Geoenvironmental and Geotechnical Criteria for Selection of River Deposits for Construction Material

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Abstract

To cater to infrastructural development of the country, vast quantities of construction material is required. The river borne materials (RBM) deposited in the fluvial system are the potential target areas for the construction materials, especially fine aggregates, as they are easily available in Indian rivers and replenished every year. However, indiscriminate mining of these river borne materials (gravel, sand, silt) is causing severe environmental degradation. At the same time, the Indian rivers are facing huge siltation, resulting in reduction in their carrying capacity, thus adding to their flood propensity. As a cumulative effect, severe bank erosion, channel migration and floods may occur frequently. To minimize impacts on river morphology, geo-hazards, and meet the growing demand of construction material, systematic selection and controlled mining of RBM in an eco-friendly sustainable manner, considering the various site specific Geoenvironmental and geotechnical criteria have become a prerequisite, which is enumerated in the write-up.

1. Introduction:

To cope up with rapidly growing populations, India is on fast track to build new infrastructures in terms of industries, townships, route corridors, etc. As a number of hydroelectric projects & other water resources projects are coming up in the mountainous regions of Himalayan and north-eastern parts of India, huge quantities of coarse and fine aggregates is required for construction purposes. The country also frequently experiences several natural hazards like, earthquakes, landslides, floods etc, and to some extent tsunamis that destructs/damages the civil structures and properties. Restoration and reconstruction of these structures become need of the hour. Consequently, to cater to these developments, besides maintenance of existing infrastructures, vast quantities of construction material is required.

India being a tropical country is blessed with numerous perennial and ephemeral rivers originating from Himalayan, extra-peninsular, Western Ghats and peninsular tracts. The potential targets for easy availability of such construction material, especially, fine aggregates are the river borne material (RBM) deposited in the middle and lower reaches of the drainage basin.

However, indiscriminate, unscientific mining of river borne materials (gravel, sand, silt) is causing severe environmental degradation. Severe bank erosion, channel migration and floods occur every year. Due to several natural and human interferences, the Indian rivers are also facing huge siltation, thereby reducing their carrying capacity. The siltation is aggravated mainly in peninsular India, due to construction of embankments to control recurring floods. This has raised the river bed level due to deposition of RBM from the adjacent natural ground level and during bankful stage breaching of such embankment, and flooding takes place causing water logging in vast areas as the flood water is unable to recede back to the rivers which is at relatively higher level. Dredging of these huge silt deposits along the rivers in plains, mouth of the rivers, hilly tracts and their disposal elsewhere, is not always sustainable and practical solution on economic and environmental considerations. Only, a little amount of the same is used for manufacturing of bricks.

Mining from, within or near a riverbed has a direct impact on the stream's physical characteristics, such as channel geometry, bed elevation, substratum composition and stability, in stream roughness of the bed, flow velocity, discharge capacity, sediment transportation capacity, turbidity, temperature, etc. Alteration or modification of the above attributes may cause hazardous impact on ecological equilibrium of river regime. This may also cause adverse impact on in stream biota and riparian habitats. This disturbance may also cause changes in channel configuration and flow-paths thus creating imbalances in fluvial regime.

Therefore, there is a need for an in-depth study to minimize siltation in river system, optimum utilization of river deposits by riverbed mining in a scientific and eco-friendly manner to meet the growing demand of construction material and restoring the carrying capacity of the river.

2. Selection Criteria for Construction Material:

2.1 Geoenvironmental Considerations:

Though the objective is optimum utilization of river borne material, but due consideration should be given on the environmental aspects before resource extraction. Mining should also be aimed for protection and restoration of the ecological system, prevention of damages to the river regime, balancing the sediment influx/ replenishment capacity of the river, restoration of the river configuration (landforms and fluvial geomorphology such as bank erosion, change of river course gradient, flow regime, etc.), mitigation of siltation problem, prevention of contamination of ground water regime, prevention of depletion of ground water reserves due to excessive draining out of groundwater, restoration of the riparian rights and in stream habitats etc. *(c.f. Hill & Kleynhans, 1999)*.

