BUREAU OF INDIAN STANDARDS

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भारतीय मानक मसौदा

जलाशय स्थलों के लिए भूवैज्ञानिक अन्वेषण — दिशानिर्देश

(IS 13216 *का पहला पुनरीक्षण*)

Draft Indian Standard

GEOLOGICAL EXPLORATION FOR RESERVOIR SITES — GUIDELINES

(*First Revision of* IS 13216)

Geological Investigation and Subsurface Exploration Sectional Committee, WRD 05

Last date for comments: 30 Nov 2022

FOREWORD

(Formal Clauses will be added later)

Keeping in view the thrust towards hydroelectric power generation and the enhancement of irrigation capacity as well as control of flood situations, in our country today, a number of projects are under way for the construction of dams. While identifying a suitable site for the proposed dam, it is of paramount importance that the proposed reservoir site be thoroughly investigated and explored. The basis of planning for such explorations is to have a rapid economical and dependable pre-investment evaluation of sub-surface conditions. It is also necessary that a degree of uniformity be followed while carrying out subsurface explorations so that the frame of reference of the investigation covers all requisite respects.

This standard lays down guidelines defining the requirements to be fulfilled while carrying out subsurface explorations for reservoir site by defining the data requirements, the investigations needed and the areas to be investigated as well as the various stages of investigation from the reconnaissance stage to the post construction stage.

This first revision of the standard has been brought out to bring it in the latest style and format of the Indian Standards. Subsequent upon revision of IS 10711, the standard has been further modified with respect to referred map scale.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 ‘Rules for rounding off numerical values (*second revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1 SCOPE

This code lays down the guidelines for surface and sub-surface geological exploration for reservoir sites.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
4453:2009	Code of practice for exploration by pits, trenches, drifts and shafts (*second revision*)
5497 : 2008	Guide for topographic surveys for river valley projects (*second revision*)
5529 (Part 1) : 2013	Code of practice for In situ permeability tests: Part 1 Test In overburden (*second revision*)
5529 (Part 2) : 2006	Code of practice for In situ Code of practice for In situ permeability tests: Part 2 Test in bed rock (*second revision*)
6065 (Part 1) : 1985	Recommendations for the preparation of geological and geotechnical maps for river valley projects : Part 1 Scales (*first revision*)
6935 : 1973	Method for determination of water level in a bore hole
SP 36 (Part 1) : 1987	Compendium of Indian Standards on Soil Engineering : Part-1 Laboratory Testing of Soils for civil Engineering Purposes

3 DATA REQUIRED

Reservoir projects in river valleys are meant to hold water, therefore, the following aspects of the reservoirs should be properly investigated

(a) water tightness of the basins,

(b) stability of the reservoir rim,

(c) availability of construction material in the reservoir area,

(d) silting,

(e) direct and indirect submergence of economic mineral wealth, and

(f) seismotechtonic.

These investigations are carried out by surface and sub-surface exploration of proposed basin during the reconnaissance, preliminary investigation, detailed investigation, construction and post-construction stages of the project.

4 INVESTIGATIONS

4.1 Reconnaissance

4.1.1 In the reconnaissance stage, the objective of investigation is to bring out the overall geological features of the reservoir and the adjacent area to enable the designers, construction engineers and geologists to pinpoint the geotechnical and ecological problems which have to be tackled. The scale of geological mapping for this stage of work need not be very large and the available geological maps on 1 : 50 000 or 1 : 250 000 scales may be made use of. It is advantageous to carry out photogeological interpretation of aerial photographs of the area, if available. If a geological map of the area is not available, a traverse geological map should be prepared at this stage preferably using the aerial photos as base maps on which the engineering evaluation of the various geotechnical features exposed in the area should be depicted.

4.1.2 A topographical index map on 1 : 50 000 scale should be used at this stage to delineate the areas which would require detailed study, subsequently.

4.1.3 To prevent an undesirable amount of leakage from the reservoir, the likely zones of such leakage, such as major dislocations and pervious or cavernous formations running across the divide of the reservoir should be identified at this stage of investigation for further detailed investigations.

