# Comparative Analysis between Crushed Aggregate from Siwalik, Lesser Himalaya and River-Bed Sources in Bagmati Region: Adopting M25 - Plain, Steel Fiber and Glass Fiber Shotcrete

Shiv Prasad Upadhyay[1] and Sudhan Kumar Subedi[2,*]

[1]Lumbini International Academy of Science and Technology, Lalitpur, Nepal
[2,*]Central Department of Geology, Tribhuvan University, Kritipur, Kathmandu, Nepal

(*Corresponding E-mail: subedisudhan227@gmail.com)

**Abstract: The escalating demand for aggregates in Nepal, driven by rapid urbanization and infrastructure development, presents significant challenges as natural resources are depleting and disrupting river ecosystems. This research examines the properties of shotcrete produced from various aggregate sources, specifically Siwalik, Lesser Himalayan, and riverbed crushed aggregates and also various composition like plain, glass fiber and steel fiber shotcretes. Key performance indicators—including air content, slump (workability), compressive strength, and flexural strength—were analyzed according to established standards. Results indicated that Lesser Himalayan crushed aggregates provided superior workability, compressive strength, and flexural strength, making them the most suitable option for high-performance applications. In contrast, riverbed aggregates showed limitations that could impact structural integrity and ecosystem. Moreover, compositionally, steel fiber shows the superiority in comparison to plain and glass fiber shotcrete. This study underscores the importance of selecting high-quality aggregates to enhance the durability and sustainability of construction projects in Nepal, advocating for the adoption of crushed rock aggregates to mitigate environmental impacts while fulfilling infrastructure needs. Future research should further explore the long-term performance and environmental implications of these materials.**

**Keywords:** ***Crushed aggregates, Shotcrete, Compressive strength, Flexural strength, Slump test, Air content.***

## Introduction

The escalating demand for aggregates in Nepal, driven by rapid population growth and infrastructure development, highlights the critical role of these materials in construction applications like concrete and shotcrete. Natural quarries of sand and gravel are insufficient to meet this rising demand, leading to significant disturbances in river ecosystems. This situation necessitates the exploration of sustainable alternatives, such as crushed rock aggregates, to supplement dwindling natural resources and support infrastructure development while minimizing environmental impacts. Over-extraction of traditional aggregate sources contributes to erosion, habitat destruction, and altered river dynamics. Therefore, high-quality aggregates are essential for the durability and longevity of civil engineering projects, influencing the structural integrity of buildings, roads, slopes, bridges, and tunnels. Understanding the properties of different aggregate sources is crucial for optimizing spray-concrete/shotcrete performance and ensuring sustainable development practices in Nepal. As the country continues to urbanize, adopting crushed rock aggregates could promote environmental sustainability while meeting the growing construction demands effectively. This research aims to compare various properties of shotcrete obtained from different aggregate sources: Siwalik, Lesser Himalayan Zone, and riverbed crushed aggregates; along with different mode of composition using Plain, Steel Fiber and Glass Fiber. The study focuses on analyzing key properties such as air content, slump (workability), compressive strength, and flexural strength of the shotcrete. By evaluating these properties, the research seeks to identify the most suitable aggregate source for shotcrete applications in Nepal, promoting better performance and sustainability in construction project and practices.

## Methodology

Materials used in this study were as follows:

- Aggregates: Siwalik crushed aggregates, Lesser Himalayan crushed aggregates, River-bed crushed aggregates.
- Cement: Ordinary Portland Cement (OPC)-43 Grade was used as per standard specifications.
- Water: Clean, portable water was utilized for mixing and curing.
- Additives: Chemical admixtures used as required for improving workability and performance.
- Superplasticizer: High grade PC chemicals where used source name is SBT Chemicals.

- Accelerator: Alkali Free accelerator is used source name is SBT Chemicals.
- Steel Fiber: Double hooked having and length of 0.60/30mm is used source name is Earth Fiber Pvt. Ltd.
- Glass Fiber: Glass fiber is used source name is Earth Fiber Pvt. Ltd.

