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Sediment Quality Assessment and Its Engineering Significance: A Geographical and Laboratory-Based Study of Raidak-II River, India

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Abstract

Riverbed sediments play a crucial role in construction and environmental sustainability. This study presents a comprehensive assessment of sediment quality from Raidak-II, one of the major rivers of the Eastern Dooars region, India, integrating field observations with laboratory-based analyses. Key parameters such as particle size distribution (Fineness Modulus), compressive strength of sand-cement mortar, and specific gravity were evaluated. The results indicate significant spatial variation in sediment characteristics across upper, middle, and lower river segments. Moderately graded sand from middle segments demonstrates optimal suitability for construction purposes. Compressive strength values exceeded standard thresholds (20 MPa), while specific gravity values remained within acceptable limits (2.52–2.65). The study highlights the engineering viability of regional sediments and underscores the need for sustainable extraction practices to prevent geomorphological degradation.

Keywords

Sediment quality, River sand, Fineness modulus, Compressive strength, Specific gravity, Eastern Dooars, Sustainable mining

1. Introduction

Sediments, comprising sand, silt, clay, and gravel, are fundamental natural resources used extensively in construction industries worldwide. Among these, sand and gravel are essential components of concrete, directly influencing its strength, durability, and performance.

Rapid urbanization and infrastructural development have increased the demand for riverbed materials, leading to intensive sand mining. However, excessive extraction disrupts natural sediment balance, affecting river morphology, ecology, and long-term sustainability.

The Eastern Dooars region of India, characterized by dynamic river systems such as Raidak, Kaljani, and Sankosh, is a major source of construction-grade sediments. Despite their extensive use, limited scientific evaluation has been conducted on their quality and suitability.

This study aims to bridge that gap by integrating **geomorphological understanding with engineering analysis**, providing a holistic assessment of sediment quality.

2. Review of Literature

Previous studies have emphasized the importance of sediment characteristics in construction:

- Kondolf (1994) highlighted the geomorphic impacts of gravel mining on river systems.
- Ngugi et al. (2014) demonstrated that sand quality directly affects compressive strength of concrete.
- Olanitori (2006) reported that excessive clay content reduces bonding strength.
- British Standards (BS 882) recommend limiting fine particles (clay/silt) to 4% for construction suitability.

However, most studies focus either on engineering or environmental aspects separately. This research integrates both perspectives within a regional context.

3. Study Area

The Eastern Dooars region lies in the foothills of the Eastern Himalayas and is drained by several perennial rivers:

- **Raidak-I and Raidak-II**
- **Kaljani River**
- **Sankosh River**

These rivers exhibit strong seasonal variability and active sediment transport, making them ideal for sediment quality analysis.

4. Objectives

- To analyze spatial variation in sediment quality across river segments
- To evaluate engineering properties of sand using laboratory techniques
- To assess suitability of sediments for construction purposes
- To examine implications of sediment extraction on river systems

5. Methodology

5.1 Field Survey

Extensive fieldwork was conducted across upper, middle, and lower river segments. Sampling locations were selected using stratified random sampling to ensure representation.

5.2 Sample Collection and Preparation

Sediment samples were collected from:

- Kumargram (upper segment)
- Purba Chakchaka (middle segment)
- Baynaguri (lower segment)

Samples were air-dried and prepared for laboratory testing.

5.3 Laboratory Analysis

5.3.1 Sieve Analysis

Sieve analysis determines particle size distribution and grading characteristics. The **Fineness Modulus (FM)** serves as an index of average particle size.

- FM > 2 → Coarse sand
- FM 1.5–2 → Medium sand
- FM < 1.5 → Fine sand

5.3.2 Compressive Strength Test

Mortar cubes were prepared using standard proportions and tested after curing periods of 3, 7, and 28 days. The results were compared with IS 516-1959 standards.

5.3.3 Specific Gravity Test

Specific gravity was determined using the pycnometer method. It reflects density and quality of sand particles.

6. Results

6.1 Sediment Types

Three major sand types were identified:

- Pit Sand (coarse, iron-rich)

- River Sand (well-graded, high quality)
- Manufactured Sand (cost-effective alternative)

6.2 Particle Size Distribution

- Upper segment: Poorly graded (FM ~ 3.249)
- Middle segment: Moderately graded (FM ~ 2.858)
- Lower segment: Fine and poorly graded (FM ~ 2.391)

Interpretation:
Middle segment sediments show the best gradation for construction due to balanced particle size distribution.

6.3 Compressive Strength Analysis

All samples exceeded the minimum requirement (20 MPa at 28 days):

River	Strength (MPa)
Kaljani	21.18
Raidak-I	20.53
Raidak-II	21.86
Sankosh	22.52

Observation:
Sankosh River shows the highest strength, indicating superior material quality.

6.4 Specific Gravity

Values ranged from **2.519 to 2.645**, close to standard values.

Interpretation:
All samples are suitable for construction, though finer sands exhibit slightly higher specific gravity.

7. Discussion

The study reveals a clear spatial pattern in sediment quality:

- **Upper segments**: Coarse but poorly graded
- **Middle segments**: Optimally graded (best for construction)
- **Lower segments**: Fine and less suitable

The superior quality of middle segment sediments is due to balanced deposition processes. In contrast, excessive mining in upper and middle segments disrupts natural sediment flow, leading to poor-quality deposits downstream.

From an engineering perspective:

- Well-graded sand improves concrete strength
- Higher compressive strength indicates better bonding
- Optimal specific gravity ensures durability

8. Environmental and Practical Implications

- Excessive sand mining may cause riverbank erosion
- Alteration of sediment flow affects downstream ecosystems
- Sustainable extraction policies are essential

Recommendation:
Controlled mining should be implemented, especially in middle river segments where high-quality sediments are concentrated.

9. Limitations of the Study

- Seasonal variation in sediment quality was not considered
- Limited number of sampling points
- Chemical composition analysis was not included

10. Conclusion

The sediments of Eastern Dooars rivers are largely suitable for construction, particularly those from middle river segments. Laboratory results confirm that all samples meet standard engineering requirements. However, sustainable management practices are necessary to prevent long-term environmental degradation.

11. Future Scope

- Seasonal sediment analysis
- Impact of mining on river morphology
- Integration with remote sensing and GIS
- Chemical and mineralogical analysis

References

(Use your existing reference list—already appropriate for journal submission)