

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.

1. Introduction:

Sediments are the loose sand, silt, clay and other loose materials that have settled at the bottom of a water body (US EPA, 2002). Sand and gravel are naturally occurring substances found on the river beds, flood plains and sea beaches (Kondolf, 1994). Sand and gravel mining refers to the process of extracting sand and gravel from the place of its actual occurrence. In construction work, a variety of sand aggregates like sand (fine, medium and coarse), gravel, cobbles, pebbles, and boulders etc. are used for multiple purposes. Sands are mainly characterized by size, being finer than gravel and coarser than silt, ranging from 0.06 mm to 2 mm. The quality and combination of sediments is one of the important factors determining the strength and combination of the concrete made of it. The quality of sand available in the study area is studied in this chapter, assessing size, strength, and mass of the sample sediments. The strength and longevity of any concrete depends upon the quality of the materials (sand and gravel) used in it. The water, cement, sand grains, and any admixtures utilized should be free from destructive contamination that directly or indirectly hampers the construction. Sand is one of the ordinary common fine aggregates utilized in the construction sector (Ngugi et al. 2014). The Nigerian

Standard Organization denotes the highest amount of mud in the sand as 8%, beyond which sand is considered as inappropriate for construction work (Olanitori & Olotuah, 2005; Olanitori, 2011). On the other hand, BS 882 states that the percentage of clay and fine silts must not exceed 4% by weight of sand for use in concrete production (Harrison & Bloodworth, 1994).

Study Area:

The study area primarily covers the Alipurduar districts of West Bengal. It originates in the Himalayas of Bhutan (where it is known as the Wang Chhu or Wong Chhu). The river enters India through the Buxa Tiger Reserve and the Doars region of Alipurduar. Near Kanjal Basti in Alipurduar, the main Raidak stream dissects into Raidak-I and Raidak-II.

