the impact of varying coarse aggregate sizes on the compressive strength of concrete sourced from different locations along its length. The significance of understanding this relationship lies in its potential to enhance the precision of concrete mix designs in regions characterized by geological heterogeneity. The variations in the riverbed composition along the Kali Gandaki

River offer a natural laboratory for studying how geological differences in coarse aggregates influence the mechanical properties of concrete.

This research seeks to address a critical knowledge gap in the field of concrete technology, providing valuable insights for engineer, construction professionals and researchers engaged in the development of durable and high-performance concrete structures. The implications of this study extend beyond academic curiosity, holding practical significance for sustainable and resilient infrastructure development.

Literature Review

Various studies have investigated the impact of different coarse aggregate sizes on the compressive strength of concrete. Many Research often suggested that there exists an optimal range of coarse aggregate sizes for maximizing compressive strength. The study conducted by Ndon and Ikpe (2021) provided valuable insights into the relationship between coarse aggregate size and compressive strength in concrete. The findings of the research consistently demonstrated that as the size of coarse aggregates is increased, there is a corresponding increase in compressive strength. Similarly The research conducted by Ogundipe et al. (2018) on the variation of aggregate size and its impact on the compressive strength of concrete had revealed a noteworthy trend, indicating that compressive strength exhibited an increase with the augmentation of coarse aggregate size, specifically up to the 20mm aggregate size. Contrary to previously stated research, the research conducted by Woode et al. (2015) on the relationship between coarse aggregate size and compressive strength in concrete had yielded different insights. The findings of the study suggested that compressive strength exhibits a decrease with an increase in coarse aggregate size. This departure from the conventional understanding raises important considerations for concrete mix design. Such insights challenge conventional assumptions and underscore the complexity of the interactions between aggregate characteristics and concrete properties. It stimulates critical thinking in the field of concrete technology and provides a basis for ongoing discussions and investigations into optimizing concrete mix designs. Based on a thorough examination of existing research and pertinent literature, it becomes apparent that a consensus regarding the impact of aggregate size on concrete strength has not been universally reached. Divergent views exist, with certain researchers asserting a direct correlation between aggregate size and concrete strength, while others present conflicting findings. 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 Kali Gandaki River. Therefore, there is need of study that specifically tailor the investigations to the unique characteristics of the river's geological formations.

Problem Statement and Objective of the Study

Concrete is a fundamental construction material used extensively in infrastructure projects, and its performance is influenced by various factors, including the size and location of coarse aggregates. The Kali Gandaki River is a critical source of coarse aggregates for construction. However, there is a growing need to understand the impact of variations in aggregate sources within the river on the compressive strength of concrete. The effectiveness of concrete as a construction material depends on its compressive strength, and this, in turn, is closely linked to the characteristics of its coarse aggregates. While the Kali Gandaki River provides a readily available source of aggregates for construction in the Syangja District, there is a lack of comprehensive research that investigates how variations in aggregate sources and sizes within the river affect the compressive strength of concrete. So this research is necessary to determine whether there is a significant variation in the quality and characteristics of coarse aggregates sourced from different points within the river, and how these variations impact concrete strength do. The objective of this study is to access the physical and mechanical properties of coarse aggregates and study the effect of coarse aggregates size variations on the compressive strength of concrete from selected locations along the length of Kali Gandaki River.

Methodology

The methods used in experimental research study plays a critical role in providing a roadmap for how the research is designed, conducted, and analyzed. It ensures transparency and replicability, allowing others to understand and potentially reproduce the study. It serves as a robust approach to test hypotheses and establish causal relationships between variables. In this section, there is detailed blueprint that elucidates the procedures, techniques, and rationale employed throughout the research process. Starting from the field visit to the final preparation of research report, the steps are as follows:

Stage I: Field Visit and Sample Collection

A field investigation was conducted to gain a broad understanding of the primary source of coarse aggregates utilized in construction projects within the Syangja district.Among these sources of coarse aggregates, following four sources (Ramdi Ghat-A, Khada Ghat-B, Pakhichaur Hungi Ghat-C, Belchaur Ghat-D) of coarse aggregates are selected for the research work.

Table 1: Latitudes and Longitudes of Sources

Source Name	Lalitude	Longitude
Ramdi Ghat-A	27.900447°	83.634361°
Khada Ghat-B	27.918166°	83.664206°
Pakhichaur	27.919051°	83.714125°
Hungi Ghat-C Belchaur Ghat-D	27.901514°	83.746053°

Stage II: Physical and Mechanical Properties of Coarse Aggregates

Physical, and mechanical properties of coarse aggregate samples are evaluated as per IS: 383-2016. The physical properties are assessed through standardized tests outlined in IS 2386 (Part 1): 2016. The mechanical properties evaluation involved conducting experiments on compression strength, impact resistance, and abrasion resistance, adhering to the methodologies prescribed in IS 2386 (Part 4), IS 2386 (Part 5), and IS 2386 (Part 6) respectively. The testing apparatus and conditions strictly follow the specifications provided in the Indian codes.