4.1.4 Major unstable zones, particularly in the vicinity of the dam in tight gorges, should be identified at this stage for carrying out detailed investigations for the stability of the reservoir rim.

4.1.5 The locations for suitable construction material available in the reservoir area should be pin pointed at this stage so that after detailed surveys such materials can be exploited for proper utilization during the construction stage prior to impounding of reservoir.

4.1.6 The rate of silting of the reservoir is vital for planning the height of the dam and working out the economic life of the project. Since the rate of silting, in addition to other factors, is dependent on the type of terrain in the catchment area of the reservoir, the

major geological formations and the ecological set up should be recognized at this stage to enable a more accurate estimation of the rate of silting of the reservoir. For example, it should be possible to estimate at this stage that forty percent of the catchment of a storage dam project is covered by quaternary sediment and this is a condition which is likely to yield a high silt rate or that ninety percent of the catchment of another storage dam project is composed of igneous and metamorphic rocks and is likely to yield a relatively low sediment rate. This information will also be useful in examining whether or not tributaries flowing for long distances through soft or unconsolidated formations, prior to forming the proposed reservoir, can be avoided and if not, what remedial measures can be taken to control the silt load brought by these tributaries.

4.1.7 The impounding of a reservoir may submerge economic/strategic mineral deposits occurring within the reservoir area or the resultant rise in the water table around the reservoir may cause flooding, increased seepage in quarries and mines located in the area and water logging in other areas. It is therefore, necessary that the economic mineral deposits, which are likely to be adversely affected by the reservoir area are identified at this stage of the investigation. For example, if an underground working is located close to a proposed storage reservoir area, it should be identified for regular systematic geohydrological studies subsequently. These studies would establish whether the impoundment of the water in the reservoir had adversely affected the underground working or not. References should also be made to various agencies dealing with the economic minerals likely to be affected by the impoundment in the reservoir for proper evaluation of the problem and suitable necessary action.

4.1.8 A dam and its reservoir are affected by the environment in which they are located and in turn they also change the environment. Impoundment of a reservoir sometimes results in an increase of seismic activity at, or near the reservoir. The seismic activity may lead to microtremors and in some cases lead to earthquakes of high magnitude. It is, therefore, necessary to undertake the regional seismotechtonic study of the project area. The faults having active seismic status should be delineated at this stage. Simultaneous action to plan and install a network of seismological observatories encompassing the reservoir area should also be taken.

4.2 Preliminary Investigation

4.2.1 The object of preliminary investigation of the reservoir area is to collect further details of the surface and subsurface geological conditions, with reference to the likely problems identified during the reconnaissance stage of investigation by means of surface mapping supplemented by photogeological interpretation of aerial photographs, hydrogeological investigations, geophysical investigations preliminary subsurface exploration and by conducting geo-seismological studies of the area.

On the basis of studies carried out during the reconnaissance stage it should be possible to estimate the extent of exploration that may be required during the preliminary stage of investigation including the total number of holes required to be drilled and the total number and depth of pits, trenches and drifts as also the extent of geophysical surveys which may

be necessary. For exploration by pits trenches, drifts and shafts guidelines laid down in IS 4453 should be followed.

4.2.2 The potential zones of leakage from the reservoir and the lateral extent of various features, such as extent of aeolian sand deposits, glacial till, landslides, major dislocations or pervious and cavernous formations running across the divide, should be delineated on a scale of 1: 50 000.

The geohydrological conditions of the reservoir rim should be established by surface and sub-surface investigation as well as inventory, as a free ground water divide rising above the proposed level of the reservoir is a favorable condition against leakage from the reservoir. The level of water in a bore hole should be determined as given in IS 6935.

