

Study on Geotechnical and Agricultural Properties of Sediment Deposited in Tungabhadra Dam (Munirabad Lake)

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Abstract - Reservoirs lose storage capacity over time due to progressive sedimentation, posing a significant threat to water resource management and dam safety. This study investigates the geotechnical and agricultural properties of sediment deposited in the Tungabhadra (TB) Dam reservoir at Munirabad Lake, Hosapete, Karnataka. Sediment samples were subjected to a battery of geotechnical tests including water content, specific gravity, sieve analysis, Atterberg limits, standard Proctor compaction, and direct shear tests, per relevant IS codes. Agricultural characterisation covered fourteen parameters including pH, electrical conductivity, available nitrogen, potassium, phosphorus, organic carbon, and trace metals (Fe, Mn, Zn, Cu, Pb, Ni, Cr). Results indicate that the sediment is predominantly sandy silt with a liquid limit of 31%, plastic limit of 18%, shrinkage limit of 7.21%, and an optimum moisture content of 10.16%. Agricultural analysis confirms that the sediment satisfies permissible ranges for all major nutrients, with pH 6.94, adequate nitrogen (340.6 kg/ha), high potassium (485.6 kg/ha), and trace metals within safe limits, indicating strong potential for use as agricultural soil amendment. The study concludes that TB Dam sediment can be beneficially utilised for agricultural purposes, contributing to both dam desilting and soil fertility improvement.

Key Words: Tungabhadra Dam, reservoir sedimentation, geotechnical properties, agricultural properties, Atterberg limits, desilting.

1. INTRODUCTION

Dams and reservoirs are vital infrastructure assets that serve multiple purposes including irrigation, hydroelectric power generation, flood control, and domestic water supply. However, the long-term performance of reservoirs is severely compromised by sedimentation — the gradual accumulation of eroded soil, silt, and sand carried by inflowing rivers and deposited as stream velocities reduce upon entering the still waters of the reservoir [1].

The Tungabhadra Dam (TB Dam), constructed across the Tungabhadra River at Hosapete, Karnataka, is one of the major multipurpose dams in South India. The reservoir has a design storage capacity of 101 TMC (thousand million cubic feet) with a catchment area of approximately 28,000 km². The dam stands 49.5 m in height and is controlled by 33 crest gates. Due to decades of sedimentation, approximately 33 TMC of silt has accumulated in the reservoir, significantly

reducing its effective storage capacity and impacting its operational efficiency [2].

Geotechnical investigation of reservoir sediment is essential to understand the physical behaviour of the deposited material, its engineering classification, and its potential for reuse. Simultaneously, the agricultural potential of dam sediment has gained attention as a sustainable resource, since sediments transported by rivers are typically enriched in plant nutrients accumulated from upstream agricultural and forest lands [3].

This study focuses on the sediment deposited at Munirabad Lake, the main reservoir area of TB Dam. The primary objective is to characterise the geotechnical and agricultural properties of this sediment to evaluate its suitability for agricultural land application, thereby enabling the twin benefits of reservoir capacity restoration through desilting and soil fertility enhancement through nutrient-rich sediment application.



Fig -1: Overview of Tungabhadra Dam and reservoir

2. STUDY AREA

The Tungabhadra Dam is located at Hosapete (Munirabad), Vijayanagara district, Karnataka, India, across the Tungabhadra River at approximately 15°N latitude and 76°E longitude. The reservoir catchment spans 28,000 km², covering parts of Karnataka and Andhra Pradesh, and is characterised by predominantly semi-arid climate with highly erodible Deccan trap soils in the upper catchment. The dam was commissioned in 1953 and is jointly managed by the governments of Karnataka and Andhra Pradesh.

Sediment samples for this study were collected from Munirabad Lake — the primary sedimentation zone of the TB Dam reservoir — during the dry season when the reservoir operates at reduced storage levels, exposing the deposited sediment. The present water level at the time of study was approximately 1621.08 ft. Sampling was carried out from

multiple accessible locations along the lake bed to ensure representativeness of the deposited material.



Fig -2: Tungabhadra reservoir at reduced water level exposing silt deposition

3. LITERATURE REVIEW

Sissakian et al. [1] conducted geological investigations at Mosul Dam to assess siting conditions, available construction materials, and expected geological hazards, demonstrating the critical importance of geotechnical investigation in dam-related studies. The geological characterisation methodology established in that study provides a foundation for reservoir sediment investigation.

Nagalingeswar Rao et al. [2] estimated the sediment production of the Tungabhadra Project in the Krishna Basin using the Universal Soil Loss Equation (USLE). Their study quantified the contributions of erosion from the catchment to reservoir silting and highlighted the need for desilting operations to restore storage capacity. The study identified sand, gravel, and rock as the primary sediment constituents.