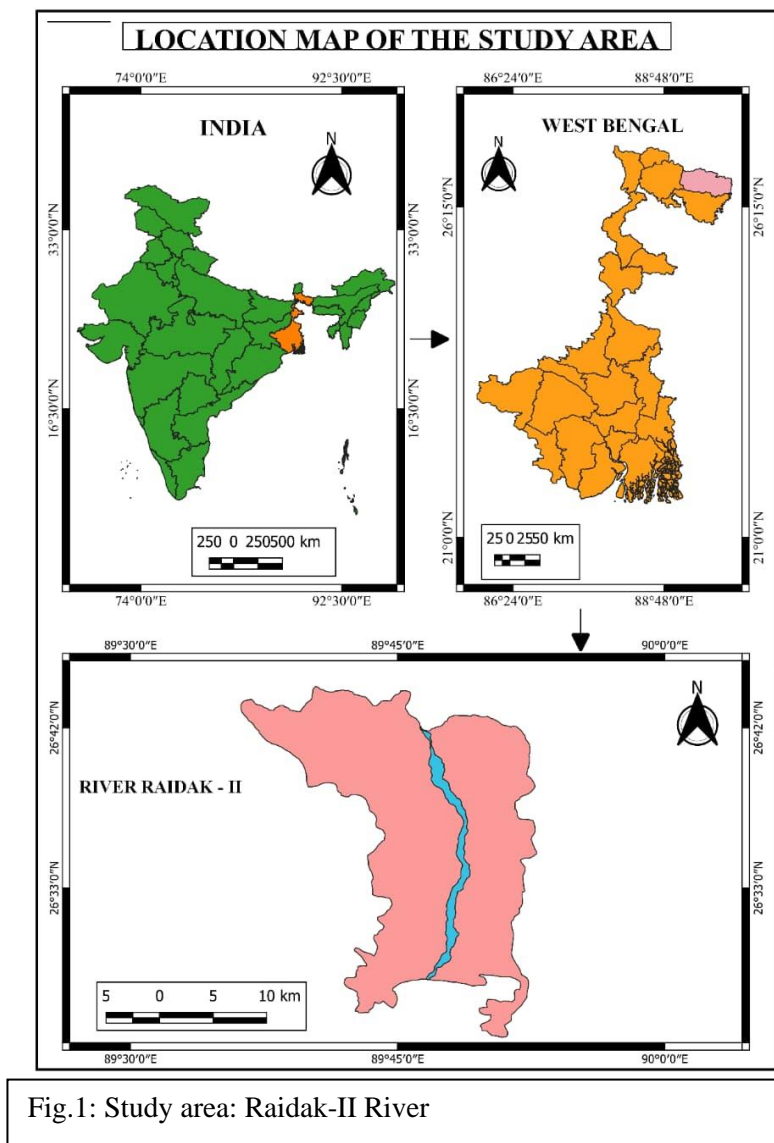


Fig.1: Study area: Raidak-II River

Objective:

The main objective of this study is to evaluate the types and quality of the sand and gravel available in the study area.

2. Methodology:

The types and uses of various sands and gravel were done through an intensive field survey. The sand quality was assessed through the steps such as sample collection, laboratory testing and analysis.

Sample Collection:

Sample sites are first fixed by stratified random sampling techniques. The samples have been collected from these prefixed stations like Kumargram (upper segment), Purba Chakchaka (middle segment) and Baynaguri (lower segment) of the Raidak-II river in the Eastern Dooars. For compressive strength and specific gravity tests, the samples have been collected following a random sample technique from prefixed mining sites on the middle segment of the river. Collected samples are then dried up at room temperature for a week to make them ready for testing.

Laboratory Test:

Sieve Analysis of Sand:

Sieve analysis of sand is the most established technique for particle size distribution and is done by passing a known load of test material progressively through a fine sieve to decide the percentage of weight in each size portion. Utilizing the result of sieve analysis test, fineness modulus (FM) is calculated. Lower FM demonstrates fine grains and higher FM shows coarser grains.

Fineness Modulus (FM) gets from the following equation (Howladar et al. 2012).

$$FM = \frac{\text{Summation of cumulative \% retained on ASTM sieves No. 4, 8, 16, 30, 50, 100}}{100}$$



Plate-1: Sieve Analyse Test

Compressive Strength Test

The collected sand samples were left in the sun for 1 hour and afterward restored at 60°C in an electronic oven for around 24 hours. The samples were then left at room temperature for about an hour and finally used for preparing mortars. Standard ratios of water: cement: sand = 0.485: 1: 2.75 has been followed for making mortars. It is put in a can for restoring, then the mortar is taken out of the container and kept for thirty minutes to expel water and be ready for testing by the compression testing machine. The obtained result is analyzed on the basis of Indian Standard IS 516-1959 (Howladar et al. 2012).



Plate-2: Compressive Strength Test

Specific Gravity Test:

The specific gravity of the sand is clarified as the extent of the mass of a given volume of sand to the mass of a similar volume of water at 4°C. The standard specific gravity of sand is 2.65 – 2.68. (ASTM, C. 1995). It is measured by the Pycnometer technique, as shown in.



Plate-3: Specific Gravity Test

The specific gravity of the sands is calculated using the following formula:

$$\text{Specific Gravity}(G) = \left[\frac{D}{C-(A-B)} \right] \quad (\text{IS: 2386,1963}).$$

Where,

D = Weight of the oven-dry sample (gm)
A = Weight of vessel+sample+ water (gm),
B = Weight of vessel+water (gm),
C = Weight of surface dry sample (gm)
G = Specific gravity

3. Result and Discussion:

Types of Sand and their variations:

The field study reveals that there are three types of sands available in the study area. These are Pit sand, M sand, and River sand are the most

Pit Sand:

Pit sand is coarse, natural sand that is collected by excavating 2-3 meters beneath the earth. Due to the presence of iron oxide around the grains, it have a red-orange hue as these sand grains are devoid of salts and do not react with the moisture content in the air. These are utilized in the building process because of their better binding qualities. The availability of pit sand is insignificant in this region compared to the other types of sand. Pit sand is a coarse form of sand, as previously mentioned and it is not suggested if the sand is coarser than the permitted limits.

