# Geotechnical Investigations for Feasibility of Constructing Four Dams in Central Part of India and Problems Encountered

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**Abstract** Central part of India is facing water scarcity during most part of the years. The difficult geographical features of this area and low intensity of rainfall do not permit for constructing high dams for storage purposes. Therefore to resolve water demand in the locality, it was proposed to construct small dams across lower and medium selected streams at different location in region. Intensive geotechnical investigations were carried out at four dam locations to ascertain the feasibility studies. Laboratory investigations such as Mechanical analysis, Atterberg limits, Proctor compaction test, Laboratory Permeability, One dimension Consolidation test, Triaxial Shear Strength test and Dispersivity of soil were carried out to ascertain index and strength properties of soil. It was revealed during laboratory investigations that soil is suitable at some dam sites with clay of intermediate plasticity soil classification possessing adequate strength and engineering properties while at other dam locations the properties of soil was clay of high plasticity and non-plastic silty soil in nature which is not suitable in constructing earthen dams. Efforts were made either to choose suitable borrow areas or blending of soils so as to fulfill the requirement of strength and other properties of soil. This paper presents results of laboratory investigations of four dams and remedial measures taken for improvement of soil properties.

**Keywords:** Earthen dam, blending, Soil, Clay core.

## 1 Introduction

The Subernarekha water basin is one of the major river basin which flows from west to south-east direction, which supported by many major and minor tributaries. This river basin feed water to the whole state of Jharkhand. To improve the irrigation facility, some of the barrage and weir structures were already constructed in few locations across River and many irrigation schemes in the river basin are in feasibility stage. Subernarekha water basin is shared by Jharkhand, West Bengal and Odisha hence construction of big storage scheme may cause internal water disputes between the states.

Climate and rainfall of the region is extreme hot in summer season between February to June and moderately cold in winter from December to February. The monsoon season which gives major rainfall to this region, happens between June to September.

The annual rainfall of the region is around 1200 mm to 1400 mm. In the past decade there is negative deviation in the rain fall pattern, which maybe due to imbalances of the ecosystem.

The geographical features of East and West Singhbhum district have difficult terrain and about 53% of the total area of the district is covered by residual mountains and hills. The elevation of the district is 213 m. to 945 m above mean sea level. Whole area has different slopes ranging from 150-300 m/km., 80-150 m/km., 20-80 m/km,10-20m/km. and slope less than 10m/km. These variations in slopes do not permit for construction of high dams for storage purposes. Therefore to resolve water crises it is proposed to construct small dams across small streams at different location in selected region.

The water use pattern for the irrigation purpose shows that 41% of total surface water and 89.4% of the total ground water is consumed for the irrigation purposes. Also 90% of the rural and 30% of the urban water consumption was depends on the ground water.

At present, Subarnarekha river basin is not fully utilized in effective water management for sustainable agriculture growth and in mitigating natural hazards such as droughts in the region and also sharp decline in ground water level. To counter act the following problems it is proposed to construct small dams across small streams at different location in particular region. It may help to increases the quantity of surface water for irrigation, with in the subsequent years ground water level in the region may also improve and with construction of small dam the soil erosion of the region will be under control. This may minimize the Rehabilitation and Resettlement of population.

## 2 Project details

Total four numbers of feasibility studies were carried out for the construction of dam on the various tributaries of Subarnarekha River.


**Fig. 1.** Project Locations of Irrigation Reservoir Schemes.

The four irrigation reservoir schemes located in East and West Singhbhum and Simdega districts of Jharkhand are shown in Fig. 1. Projects 2 & 3 are situated at the west side of Saranda Singhbhum range and Projects 1 & 4 are situated at the east side of Saranda Singhbhum range. The primary function of the Project is to facilitate the irrigation facility to the locality

## 3 Geotechnical investigations

The Project locations of irrigation schemes are shown in Figure-1 and numbers of foundation and borrow area investigations details are shown in Table-1. Foundation investigation depends on the size of Project and terrain. Whereas numbers of borrow area depends upon the requirement and availability of soil quantity of and the distance from the Project site. All the four Projects are in feasibility stage only.