Ghorpade et al. [3] reviewed de-silting methods for dams, evaluating physical, hydraulic, and mechanical approaches to sediment removal and their relative effectiveness in restoring reservoir capacity. The study underscored that de-silted material should be characterised before disposal or reuse.

Kondolf et al. [4] presented a comprehensive review of sustainable sediment management in reservoirs and regulated rivers, discussing causes of dam failures due to sediment formation, techniques for passing sediment through reservoirs, and strategies for managing downstream sediment starvation. The study established that managed sediment removal and redistribution offers environmental and agricultural co-benefits.

Umesh Babu and Puttaiah [5] investigated water resource management issues in the Tungabhadra River Basin, identifying key constraints associated with changing climate, sedimentation, and water allocation. Their work underlines the urgency of addressing sedimentation in TB Dam to sustain the basin's water resource potential.

4. OBJECTIVES

- To determine the geotechnical properties of sediment deposited in TB Dam (Munirabad Lake).
- To determine the chemical and agricultural properties of the sediment.

- To calculate the proportions of sand, silt, and clay present in the sediment.
- To identify the size and arrangement of grains in the sediment.
- To evaluate the nutrient content and its suitability for agricultural application.
- To propose beneficial utilisation of de-silted material for agricultural purposes, contributing to increased dam storage capacity and soil fertility.

5. MATERIALS AND METHODOLOGY

5.1 Sample Collection

Sediment samples were collected directly from the exposed lake bed at Munirabad Lake during the low-water season. Samples were collected using standard soil sampling equipment from multiple points to ensure spatial representativeness. The collected sediment was a mix of fine-grained soil and silt, dark grey-brown in colour, with a moist and cohesive consistency.

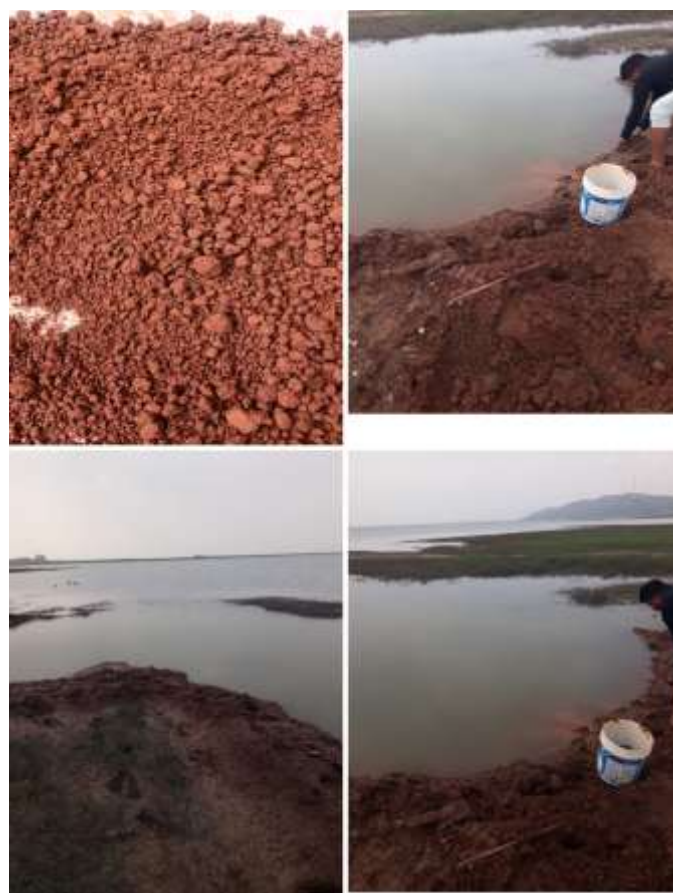


Fig -3: Silt collection at TB Dam (Munirabad Lake)

5.2 Geotechnical Tests Performed

All geotechnical tests were conducted at the Civil Engineering laboratory, BITM, Ballari, in accordance with the relevant IS codes as listed below:

Table -1: Geotechnical Tests and Applicable IS Codes

SL.N o.	Test	IS Code
1	Water Content — Oven Dry Method	IS 2720 (Pt-2):1973
2	Specific Gravity	IS 2720 (Pt-3):1980
3	Grain Size Distribution (Dry Sieve)	IS 2720 (Pt-4):1983
4	Liquid Limit (Casagrande's Method)	IS 2720 (Pt-5):1985
5	Plastic Limit	IS 2720 (Pt-5):1985
6	Shrinkage Limit	IS 2720 (Pt-6):1972
7	Standard Proctor Compaction Test	IS 2720 (Pt-7/8):1980/83
8	Direct Shear Test	IS 2720 (Pt-13):1986

5.3 Agricultural Analysis

Chemical and agricultural properties of the sediment were determined by a NABL-accredited laboratory following protocols prescribed by IS codes and standard soil testing methods. Fourteen parameters were evaluated including pH, moisture content, electrical conductivity, macronutrients (N, P, K), organic carbon, and trace metals (Fe, Mn, Zn, Cu, Pb, Ni, Cr).