Sand from the River:

River sand is collected from riverbanks and riverbeds. The special character of the sand is that it is generally white or grey and highly graded. The trapped moisture in between this type of sand makes it more suitable for a variety of concrete purposes compared to pit sand and M-sand. Hence, river sand is the most suitable for masonry applications. The study deals with the river sand that is extracted from the river bank and river bed only.

M-Sand:

M-Sand means manufactured sand that substitutes's river sand. Hard granite stone is crushed to make M-sand. M-Sand is made by cubically shaping, grading, and cleaning it with a VSI machine. M-sand is smaller than 4.75mm in size. M-sand can range in colour from grayish-blue to crimson depending on the kind of rock crushed. The cost of this type of sand is much lower (10% to 15%) than river sand because of very low labour charges, low shipping costs and made by machine.

Sieve Analysis Test:

The Fineness Modulus is an index number that represents the mean size of the particles. In 1925, Duff Abrams introduced the concept of fineness modulus (FM) for estimating the portions of fine and coarse

aggregates in the concrete mixture. The fineness modulus is roughly proportional to the particle size of the aggregates. It means the finer the particle (having a small particle size), the less the fineness modulus. After conducting the sieve analysis test, it has been observed that the sand found in the upper portion of the river has an average fineness modulus (FM) of 3.249. It means the average value of the aggregate is between the 3rd and 4th sieve. Here it lies somewhere in the range of 0.6mm and 1.18 mm sieve which reveals that the sand found in the upper portion of the river bit of the Raidak-II is not enough well-graded it means or gap graded. The materials available in the middle portion of the river have a fineness modulus of 2.858, which reveals that the average value of the aggregate is somewhere between the 3rd and 4th sieve, and it lies somewhere in the range of 0.6mm and 1.18mm, which signifies that the sand found in the middle portion of the river is moderately graded. Such well graded materials are more suitable for any construction purpose, which is why most of the mining sites are concentrated in the middle portion of the river. However, The fineness modulus of the lower portion of the river is 2.391, which is significantly lower than the values of the upper and middle portions, indicating that the materials available in the middle and upper portions are comparatively well distributed and suitable for construction purposes as compared to the lower portion, because the sand available in the lower portion is poorly graded for mixing and disturbing natural gradation of sediments due to mining at the upper and middle portions. According to IS: 383, the standard prescribed fineness modulus of sand is between 1.2 and 1.5 for fine aggregates, 1.5-2 for medium aggregates, and greater than 2 for coarse aggregates

Table 1: Fineness Modulus Analysis of Sample Collected from Upper Segment of River Raidak-II

Sl. No	Sieve Size No	Standard Opening(m m)	Material retained(gm)	Percent of material retained (%)	Cumulative Percent Retained (%)	Percent Finer	Fineness Modulus
1	No. 3/8"	9.5	Nil	0	0	100	3.249
2	No.4	4.75	21	2.1	2.1	97.9	
3	No.8	2.36	45	4.5	6.6	93.4	
4	No.16	1.18	360	36	42.6	57.4	
5	No.30	0.6	341	34.1	76.7	23.3	
6	No.50	0.3	211	21.1	97.8	2.2	
7	No.100	0.15	13	1.3	99.1	0.9	
8	No.200	0.075	5	0.5	99.6	0.4	
9	Pan	0	4	0.4	100	0	
	Total		1000	100			

