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DPR Requirements for Preparation of Geotechnical Investigation and Construction Materials Survey Chapter for Hydro Electric Project

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Abstract: The environment-friendly renewable sustainable energy source is the need of time to promote and propagate to meet the growing power demand. More than 65% of India's electricity is generated by thermal power plants and 85% of the country's thermal power generation is coal-based. Our coal and gas reserves are limited and can last only for another 20-30 years. India is having enough hydropower potential i.e. to a tune of 148 GW (which would be able to meet a demand of 84 GW at 60% load factor) but as of date, its contribution is only 12.2% out of our total demand. Though the initial cost of hydro projects is comparatively high but the maintenance cost is minimal. To initiate a project Detailed Project Report (DPR) is required to be prepared. Since huge investment is involved in the hydroelectric project, hence, exhaustive techno-economic examining is required to decide for investing. Covering all the aspects of investigation enables the apprising agencies to examine the report holistically and provide clearances in a minimal time frame. In the scope of construction materials survey and geotechnical investigation, the availability and suitability of construction materials are to be assessed. The geotechnical investigation provides design parameters to the designer.
Keywords: detailed project report, construction materials survey, rock, soil, concrete, rockfill.

I. INTRODUCTION

Hydropower provided the impetus to the industrialization of the country. If we go back, from the 1980s onwards share of hydropower in the overall energy matrix of the country has fallen. In 1980, hydro provided around 40% of installed capacity which is now around 12% only. It has many reasons but now policies of government are quite encouraging. In January 2019, a parliamentary standing committee in its report had expressed concern over the slow pace of the hydropower sector stating that it has not got the deserved attention despite having numerous benefits. Six basin/rivers system viz. Indus, Ganga, Central India Rivers, West Flowing Rivers, East Flowing Rivers, and the Brahmaputra are prevailing in India. North and North Eastern states of India have the largest hydropower potential. Only north-eastern states are having about 40% of the total potential. Present status of hydroelectric projects above 25 MW in the country - 15 projects in the central sector, 12 projects in the state sector, and 9 projects in the private sector are under execution, and many more to come. DPR of a project is a document that consists of all investigation, clearances, valuation, planning, technicality, and viability. Investigation for a suitable site, hydrology of river, catchment area, materials, man and machine, environment, ecology, flora and fauna, power, irrigation area, drinking water, finance, marketing, etc. requires an investigation. The techno-economic success of the project depends on a meticulous investigation of each aspect of the project. Compilation of all the investigation reports and clearances makes DPR.

II. GEOTECHNICAL/FOUNDATION INVESTIGATIONS

Primarily geotechnical / foundation investigation includes in-situ and laboratory tests for the structure and detailed reports to be appended for review. The quantum of investigations varies by the type and size of structures, geological variations of subsurface strata/materials, etc. It is evident that site investigation/tests are to be carried out as per the design requirement of structures and it covers engineering properties of rock/rockfill/soil. The geotechnical investigation starts with site exploration, drilling, pit, trenches, and drifts. It is further corroborated by laboratory investigation, geophysical investigation, and in-situ testing. Data obtained from these investigations decide the location of the dam, powerhouse, machine hall, etc. Material properties decide the type of dam and appurtenant structures. The engineering properties of geotechnical foundation materials which include soil/boulder/overburden/rock are required for designing the structures.

The subsurface investigation is a behaviour study of foundation material under the expected loads of the proposed structure. The subsurface investigation of river valley projects can be carried out by exploratory drilling, exploratory pits, trenches, shafts & drifts, and geophysical methods.