6. RESULTS AND DISCUSSION

6.1 Water Content

The water content of the collected sediment was determined by the oven-dry method. Three trials were conducted and the results are presented in Table 2.

Table -2: Water Content by Oven Dry Method

Trial No.	Water Content (%)
1	30.00
2	34.78
3	34.78
Average	33.18

The average water content of 33.18% is characteristic of fine-grained silty soils with moderate to high natural moisture retention, consistent with sediment that has been in prolonged contact with reservoir water.

6.2 Specific Gravity

Specific gravity was determined using both the pycnometer and density bottle methods. Results from three trials for each method are presented in Table 3.

Table -3: Specific Gravity Results

Trial	Density Bottle Gs	Pycnometer Gs
1	2.30	2.55
2	2.60	2.50
3	2.33	2.56
Average	2.41	2.53

The average specific gravity of approximately 2.41–2.53 is consistent with fine-grained silty soils of mineral origin. Values in this range are typical for soils containing a mixture of quartz, feldspar, and clay minerals carried in suspension by the Tungabhadra River from its upstream catchment.

6.3 Grain Size Distribution

Dry sieve analysis was carried out on the sediment sample. The results are presented in Table 4.

Table -4: Dry Sieve Analysis of TB Dam Sediment

IS Sieve (mm)	Wt. Ret. (g)	% Ret.	Cum. % Ret.	% Finer
4.750	3	0.3	0.3	99.7
2.360	50	5.0	5.3	94.7
1.180	179	17.9	23.2	76.8
0.600	199	19.9	43.1	56.9
0.425	168	16.8	59.1	40.9
0.300	68	6.8	66.7	33.3
0.150	199	19.9	86.6	13.4
0.075	98	9.8	96.4	3.6
Pan	36	3.6	100.0	0.0

The grain size distribution indicates that the sediment is predominantly composed of fine sand and silt fractions (particles between 0.075 mm and 0.600 mm constitute approximately 66% of the sample by weight). Only 3.6% of particles are finer than 0.075 mm (clay-sized), confirming the classification of the sediment as sandy silt (SM classification

per IS 1498). The coarser fraction (retained on 2.36 mm) accounts for only 5.3%, consistent with the low transport energy available for coarse particles in a large reservoir.

6.4 Atterberg Limits

The consistency limits of the sediment were determined by the Casagrande method for liquid limit, thread rolling for plastic limit, and mercury displacement method for shrinkage limit. Results are presented in Tables 5, 6, and 7.

Table -5: Liquid Limit Test (Casagrande's Method)

Parameter	T1	T2	T3	T4
Container No.	503	501	15	18
Wt. container (g)	11	11	10	12
Wt. cont.+wet soil (g)	24	36	18	28
Wt. cont.+dry soil (g)	20	30	16	23
Wt. of water (g)	4	6	2	5
Wt. of dry soil (g)	9	19	6	11
Moisture content (%)	30	28	34	36
Number of blows	28	35	19	12

Liquid Limit WL = 31% Flow Index If = 16.30

Table -6: Plastic Limit Test

Parameter	Trial 1	Trial 2	Trial 3
Container No.	5	114	6
Wt. cont.+lid (g)	9.85	18.49	18.91
Wt. cont.+lid+wet soil (g)	16.12	25.43	28.52
Wt. cont.+lid+dry soil (g)	15.19	24.38	27.04
Wt. of dry sample (g)	5.34	5.89	8.13
Wt. of water (g)	0.93	1.05	1.48
Water content (%)	17.71	17.82	18.20

Average Plastic Limit PL = 18%

Table -7: Shrinkage Limit Test

Parameter	Value
Wt. of shrinkage dish (g)	32.30
Wt. of dish + wet soil pat (g)	67.26
Wt. of dish + dry soil pat (g)	58.94
Wt. of wet soil pat W1 (g)	30.00
Wt. of dry soil pat W2 (g)	25.60
Water content of wet soil pat (%)	38.73
Volume of wet soil pat V (cc)	281.70
Volume of dry soil pat V0 (cc)	20.82
Shrinkage Limit WS (%)	7.21
Shrinkage Ratio R	0.12
Volumetric Shrinkage VS	1.45

The plasticity index ($PI = WL - PL = 31 - 18 = 13\%$) classifies the sediment as medium plasticity silt of low to intermediate compressibility. The low shrinkage limit of 7.21% indicates that the sediment will exhibit significant volume change between its wet and dry states, relevant for agricultural application in areas subject to alternate wetting and drying cycles. The flow index of 16.30 indicates the rate of strength loss with increasing water content.