Stage III: Concrete Cubes Casting and Compression Test

The proportion of various size of aggregate passing from the seive will be as follows:

Table 2: Percentage of Aggregate Sizes

	Percentage of Aggregates					
Aggregate Combination Code	Code as per source	4.75-10mm	10-16mm	16-20mm	20-25mm	25-31.5mm
1	A1,B1,C1,D1		100			
2	A2,B2,C2,D2			100		
3	A3,B3,C3,D3				100	
4	A4,B4,C4,D4					100
5	A5,B5,C5,D5	20	20	20	20	20

The concrete cube was casted from mix design process with characteristic strength of 20Mpa keeping coarse aggregate sample as variable . Water /cement ratio being maintained was 0.5 Chhetri(2021). Shivam Cement Factory's 43 Grade Ordinary Portland Cement was utilized in the process. The sand was sourced from Ramdi Ghat of the Kali Gandaki River, and ordinary tap water from the Civil Engineering lab at Paschimanchal Campus was used for mixing. After obtaining compression test data, statistical analysis of the obtained data are performed to derive meaningful correlations and insights.

Results and Discussions

After site visit, the elevations of the site, distances between the sections were noted and are shown in the table 3. Similarly the result from the seive analysis is shown below. Similarly specific gravity, water absorption, LA Abrasion Value, Aggregate Crushing Value, Aggregate Impact Value from the test are shown below.

Table 3: Average slope between locations

Source Name	Elevation(m)	Distance(km)	Average Slope
Ramdi Ghat	395	-	-
Khada Ghat	391	5.05	0.079%
Pakhichaur Hungi Ghat	378	7.15	0.181%
Belchaur Ghat	364	4.95	0.282%

From the table 3, we can see a series of locations (Ghats) along with their elevations, distances from the previous location, and the average slope between each location. Ramdi Ghat is taken as the reference location for our study with an elevation of 395 meters. The average slope values are relatively small, indicating gradual changes in elevation over the specified distances. The average slope is calculated by dividing the change in elevation by the distance , expressed as a percentage. It gives an indication of how much the elevation changes over a certain distance.

Table 4: Lab results of mechanical properties of aggregates

Sources	Specific Gravity	Water Absorption	LA Abrasion Value	Aggregate Crushing Value	Aggregate Impact Value	Elongation Index	Flakiness Index
A	2.61	0.58%	17%	20%	14%	28%	24%
B	2.64	0.56%	14%	17%	12%	25%	21%
C	2.68	0.53%	13%	17%	11%	24%	20%
D	2.71	0.51%	11%	16%	9%	21%	17%

Figure 1: Water Absorption of Coarse Aggregates From Various Locations

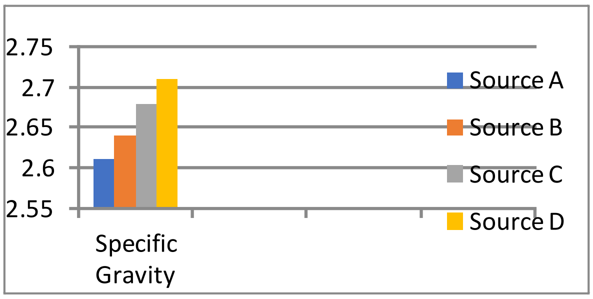
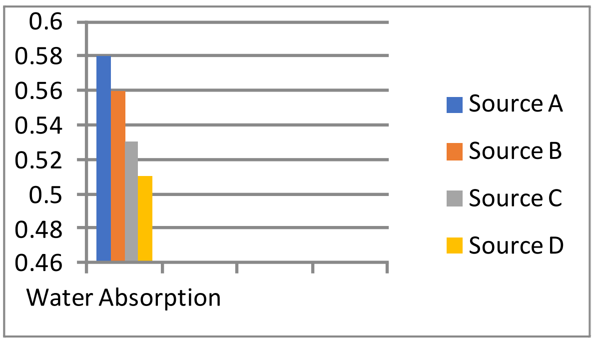