The riverbed mining may be undertaken considering minimization of the above mentioned deleterious impacts. Following geoscientific considerations are suggested to be taken into account for sand/ gravel mining *(c.f. GSI guidelines on river bed mining)*:

a. Abandoned stream channels on terrace and inactive floodplains may be preferred rather than active channels and their deltas and floodplains.
b. Replenishment of ground water has to be ensured if excessive pumping out of water is required during mining.
c. Stream should not be diverted to form inactive channel.
d. Mining below subterranean water level should be avoided as a safeguard against environmental contamination and over exploitation of resources.
e. Large rivers and streams whose periodic sediment replenishment capacity are larger, may be preferred than smaller rivers.
f. Segments of braided river system should be used preferably falling within the lateral migration area of the river regime that enhances the feasibility of sediment replenishment.
g. Mining at the concave side of the river channel should be avoided to prevent bank erosion. Similarly meandering segment of a river should be selected for mining in such a way as to avoid natural eroding banks and to promote mining on naturally building (aggrading) meander components.
h. Scraping of upper level sediment bars (above the water flow level) in the lean period may be preferred for sustainable mining.
i. The Piedmont Zone (Bhabbar area) particularly in the Himalayan foothills, where riverbed material is mined. This sandy- gravelly track constitutes excellent conduits and holds greater potential for ground water recharge. Mining in such areas should be preferred in locations selected away from the channel bank stretches. Areas where channel banks are not well defined, particularly in the braided river system, midstream areas should be selected for mining of riverbed materials for minimizing adverse effects on flow regime and instream habitat.
j. Mining resulting in formation of deep pits, should be avoided in the river bed which accentuates turbulence and erosion and also harms the ecological system of instream habitats. Mining of gravel and sand from the riverbed should be restricted to a maximum depth of 3m from the surface. For surface mining operations beyond this depth of 3m (10 feet), it is imperative to adopt quarrying in a systematic bench- like disposition, which is generally not feasible in riverbed mining. Hence, for safety and sustainability restriction of mining of riverbed material to maximum depth of 3m is suggested.
k. Mining of riverbed material should also take cognizance of the location of the active channel banks. It should be located sufficiently away from such river banks to minimize effects on river bank erosion and avoid consequent channel migration.
l. Continued riverbed material mining in a given segment of the river will induce seasonal scouring and intensify the erosion activity within the channel. This will have an adverse effect not only within the mining area but also both in upstream and downstream of the river course. Hazardous effects of such scouring and enhanced erosion due to riverbed mining should be evaluated periodically and avoided for sustainable mining activities.

m. Mineral processing in case of riverbed mining of the sandy- gravelly material may consist of simple washing to remove clay and silt fractions. It may also involve crushing, grinding and separation of rock fragments from the desirable material. The volume of such waste material may range from 10 to 90%. Therefore, such huge quantities of mine wastes should be dumped into artificially created/ mined - out pits. Where such tailings / waste materials are very fine grained, they may act as a source of dust when dry. Therefore, such disposal of wastes should be properly stabilized and vegetated to prevent their erosion by winds. Moreover, dumping of such finer material within the riverbed may choke the natural filtering mechanism through which ground water recharges from the river. It may result in depletion of groundwater resources in the long run.

n. The mined out pits should be backfilled where warranted and area should be suitably landscaped to prevent environmental degradation.

o. Mining of RBM generally has a huge impact on the irrigation and drinking water resources. These attributes should be clearly evaluated for short-term as well as long-term remediation.

p. Dumping of mining waste should be done properly during coarse aggregate mining to avoid environmental degradation.

2.2 Geotechnical Considerations:

In general, boulder, gravel, sand can be used for construction of roads, semi-permanent settlements, etc. Fine silt can be used for manufacturing of bricks. Moreover, coarse, medium and fine sands can be used for construction of buildings and other civil structures, if found suitable or after improving their suitability through dressing and grade processing. However, their use in hydroprojects, other water resource development projects and heavy civil engineering projects depends on their physico-mechanical and chemical properties for different type of structures for instance such material for concrete dam, rock fill dam, cofferdam, tunnel, underground cavern etc, have to pass through several suitability tests. Quality of coarse aggregate also depends on the disposition of the structures with respect to its contact with water. Concrete for wearing surfaces is used in upstream part of dam, hydro-tunnel as they remains in contact with water, whereas, the same for non-wearing surfaces are used for the structures like, powerhouse, downstream portion of dam and other structures and buildings which do not remain in contact with water permanently. The engineering properties of coarse aggregates suitable for concrete for non-wearing surfaces may or may not be suitable for wearing surfaces, while the wearing surface concrete is always suitable for all.

The physico-mechanical and chemical properties of the RBM has to be tested for acceptance as coarse and fine aggregate for use in concrete/ masonry/ rock fill/earth dams, powerhouse and other structures. In addition, composition of the sand plays important role. Through petrographic examination (IS: 2386 (Part-8)-1963), presence/absence, composition and percentage of minerals, etc are determined. Higher percentage of quartz (> 25%) is preferred and presence of rock fragments, flaky and micaceous minerals, strained quartz etc. have adverse effects and their percentage should be limited in RBM. Geotechnical criteria suitable for coarse aggregate for use in concrete is given in Table 1 and for fine aggregate are given in Table 2.