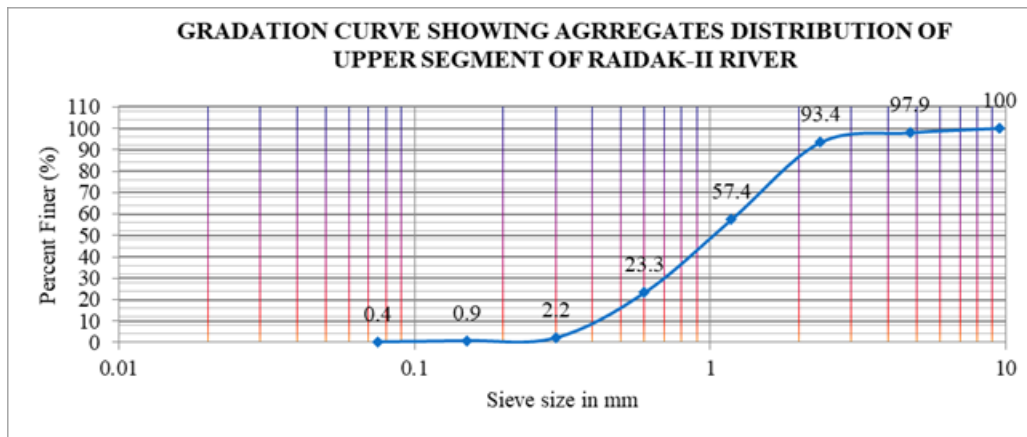


Fig. 2: Gradation Curve Showing Aggregates Distribution Of Upper Segment Of Raidak-II River

Sl. No	Sieve Size No	Standard Opening(mm)	Material retained(gm)	Percent of material retained (%)	Cumulative Percent Retained (%)	Percent Finer	Fineness Modulus
1	No.3/8"	9.5	Nil	0	0	100	2.858
2	No.4	4.75	11	1.1	1.1	98.9	
3	No.8	2.36	35	3.5	4.6	95.4	
4	No.16	1.18	260	26	30.6	69.4	
5	No.30	0.6	341	34.1	64.7	35.3	
6	No.50	0.3	211	21.1	85.8	14.2	
7	No.100	0.15	132	13.2	99	1	
8	No.200	0.075	5	0.5	99.5	0.5	
9	Pan	0	5	0.5	100	0	
	Total		1000	100			

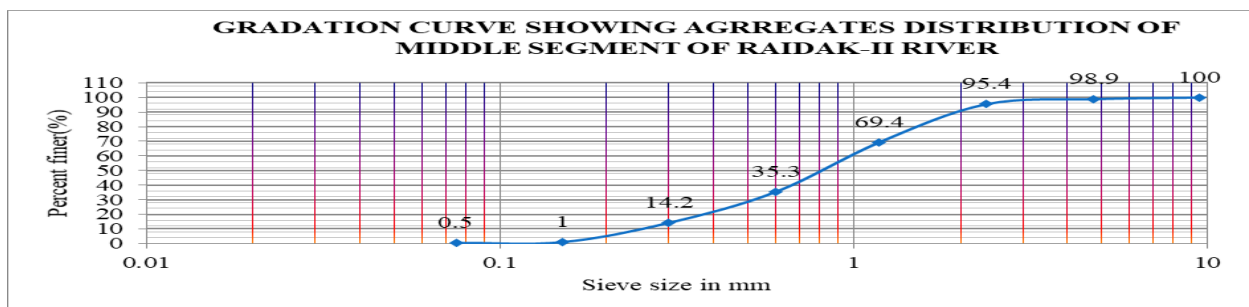


Fig. 3 : Gradation Curve Showing Aggregates Distribution Of Middle Segment Of Raidak-II River

Sl. No	Sieve Size No	Standard Opening(mm)	Material retained(gm)	Percent of material retained (%)	Cumulative Percent Retained (%)	Percent Finer	Fineness Modulus
1	No.3/8"	9.5	0	0	0	100	2.397
2	No.4	4.75	2	0.2	0.2	99.8	
3	No.8	2.36	15	1.5	1.7	98.3	
4	No.16	1.18	52	5.2	6.9	93.1	
5	No.30	0.6	316	31.6	38.5	61.5	
6	No.50	0.3	552	55.2	93.7	6.3	
7	No.100	0.15	50	5	98.7	1.3	
8	No.200	0.075	13	1.3	100	0	
9	Pan	0	0	0	0	0	
	Total		1000	100			