Figure 2: Specific Gravity of Coarse Aggregates From Various Locations



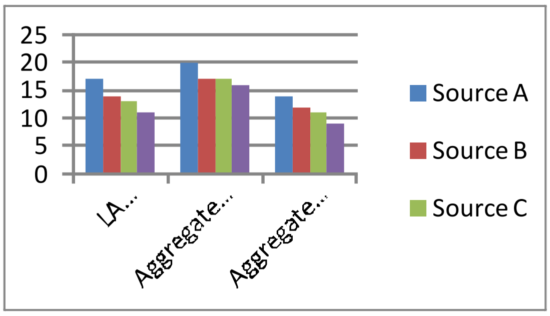
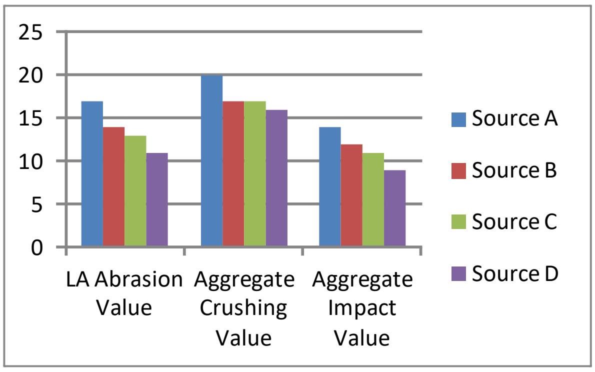


Figure 3: Mechanical Properties of Coarse Aggregates from Various Locations



From the figures we can see that the physical and mechanical properties of aggregates is improving as we move towards downstream of the river. This is due to the fact that gravel, transported by the movement of water, undergoes interactions with various geological boundaries, resulting in surface abrasion and contributing to its increased hardness and smoother texture.

Sand is used from Ramdi Ghat as fine aggregate and tested as per IS 383: 2016. The sand conforms to Zone II, the test results are shown in the table 5.Similary, the study showed that the specific gravity of sand used was found to be 2.51 as shown in table 6.

Fine Aggregate:

Table 5: Seive Analysis of Sand

Seive Size(mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Weight Passed (gm)	% Passed	% Permissible Values as per IS 383-2016 (Table 9) Grading Zone II
4.75	13	10	1862.6	95.81	90-100
2.36	25	35	1600	82.30	75-100
1.18	45	80	1425	73.30	55-90
0.6	578	658	1072	55.14	35-59
0.3	695	1353	595	30.60	58-30
0.15	435	1788	152.7	7.85	0-10
Pan	153				
Total Weight	1944				

Table 6: Specific Gravity Test of Sand

Symbol	Description	Weight (gm)
W1	Weight of Pycnometer	192.20
W2	Weight of Pycnometer + Dry Sand	463.20
W3	Weight of Pycnometer + Sand + Water	926.00
W4	Weight of Pycnometer + Water	715.40
Specific Gravity	=((W2-W1)/(W4-W1)-(W3-W2))=2.51	

Compressive Strength Test

The mix design of M20 grade concrete was based on the Indian Standard IS 10262 and IS 456 from the mix design we get final mix proportion as 1: 2.055: 3.283(Cement: Fine aggregates: Coarse aggregates) at 0.55 w/c ratio. Concrete cubes were prepared for each location A, B, C, D, E and aggregates combinations were done as per discussed in Table 2.Foe each locations with specific aggregate size proportions, 3 samples were prepared. The result of compressive strength for each type of aggregate sample is shown in Fig.4 and Fig.5

Table 7: Compressive Strength Test Results

Sources	Cube Test Results				
	7 Days Compression Test				
N	1	2	3	4	5
A	15.11	15.99	16.18	16.01	16.71
B	15.76	16.79	16.98	16.79	17.51
C	16.77	17.72	17.90	17.76	18.64
D	17.06	18.04	18.25	18.11	18.89
	28 Days Compression Test				
A	24.42	25.84	26.16	25.85	27.16
B	25.48	27.12	27.52	27.16	28.33
C	27.09	28.69	28.96	28.70	30.16
D	27.62	29.19	29.57	29.25	30.52