6.5 Standard Proctor Compaction Test

The standard Proctor compaction test was conducted at six moisture content levels to establish the optimum moisture content (OMC) and maximum dry density (MDD). Results are presented in Table 8.

Table -8: Standard Proctor Compaction Test Results

Parameter	D1	D2	D3	D4	D5	D6
Moisture content (%)	10	12	14	16	18	20
Wt. compacted soil (g)	3930	4070	4050	4050	3980	3770
Wet density (g/cc)	6.19	6.33	6.31	6.31	6.24	6.03
Dry density (g/cc)	5.61	5.93	5.75	5.73	5.97	5.57

The optimum moisture content (OMC) is 10.16% and the maximum dry density (MDD) is 6.317 g/cc. These values are consistent with silty sand materials. The MDD-OMC relationship follows the expected trend of dry density

increasing to a peak at OMC and then reducing as excess moisture occupies void spaces.

6.6 Direct Shear Test

The direct shear test was conducted to determine the shear strength parameters of the sediment — cohesion intercept (c) and angle of internal friction (ϕ) — as per IS 2720 (Part 13):1986. The shear stress versus normal stress relationship is plotted in Figure 4. The graph shows a linear relationship consistent with Mohr–Coulomb failure criterion, confirming the frictional and cohesive characteristics of the silty sediment.

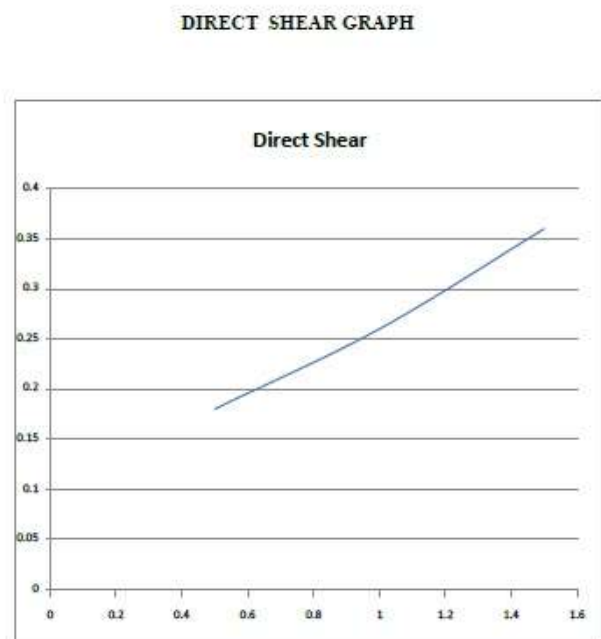


Fig -4: Direct shear graph — shear stress vs. normal stress for TB Dam sediment

6.7 Agricultural Properties

The chemical and agricultural properties of the sediment were determined and compared against permissible ranges for agricultural soils. The complete results are presented in Table 9.

Table -9: Agricultural Properties of TB Dam Sediment

No.	Parameter	Unit	Result	Permissible Range
1	pH	—	6.94	6.5–7.5
2	Moisture	%	5.12	—
3	Conductivity	mS/cm	0.399	0.01–1 mS/cm
4	Available Nitrogen	kg/ha	340.6	<10 to >50 mg/kg
5	Available Potassium (K)	kg/ha	485.6	<110 to >280 kg/ha
6	Available Phosphorus (P)	kg/ha	19.6	<11 to >22 kg/ha
7	Organic Carbon	%	0.48	0.7%–4%
8	Iron (Fe)	mg/kg	38422.25	200000–550000
9	Manganese (Mn)	mg/kg	3328.72	450–40000
10	Zinc (Zn)	mg/kg	8.84	5–10
11	Copper (Cu)	mg/kg	8.91	<10
12	Lead (Pb)	mg/kg	Nil	<400 ppm
13	Nickel (Ni)	mg/kg	26.31	20–30
14	Chromium (Cr)	mg/kg	156.35	10–350

The agricultural analysis results reveal that TB Dam sediment is largely suitable for agricultural land application. The pH of 6.94 is near neutral, optimal for the growth of a wide range of crops. The electrical conductivity of 0.399 mS/cm is well

within the safe threshold of 1 mS/cm, indicating no salinity hazard.