A. *Foundation / Subsurface investigation of Rock*

1) *In-Situ Testing of Rock:* Ideal intact rock is seldom found in nature for the construction of hydroelectric projects. It has joints, folds, faults, dips, shear zones/seams, etc and that is why the rock mass is termed discontinuous, inhomogeneous, anisotropic, and non-elastic. The structural arrangement of mineral grains mainly plays an important role in defining the properties of intact rock material. On the other hand, discontinuities govern the behaviour of rock mass to the imposed stresses to a large extent. Apart from the geological factors and site conditions, the size of the sample greatly influences the engineering properties of the rock. The strength and elastic properties of intact rocks are significantly high compared to the properties of rock mass containing discontinuities. Therefore, in-situ tests are essentially required for characterizing the rock mass. Parameters that are essentially required for the characterization of rock mass are:

a) Shear strength parameters (cohesion and friction angle) of rock mass, discontinuities, and interfaces.
b) Modulus of deformation either by plate loading tests or by Goodman jack tests on rock mass.
c) Seismic wave velocity
d) Bearing capacity test
e) Permeability and groutability tests

2) *Laboratory Testing of Rock:* For the intact rock characterizations following physico-chemical tests are commonly carried out. The quantity and type of tests for any particular structure may vary with the size and type of intended structure, geological variations, design requirements, or site-specific issues.

a) Index Properties (Density, water content, specific gravity, void ratio, porosity, etc.)
b) Unconfined compressive strength
c) Modulus of Elasticity and Poisson's ratio
d) Specific gravity and water absorption
e) Slake durability
f) Shear and Compression ultrasonic velocities
g) Shear strength of infilling material
h) Tests for Swelling
i) Joint stiffness test
j) Tri-axial Testing for the determination of shear strength parameters
k) Abrasion resistance tests

The laboratory testing needs to be carried out in both dry and saturated samples.

B. *Foundation / Subsurface investigation of soil and soil as construction material*

Depending on the type of structure soil investigations are required to be carried out. Soil as a material used in earth dam, embankment dam (earth fill or rock fill), earth cum rockfill dam etc. In general, the following information is required to be evaluated for DPR. The tests and numbers can be decided by an expert after the site visit and due consultation.

1) Borehole log should consist of information on the water table, description of strata, soil classification, log, size of the hole, sample details (sample depth, sample type, filed no. lab no.), permeability value, SPT 'N' value, etc.
2) Mechanical Analysis
3) Atterberg limits
4) Soil classification
5) In-situ Density/Natural Moisture Content
6) Specific Gravity
7) Shear Strength Tests

a) Triaxial Shear Test - Consolidated Undrained test with Pore pressure or
b) Direct Shear Test

8) One Dimensional Consolidation
9) Chemical Analysis of Soil
a) Ph
b) Total Soluble Salts
c) Calcium Carbonate
d) Water Soluble Sulphate
e) Water-Soluble Chloride
f) Organic Matter

C. Borrow Area Investigations for Construction Materials

Soil as construction materials for impervious core, semi pervious and previous zone of earth and rockfill dam, embankment needs to be investigated for their suitability. Following tests are required for ascertaining the suitability of soil as construction material. The tests and numbers can be decided by an expert after the site visit and due consultation.

1) Mechanical Analysis
2) Atterberg limits
3) Soil classification
4) Shrinkage Limit
5) Standard Proctor Compaction
6) Specific Gravity
7) Shear Strength Tests
a) Triaxial Shear Test - Consolidated Undrained test with Pore pressure measurement or
b) Direct Shear Test

8) One Dimensional Consolidation
9) Laboratory Permeability
10) Soil Dispersivity Identification Tests (as per standard procedures)
a) Pin-Hole Test
b) SCS Double Hydrometer Test
c) Crumb Test
d) Chemical Analysis of Pore-Water Extract Test

11) Chemical Analysis of Soil
a) pH
b) Total Soluble Salts
c) Calcium Carbonate
d) Water Soluble Sulphate
e) Water-Soluble Chloride
f) Organic Matter

III. INVESTIGATION OF ROCKFILL MATERIALS

Boulders, cobbles, coarse gravels obtained either by blasting of rock mass or from naturally available river bed materials are used as rockfill materials. Maximum particle size may be up to 1200 mm. For the construction of earth core rockfill dams (ECRD) or concrete faced rockfill dams (CFRD) rockfill materials are widely used.

The prime advantages of rockfill dam are its flexibility, capacity to absorb large seismic energy and adaptability to various foundations. According to the International Commission on Large Dams (ICOLD), dams with the height of more than 15 m are referred to as high dams. If rockfill dam/barrage of height more than 15 m or more, detailed field and laboratory investigations of rockfill material need to be carried out to understand the stress-strain-volume change behaviour, evaluation of shear strength parameters and deformability and permeability characteristics of rockfill materials which are very important for the safe and economical design of rockfill/cofferdam structures.