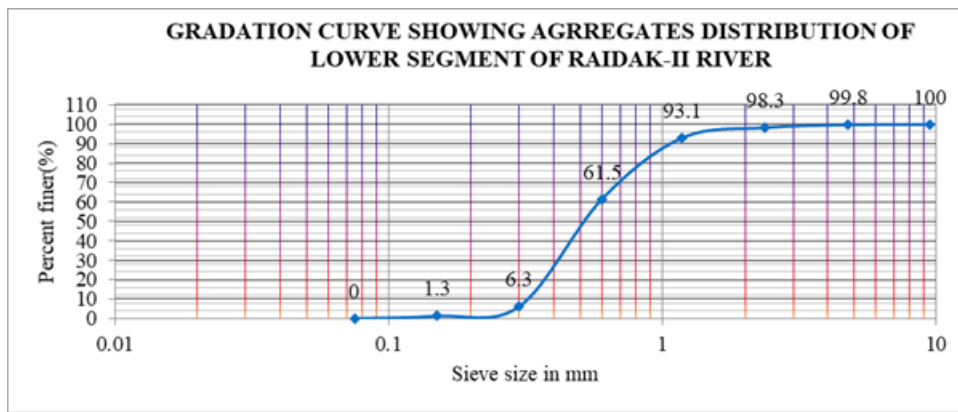


Fig. 4 : Gradation Curve Showing Aggregates Distribution Of Lower Segment Of Raidak-II River

Locational area	Fineness Modulus (FM)
Sari Ghat River (Bangladesh)	1.24-2.94
Dhaka Area (Bangladesh)	1.20-1.60
Cumilla (Bangladesh)	1.30-1.50

Source: Howladar et al. 2012

4. Compressive Strength of Sand-Cement Mortar:

River-wise the average compressive strength of mortar with an increasing curing period is tabulated below:

Age(days)	Specimen No	Specimen Area (mm)	Compressive strength(MPa)	Average value (MPa)

3	1	150x150x150	10.92	12.73
	2	150x150x150	12.19	
	3	150x150x150	15.10	
7	1	150x150x150	13.70	14.61
	2	150x150x150	12.95	
	3	150x150x150	17.19	
28	1	150x150x150	19.48	21.86
	2	150x150x150	21.14	
	3	150x150x150	24.96	

The average compressive strength values of the study river for 28 days is 21.86 Mpa..As the compressive strength value of the river (28 days) is more than the standard value (20 Mpa) which is required for construction purposes, that’s why the materials available in the study region are highly recommended for any construction purposes. The calculated compressive strength value is a little higher than the standard value as per Indian Standard IS 516-1959.

Specific Gravity

The specific gravity of the sand is explained as the proportion of the mass of a given volume of sand to the mass of the same volume of water at 4°C. The specific gravity of sand is 2.65 –2.68. Determine the specific gravity by the Pycnometer method, shown in plate-3 Specific gravity depends on temperature, so it has to be measured.

Table-6: The specific gravity of Raidak-II River sand at 28°C

Observation No	WS	WA (gm)	WB (gm)	WC (gm)	WD (gm)	G_s (gm)	The average value of G
1	1000	3373	2771	991	982	2.524	2.519
2	1000	3372	2772	991	983	2.514	

The average specific gravity of river bed materials of Raidak-II is 2.519. Fine sand shows higher specific gravity having good quality whereas the medium sand grain shows lower specific gravity having comparatively lower quality. But as specific gravity of all the samples are having nearer to the standard value (2.652 - 2.67), are more or less suitable for constructional purpose. The specific gravity of the sand may vary with the size of the materials in the study area i.e. fine sand showing higher specific gravity and the medium sand grains showing lower specific gravity.

5. Conclusion:

This study reveals that most of the materials found along the Raidak-II river are fine to medium-grained, which are very suitable for different plastering purposes, filling any low land areas, and higher concreting purposes. But somewhere, the sand mixed with silt and clay is not suitable for plastering except for filling low land areas. The materials available in this area are also suitable for mortar and concrete purposes. The compressive strength of the mortar increases with the curing period. But the materials found in the upper segment are far better than the materials found in the lower segment of the river.

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