Samples of shotcrete were prepared according to the guidelines provided in IS 456:2000, IS 10262-2019, SSFRB-2078, and IS 9012. The preparation involved:

- Cubic Samples for Compressive Strength: Cubes of size 10 cm x 10 cm x 10 cm were cast to evaluate compressive strength.
- Beam Samples for Flexural Strength: Beams of size 140 cm x 10 cm x 10 cm were cast for flexural strength testing (based on laboratory trial).

### *Testing Procedures*

Workability Measurement (Slump Test): The slump cone test method was employed to assess the workability of the wet shotcrete (spray-concrete) mix. A fixed water-cement ratio was maintained according to the mix design guidelines (IS) for consistent results.

- Compressive Strength Testing: The compressive strength was evaluated at intervals of 1,3, 7, and 28 days using a compressive testing machine.
- Flexural Strength Testing: The flexural strength was tested after 28 days of curing, measuring the load at which the beam fails; using a universal testing machine.
- Air Content Measurement: The air content was measured using an appropriate method to evaluate the influence of different aggregates on the air voids in the concrete mix.

## Results and Discussion

Lesser Himalayan (Quartzite, Metasandstone) crushed aggregates produced a higher slump, indicating better workability, likely due to their angular shape and gradation; as similar to the river-bed crushed aggregates, while Siwalik's aggregates exhibited moderate workability, suggesting challenges in achieving the desired flow and application of shotcrete. In addition, Steel Fiber Shotcrete shows better compressive strength in comparison to Plain and Glass Fiber Shotcrete in respective sequence. The water-cement ratio significantly influenced workability, emphasizing the importance of appropriate mix design to ensure optimal performance in shotcrete applications.

### *Compressive Strength*

The compressive strength results indicated variations based on aggregate type:

- Siwalik Aggregates: Showed satisfactory strength development but were slightly inferior to Lesser Himalayan crushed aggregates.
- Lesser Himalayan Aggregates: Demonstrated superior compressive strength across all curing periods, highlighting their suitability for high-performance applications.
- River-Bed Crushed Aggregates: Underperformed in compressive strength tests, indicating potential limitations in structural applications.

Also, based on the composition, results indicate the variation in increasing order of compressive strength as: Glass Fiber→Plain→Steel Fiber Shotcrete.

### *Flexural Strength*

The flexural strength results followed similar trends to compressive strength. Lesser Himalayan crushed aggregates yielded the highest flexural strength, indicating robust structural performance. Siwalik's crushed aggregates exhibited adequate flexural properties. These findings highlight the necessity of selecting appropriate aggregate sources to achieve desired flexural properties in shotcrete applications.

### *Air Content*

The air content measurements revealed that aggregates' shape, texture, and gradation significantly influenced the air voids in shotcrete. Higher air content can lead to reduced density and strength, impacting the overall durability of the shotcrete.

## Conclusion

In conclusion, the growing demand for aggregates in Nepal, driven by rapid urbanization and infrastructural development, necessitates a shift towards sustainable alternatives. The research highlights the importance of using crushed rock aggregates to mitigate environmental impacts while meeting construction needs. Lesser Himalayan (quartzite, metasandstone) crushed aggregates emerged as the most favorable option, exhibiting superior workability, compressive strength, and flexural strength, making them ideal for high-performance applications. Siwalik (sandstone) aggregates showed adequate performance, while riverbed aggregates demonstrated limitations that could compromise structural integrity. Among Plain, Glass Fiber and Steel Fiber Shotcrete, Steel Fiber and Plain Shotcrete shows the highest strength and optimum density in comparison to the Glass Fiber. Overall, this study underscores the critical role of aggregate quality in ensuring the durability and sustainability of construction projects in Nepal. Future research should explore the long-term performance of shotcrete with different aggregate blends and assess their environmental impacts, further contributing to the sustainable development of the region's infrastructure.