For carrying out the above studies field and laboratory tests are to be conducted on rockfill material are as follows:
1) Field grain size distribution test to evaluate an average prototype grain size distribution curve.
2) Relative density test for determining the minimum and maximum dry densities.
3) Large size triaxial shear test to study the stress-strain-volume change behaviour and evaluate the shear strength parameters i.e., angle of internal friction, f, and cohesion, c.
4) One-dimensional compression test to determine deformability and permeability characteristics.

IV. CONSTRUCTION MATERIAL SURVEY AND MATERIAL CHARACTERISATION FOR CONCRETE

Construction materials survey primarily start with geological surface reconnaissance with geo-morphological features like outcrop, overburden, bedrock, variation of strata, etc. For the suitable coarse and fine aggregates, probable quarry sites are identified and quantified according to the structures of the project. The concrete-making material needs to be investigated for its suitability as per the standards. For any construction, coarse and fine aggregates are largely required which can be obtained from rock quarries, river bed materials, terrace deposit, alluvial fans, talus accumulation, etc. Detailed construction materials survey includes general information of quarries, an approximate estimation of availability, length of haul, and geological data (if available) which include proper marking on the geological map. The numbers of samples may vary from geological discernible strata from the quarry area considered for the production of aggregate or size of quarry. Further, it can be decided more precisely by due consultation and site visit of the expert team. According to components of the project, quantify the wearing and non-wearing surfaces aggregate separately and yield of the quarry to report considering 38 percent wastage in processing, transportation, and handling of aggregates.

A. Coarse and Fine Aggregate

To establish the suitability of coarse aggregate to use in concrete generally below mentioned tests are required to do:
1) Physical Properties : Specific Gravity, Density, Water absorption, Soundness
2) Mechanical Properties:Impact Test, Crushing Test, Abrasion Test
3) Petrographic examination and alkali-aggregate reaction test

For fine aggregate in general following tests are required to establish suitability to use as fine aggregate in concrete:
a) Gradation and fineness modulus (FM)
b) Specific Gravity
c) Material finer than 75 microns
d) Mica content
e) Organic Impurities
f) Soundness Loss
g) Alkali-Aggregate Reaction
h) Petrographic Analysis

B. Cement

For any construction project cement is the primary binding material. It is, therefore, important to identify suitable suppliers within the vicinity of the project to meet the demand even during the peak construction of the project. Since it is the primary binding material in the concrete; hence, quality should meet all the parameters laid by the Bureau of Indian Standard.

C. Water

Water is the key ingredient for concrete and abundance in the hydro project but is equally neglected. To use for the mixing and curing of concrete, the source of the water is to be identified and ascertain its suitability as per codal provision. Generally, test the water at pre-monsoon, monsoon, and post-monsoon period for the parameters as mentioned below:
1) Alkalinity
2) Acidity
3) pH Value
4) Organic solids
5) Inorganic solids
6) Sulphates (as SO_3)
7) Chlorides
8) Suspended Matter

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D. Reinforcement

Like cement, a source of reinforcement is to be identified and ensure the uninterrupted supply during the peak demand of projects. The quality of reinforcement steel has to be checked periodically as per the codal provision.

E. Chemical and Mineral Admixtures

Chemical and mineral admixtures are an inevitable component in modern concrete. To enhance the concrete quality and to achieve desired workability, flowability, compatibility, pumpability, control the setting time, lightweight concrete, Steel Fibre Reinforced Concrete (SFRC), grouting, and many more, these materials are extensively used. Availability of suitable admixtures and identifying suitable suppliers to meet the demand of chemical or mineral admixtures for the project are very important. The chemical or mineral admixtures shall be checked periodically as per the provision of code.

V. CONCLUSION

Geotechnical investigation carries important input data for the designer whereas construction material survey ascertains the availability of suitable material for the project. In nature ideal materials are seldom available; hence deficiencies can be managed by selective quarrying and adopting preventive measures. The quantity and type of tests depend on many parameters like size and type of intended structure, geological variations, design requirements, or site-specific problems. Therefore, it is always advisable to consult an expert of this field. All investigation is to be carried out before submitting the DPR and complying with all the recommendations/suggestions offered by the apprising agencies.