Table1
Acceptance criteria for suitability of coarse aggregate for use in concrete *

No	Items	Suitability criteria
1	Water absorption-	≤ 5 %
2	Specific gravity-	≥ 2.60
3	Aggregate impact value-	≤45% for concrete for non-wearing surfaces ≤ 30% for concrete for wearing surfaces
4	Aggregate crushing value-	≤45% for concrete for non-wearing surfaces ≤ 30% for concrete for wearing surfaces
5	Aggregate abrasion (Los Angeles) value-	≤50% for concrete for non-wearing surfaces ≤ 30% for concrete for wearing surfaces
6	Soundness -	≤ 12% (5 cycles of Na_2S0_4) ≤ 18% (when tested with magnesium sulphate)
7	Flakiness Index-	≤15%
8	Elongation Index-	≤ 25.00% of any size (flat or elongated fragments)
9	Alkali-aggregate reactivity - (chemical method)	A potentially deleterious degree of alkali reactivity is indicated if the plotted test data point falls to the right of the boundary line (Rc vs Sc) of IS: 2386 (Part-VII)-1963.
10	Alkali-aggregate reactivity - (accelerated mortar bar test)	As per ASTM Designation C1260-01 Expansions of less than 0.10% at 16 days after casting are indicative of innocuous behaviour in most cases. Expansions of more than 0.20% at 16 days after casting are indicative of potentially deleterious expansion. Expansions between 0.10 to 0.20% at 16 days after casting include both aggregate that are known to be innocuous and deleterious in field performance. In such a situation, it may be useful to take comparator readings until 28 days.

**ASTM C 1260-01, IS 2386-1963, IS:383-1970, ACI Education Bulletin E1-07, http://www.in.gov/indot/files/chapter_04.pdf*

Table 2
Acceptance criteria for suitability of fine aggregate for use in concrete *

No	Items	Suitability criteria
1	Gradation-	Within the limits given in table 4 of IS: 383-1970
2	Specific gravity-	≥ 2.60
3	Fineness modulus-	2-3.3
4	Silt and clay content-	≤3.00% for uncrushed fine aggregate ≤ 15% for crushed fine aggregate
5	Organic impurities-	Shall pass color test. Presence of Organic- iron oxide, coal, lignite, strained quartz, gypsum, anhydrite, chert etc. are not suitable
6	Soundness-	≤10% (5 cycles of Na_2So_4) ≤ 15% (when tested with magnesium sulphate)
7	Compressive strength of cement: sand mortar-	Should show progressive increase in compressive strength with age
8	Alkali-aggregate reactivity - (chemical method)	Same as coarse aggregate (Ref Table.1)
9	Alkali-aggregate reactivity - (accelerated mortar bar test)	Same as coarse aggregate (Ref Table.1)

**ASTM C 1260-01, IS 2386-1963, IS:383-1970, ACI Education Bulletin E1-07, http://www.in.gov/indot/files/chapter_04.pdf*

3. Conclusions:

To meet the growing demand of construction material, there is a need to utilize the riverine material by riverbed mining. However, the quarry areas should be identified in a scientific way, without causing environmental degradation and not affecting the river morphology. Geotechnical considerations are also looked for selecting and processing need specific suitable materials as per the established standards for physico-mechanical durability of structures.

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References:

1. ACI Education Bulletin E1-07, (2007). Aggregate for concrete, American Concrete Institute.
2. IS Guidelines (IS 2386-1963: Methods of test for aggregates for concrete).
3. IS: 383-1970: Specification for coarse and fine aggregates for natural sources for concrete.
4. ASTM (American Society for Testing and Material) C 1260-01 Test Procedure – *Standard Test Method for Potential Alkali, Reactivity of Aggregates (Mortar-Bar Method),* Vol. C 4.02, ASTM, International, 100 Barr Harbour Drive, Conshohocken, PA 19428-2959, 2004.
5. A Model Document on Impacts and Methodology of Systematic and Scientific Mining of the River Bed Material, (2009). www.portal.gsi.gov.in/gsiDoc/pub/riverbed_mining_guidelines.pdf
6. Preliminary Guidance document for authorization and licensing of Sand Mining / Gravel Extraction, in terms of Impacts on In stream and Riparian Habitats, L. Hill & C.J. Kleynhans, IWQS, March 1999
7. Aggregate specifications and requirements, www.in.gov/indot/files/chapter_04.pdf