**Table. 1.** Geotechnical investigation.

| Sl. No | Project | Foundation Investigation | Borrow Area Investigation | Proposed Project Details (Medium high dams) |
|---|---|---|---|---|
| 1 | Project-1 | 2 nos. | 3 nos. | Embankment dam, Length of dam around 150 m |
| 2 | Project-2 | - | 3 nos. | Embankment dam, Length of dam around 800 m |
| 3 | Project-3 | 1 nos. | - | Embankment dam, Length of dam around 200 m |
| 4 | Project-4 | - | 3 nos. | Embankment dam, Length of dam about 120 m |

### 3.1 Field investigations

The field investigations include foundation investigations for ascertaining the competency of the foundation strata of the dam. Hence 3.0 m × 3.0 m × 3.0 m pits were excavated along the dam axis to obtain the undisturbed soil samples. The open pits of site consist of rocky nature and its makes difficulty in collecting undisturbed samples, hence minimum undisturbed soil samples were collected from the foundation. Insitu Permeability Tests were conducted in these foundation pits using falling head method. The results of Insitu Permeability Tests of foundation indicate that the Project-1 foundation strata possess impervious drainage characteristics and Project-3 foundation strata possess pervious drainage characteristics except the foundation strata at second pit shows impervious drainage characteristics up to depth 1.5 m.

### 3.2 Laboratory investigations

Laboratory investigations such as Mechanical analysis, Atterberg limits, Proctor compaction test, Laboratory Permeability, One dimension Consolidation test, Triaxial Shear Strength test and Dispersivity of soil were carried out to ascertain index and strength properties of soil. The test results of laboratory investigation for the project 1 to 4 are given in Table 2.

It can be seen from the Table 2 that, for Projects 1 to 3, the available soil from the borrow areas are suitable for constructing the clay core of the embankment dams. However, in Project 4, three borrow areas were identified falls under SM (Silty Sand), SW–SM (Well Graded Sand and Silty Sand) and CH (Clay with High Plasticity). As per IS 12169, soil types SM and CH are fairly suitable for clay core of embankment dam. Hence, alternate borrow area needs to be identified or modification of material using blending with other natural or artificial materials need to be done in order to obtain required quality material for the construction of clay core.

**Table. 2.** Test Results of Laboratory and Field Investigation.

| Parameters | Project-1 Foundation | Project-3 Foundation | Parameters | Project-1 Borrow Area | Project-2 Borrow Area | Project-4 Borrow Area | Project-4 , trial-2 blending materials |
|---|---|---|---|---|---|---|---|
| IS soil Classification of majority samples | CI | CI | IS soil Classification of majority samples | CI | SC | SM | CL |
| Average Insitu Dry Density, $\gamma_d$, (g/cc) | 1.835 | 1.86 | Average Maximum dry density MDD, (g/cc) | 1.9 | 1.85 | 1.93 | 1.92 |
| Specific Gravity | 2.71 | 2.67 | Specific Gravity | 2.72 | 2.62 | 2.72 | |
| Average Field Moisture Content, FMC (%) | 21.0 | 21.1 | Average Optimum Moisture Content,OMC (%) | 13.9 | 10.5 | 10.5 | 14 |
| Average. Triaxial Shear strength | | | | | | | |
| Total Cohesion, c, (kg/cm2) | 0.27 | 0.29 | c, (kg/cm2) | 0.16 | 0.21 | 0.21 | 0.22 |
| Total Angle of Shearing Resistance ($\phi$) | 20.4° | 14.1° | ($\phi$) | 18.4° | 22.8° | 31.7° | 26.4° |
| Effective Cohesion c', (kg/cm2) | 0.17 | 0.20 | c', (kg/cm2) | 0.08 | 0.12 | 0.11 | 0.11 |
| Effective Angle of Shearing Resistance ($\phi'$) | 30.1° | 27.3° | ($\phi'$) | 28.6° | 31.7° | 33.4° | 31.1° |
| Average one Dimensional Consolidation | | | | | | | |
| Average Compression Index (Cc) | 0.149 | 0.138 | (Cc) | 0.130 | 0.120 | 0.066 | |
| Average Swelling Index (Cs) | 0.023 | 0.076 | (Cs) | 0.031 | 0.0150 | 0.004 | |
| Average Co-efficient of Permeability (k) cm/sec | | | | No flow | No flow | $8.1*10^{-6}$ | $2.3*10^{-7}$ |

Note: For foundation investigation Insitu Dry Density ($\gamma_d$), Natural Moisture Content results shows and for borrow area samples results Maximum dry density (MDD), Optimum moisture content (OMC) results shown in above table.

### 3.3 Laboratory results with blending of three types soils for Project-4

There was no additional suitable borrow area in the vicinity of the project site as informed by the Project Authority. Therefore it was decided to blend the available soil samples in the different ratio as shown in Table-3.
The first trial was prepared by combining 33% of each of the three borrow area samples SM, SW-SM and CH. The second trial was revised by blending 25% of the SM and SW-SM soil samples with 50% of the CH soil sample.

Results of Mechanical Analysis results are shown in Table 3. Graphical representations of Grain size distribution of Project-4 samples are presented in Fig. 2. The Atterberg's limits LL, PL and PI of CH soil, Trial-1 (sample-D) and trial-2 (sample-E) are shown in Fig. 3.