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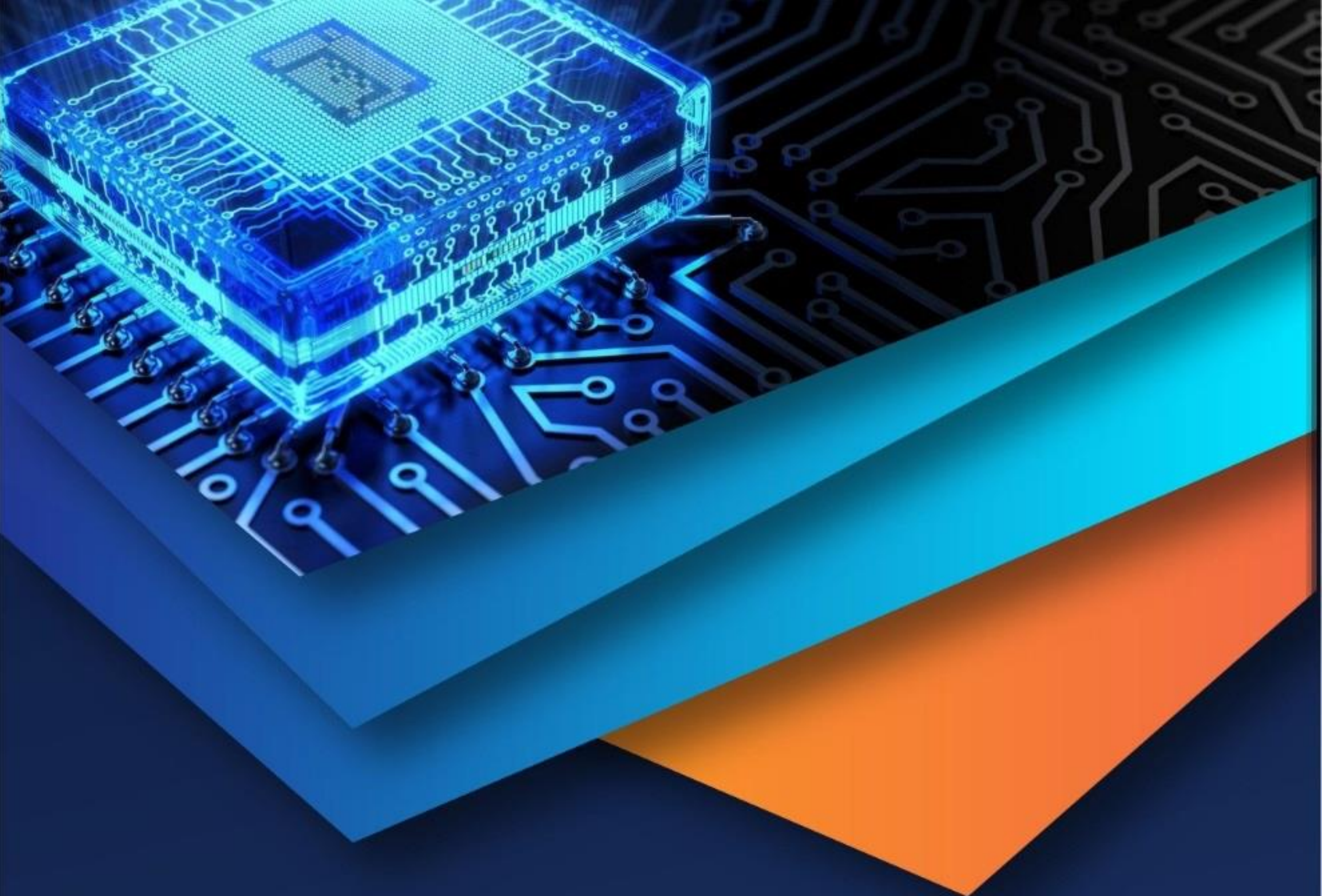

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