Fig 4: 7 Day Compressive Strength

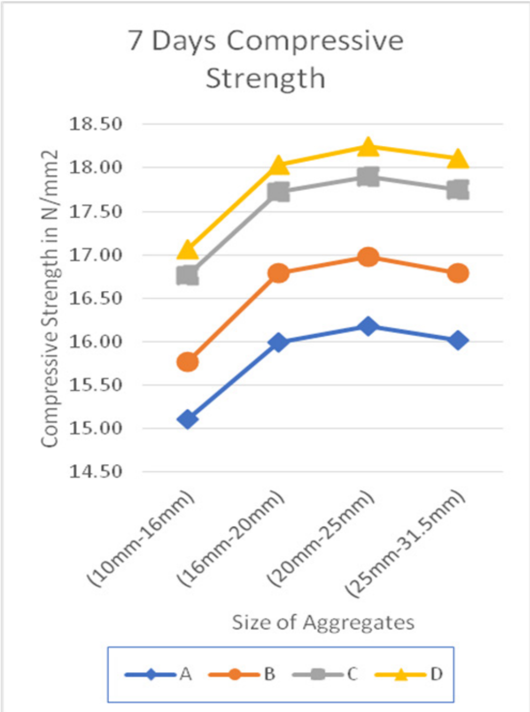
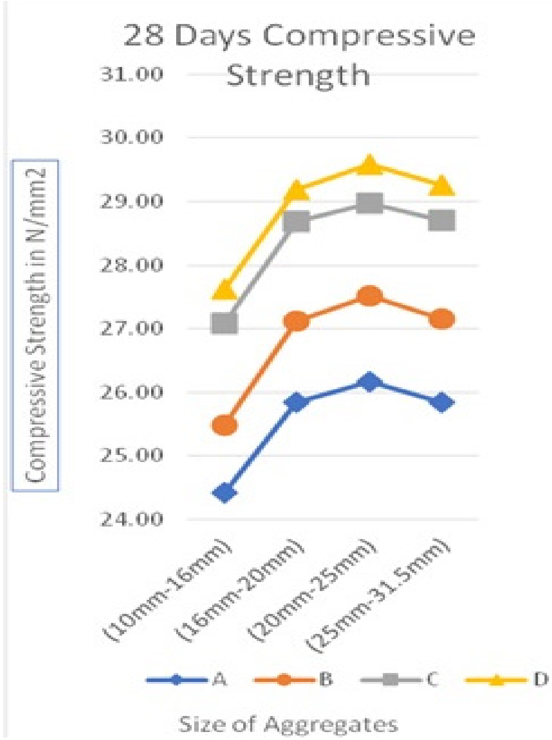


Fig 5: 28 Days Compressive Strength



The compressive strength outcomes for all specimens are depicted in Fig 4 and Fig 5, as well as presented in Table 7.It showed a notable augmentation in compressive strength with an increase in the size of coarse aggregates up to 25mm. This phenomenon can be attributed to the reduction in the surface area of coarse aggregates as their size increases in concrete. Consequently, the amount of bonding material per unit surface area rises, leading to elevated bond stress and, consequently, an increase in the compressive strength of the concrete. Therefore, it is shown that the optimal maximum coarse aggregate size for the mix in this investigation is approximately 25mm. Conversely, surpassing the 25mm, there is greater impact of heterogeneity, leading to a decline in compressive strength.

Statistical analysis for coarse aggregate size variation for 28 days compressive strength

Table 8: One Way ANOVA for Studying Effects of Coarse Aggregate Size Variations of Belchaur Location with 28 days Compressive Strength of Concrete

D1	D2	D3	D4	D5
26.81	29.11	30.23	30.18	32.12
27.52	28.56	28.93	28.42	29.26
28.52	29.89	29.56	29.16	30.16
Groups	Count	Sum	Average	Variance
D1	3	82.85	27.61	0.73
D2	3	87.56	29.18	0.44
D3	3	88.72	29.57	0.42
D4	3	87.7614	29.25	0.78
D5	3	91.54	30.51	2.13
Analysis Result				
Source of Variation	SS	df	MS	F

Between Groups	13.11	4	3.27	3.62
Within Groups	9.05	10	0.90	
Total	22.16	14		

The examination of compressive strength tests at 7 days and 28 days revealed that the Belchaur site exhibited the highest compressive strength. Accordingly, for the Belchaur location, a single-factor or one-way ANOVA analysis was employed to assess the null hypothesis, which posited that variations in coarse aggregate size have no impact on the compressive strength of the M20 design mix. However, the null hypothesis is rejected since the critical F value is less than the calculated F value, as illustrated in the table below. Consequently, it can be concluded that fluctuations in coarse aggregate size significantly influence the 28 days compressive strength.

Conclusions

The mechanical and physical properties of the coarse aggregate from Kali Gandaki River improved from upstream to downstream starting from Ramdi ghat to Belchaur ghat. This improvement was attributed to the interaction of gravel with different geological boundaries during its transportation by flowing water, causing the removal of weaker parts and surface wear and tear, making it harder and smoother.The compressive strength exhibited an upward trend with an increase in the size of coarse aggregates. This phenomenon was attributed to the reduction in the surface area of coarse aggregates as their size in concrete increased. Consequently, the quantity of cementing material per unit surface area increased, leading to heightened bond stress and, therefore, an elevation in the compressive strength of the concrete. This study indicated that the optimal coarse aggregate size for the mix was within the range of 20-25 mm. Conversely, when the size of coarse aggregates exceeded 25mm, there was a more pronounced impact of heterogeneity, resulting in a decline in compressive strength.

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