Available nitrogen at 340.6 kg/ha and potassium at 485.6 kg/ha are in the high-availability range, which would significantly benefit crop growth. Available phosphorus at 19.6 kg/ha falls within the medium range (11–22 kg/ha), adequate for cell division and reproductive growth. Organic carbon at 0.48% is slightly below the optimum range (0.7–4%), suggesting that the sediment may benefit from supplementation with organic matter before use as a primary soil amendment.

All trace metal concentrations are within permissible agricultural limits. Lead was undetected (nil), confirming the absence of heavy metal contamination from industrial sources. Zinc (8.84 mg/kg), copper (8.91 mg/kg), nickel (26.31 mg/kg), and chromium (156.35 mg/kg) all fall within their respective acceptable ranges. Iron at 38422.25 mg/kg and manganese at 3328.72 mg/kg are within safe limits and will contribute to micronutrient availability in the receiving soil.

7. CONCLUSIONS

Based on the comprehensive geotechnical and agricultural characterisation of sediment deposited in TB Dam (Munirabad Lake), the following conclusions are drawn:

- The sediment is classified as sandy silt (SM), with fine sand and silt fractions dominating the grain size distribution. Only 3.6% of particles are finer than 0.075 mm.
- The natural water content (33.18%), specific gravity (2.41–2.53), liquid limit (31%), plastic limit (18%), plasticity index (13%), and shrinkage limit (7.21%) are characteristic of medium-plasticity silt of low to intermediate compressibility.
- The optimum moisture content is 10.16%, indicating adequate compaction characteristics for potential use as fill or agricultural topsoil.
- Agricultural analysis confirms that the sediment satisfies permissible ranges for all fourteen parameters tested, including pH, electrical conductivity, macronutrients (N, P, K), and trace metals.
- The sediment is enriched in available nitrogen (340.6 kg/ha) and potassium (485.6 kg/ha), making it a valuable soil amendment for improving crop yields in the agricultural lands surrounding the TB Dam command area.
- Lead contamination is absent (nil), and all other trace metals are within safe agricultural limits, confirming that the sediment poses no heavy metal toxicity risk to crops or soils.
- The study demonstrates that TB Dam sediment can be profitably utilised for agricultural purposes. Planned desilting operations would simultaneously restore reservoir storage capacity (currently reduced by approximately 33 TMC due to sedimentation) and generate nutrient-rich soil amendment material, providing a dual environmental and agricultural benefit.

REFERENCES

- [1] V. K. Sissakian, N. Adamo, and N. Al-Ansari, “The role of geological investigations for dam siting: Mosul Dam a case study,” *Engineering*, vol. 6, pp. 352–368, 2014.
- [2] G. V. Nagalingeswar Rao, C. Sashidhar, and G. Abbaiah, “Estimation of sediment production of Tungabhadra

- Project in Krishna Basin using Universal Soil Loss Equation,” Int. J. Eng. Res. Appl., 2014.
- [3] P. R. Ghorpade, A. R. Chavan, and H. P. Kadam, “De-silting artifice for dams,” Int. J. Adv. Res. Sci. Eng., 2017.
- [4] G. M. Kondolf, Y. Gao, G. W. Annandale, et al., “Sustainable sediment management in reservoirs and regulated rivers: experiences from five continents,” Earth’s Future, vol. 2, no. 5, pp. 256–280, 2014.
- [5] M. S. Umesh Babu and E. T. Puttaiah, “Issues and constraints of water resource management in Tungabhadra River Basin in India,” Environ. Sci. Eng., 2012.
- [6] IS 2720 (Part 2):1973, Determination of Water Content. Bureau of Indian Standards, New Delhi.
- [7] IS 2720 (Part 3):1980, Determination of Specific Gravity. Bureau of Indian Standards, New Delhi.
- [8] IS 2720 (Part 4):1983, Grain Size Analysis. Bureau of Indian Standards, New Delhi.
- [9] IS 2720 (Part 5):1985, Determination of Liquid and Plastic Limit. Bureau of Indian Standards, New Delhi.
- [10] IS 2720 (Part 6):1972, Determination of Shrinkage Factors. Bureau of Indian Standards, New Delhi.
- [11] IS 2720 (Part 7/8):1980/83, Determination of Water Content–Dry Density Relation (Standard Proctor Test). Bureau of Indian Standards, New Delhi.
- [12] IS 2720 (Part 13):1986, Direct Shear Test. Bureau of Indian Standards, New Delhi.