**Table.** 3. Results of Mechanical Analysis

| S.N. | Sample | Clay & Silt | Fine Sand | Medium Sand | Coarse Sand | LL | PL | PI | Classification |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 20.3 | 47.5 | 31.8 | 0.4 | 24.7 | NP | NP | SM |
| 2 | B | 9.1 | 10.0 | 59.4 | 21.5 | 34.7 | NP | NP | SW-SM |
| 3 | C | 95.8 | 3.4 | 0.8 | - | 60.8 | 24.8 | 35.9 | CH |
| Trial-1 | D=33% (A+B+C) | 43.5 | 21.9 | 27.4 | 7.2 | 26.3 | 15.8 | 10.5 | SC |
| Trial-2 | E=25%(A+B) +50% 'C' | 71.7 | 10.9 | 16.5 | 0.9 | 33.9 | 18.4 | 15.5 | CL |

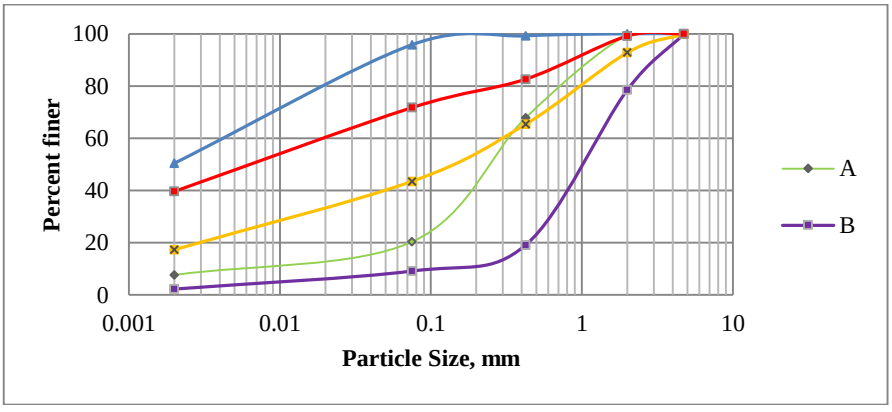


**Fig. 2** Grain size distribution of Project-4 samples and trials.

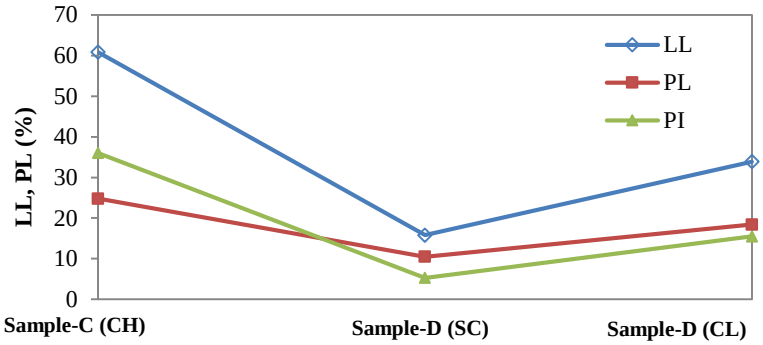


**Fig. 3** LL & PL of Soil type CH and trials.

Based on the grain size distribution graph, borrow area sample A and B the dominant size fraction is coarse grained soil and the borrow area sample C is fine grained soils. In Trial-1 (sample-D) and Trial-2 (sample-E) after blending soil samples, presence of all size particles can be seen from the graph.

Based on the blended results of grain size distribution and Atterberg limits tests, soil sample D falls under SC (Clayey Sand) and sample E falls under CL (Clays with Low Compressibility) group as per soil classification system [3].

The liquid limit of the CH sample decreases by 74% for sample-D blended sample, and decreases by 44 % for sample-E. The plastic limit of the CH sample decreases by 58% for the blended soil sample for sample-D and decreases by 26% for the blended soil sample of sample-E. The plastic index of the CH soil sample decreases by 85% for the blended soil sample for sample-D and decreases by 57% for the blended soil sample of sample-E.

## 4 Conclusion

It can be concluded from the field and Laboratory investigation that:

- Construction materials of Projects (1 to 3) are suitable for construction of clay core embankment dams. However, the borrow area soil properties of Project-4 is not appropriate for the clay core of earthen dam.

- Based on the test tests results of trail-1 (sample-D) (33% SM+33%SW-SM+33%SM) and trial-2 (sample-E) (25% SM+25%SW-SM+50%CH), sample-E is found more suitable for clay core embankment dam.

- The above investigative analysis shall support in construction of irrigation dams based on the available materials by blending different soil types. Furthermore, it will accommodate the requirements of water for irrigation and drinking purposes in the Central India.

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