4.2.3 The extension of various features at depth, wherever necessary, is investigated by geophysical exploration and by means of pits trenches, drifts and drill holes. For example, the resistivity survey should be able to identify water saturated zones. The nature of the material is investigated by means of laboratory and *in situ* tests, to determine permeability and assess the quantum of leakage which may take place through these zones on impoundment of the reservoir. Moreover, permeability of rocks/overburden in the reservoir, area is determined from water table fluctuations and pumping tests in wells. For determining in *situ* permeability in over burden and bedrock, reference should be made to IS 5529 (Part 1) and IS 5529 (Part 2) respectively. The information about permeability would enable the designers to estimate the treatment cost for controlling leakage/seepage from the reservoir and to decide whether it would be desirable to change the location of height of the dam to avoid these zones.

NOTE — For conducting laboratory tests, reference should be made to SP 36 (Part 1)

4.2.4 Major unstable zones along the reservoir identified during the reconnaissance stage and which are of consequence to the storage scheme should be investigated in detail at this stage by means of surface and sub-surface exploration. The areas should be geologically mapped in detail on a scale of 1: 2 000. The suspect planes/zones of failure should be identified and explored by means of drifts, trenches and pits. Disturbed and undisturbed samples of the plastic material should be tested for cohesion (c) and angle of internal friction (0) as well as for other relevant properties. The stability of slopes should also be evaluated considering the reservoirs operational conditions. These studies should provide the designers with an idea of the magnitude of the problems, that may be encountered, so that they may be able to take remedial to stabilize zones or to abandon the site altogether, if the situation demands.

4.2.5 The topographic survey of the reservoir area shall be carried out as per IS 5497 and the scale of mapping shall be as per IS 6065 (Part 1).

4.2.6 During the reconnaissance stage it should have been possible to identify those reaches of the main river and tributories which, due to their geological and ecological set up, are likely to yield abnormally high silt loads. A systematic network of silt observation stations should be set up to provide accurate date for planning remedial measures such as check dams afforestation, etc.

4.2.7 The areas having potential economic mineral wealth and which are likely to be adversely affected by the impoundment of the reservoir should be explored by means of surface and sub-surface investigation to establish their importance both in terms of their value as well as strategic importance. This information would be necessary for arriving at a decision regarding the submergence, or otherwise, of the mineral deposit. The nature and amount of the existing seepage, if any, in the existing mines and quarries in the adjacent areas of the reservoir should be recorded and monitored regularly. This data is necessary, to ascertain whether or not there has been any change in the quantum of seepage in the mines and quarries due to the impoundment of water in the reservoir, directly or indirectly.

4.2.8 Large scale geological mapping and terrace matching across the faults with seismically active status, delineated during the reconnaissance stage, should be carried out on a scale of 1 : 2000 and the trend, and behaviour of the fault plane should be investigated in detail by means of surface studies and sub-surface exploration by pits, trenches and drifts etc. A network of geodetic survey points should be established on either side of the suspected faults to study micromovements along these suspected faults, if any, both prior to and after impoundment of the reservoir. Micro earthquake studies should be carried out using portable 3 station or 4 station networks in areas with proven seismically active fault features.

4.2.9 The data from the seismological observatories available till now should be evaluated so that shift or addition in the network of the observatories, if necessary could be considered.

4.3 Detailed Investigation Stage (Pre–Construction Stage)

4.3.1 On the basis of the studies carried out during the preliminary stage it should be possible to estimate the quantum of exploration which may be required during the detailed stage of investigation including the total number of holes required to be drilled and the total number and depth of pits, trenches and drifts as also the extent of geophysical survey which may be necessary.

4.3.2 Detailed surface and sub–surface investigation of all features connected with the reservoir should be carried out to provide information on leakage of water through the periphery and/or basin of the reservoir area. Based on these investigations and analysis of data it should be possible to decide as to whether the reservoir area in question would hold water without undue leakage. If, not, the dam site may have to be abandoned in favour of suitable alternative site.

4.3.3 The zones, which on preliminary investigation are found to be potential zones of leakage/seepage from the reservoir, and which due to other considerations cannot be avoided are geologically mapped on a scale of 1 : 2 000 and investigated in detail at this stage by means of a close spaced sub-surface exploration programme. The purpose of this stage of investigation is to provide the designers sufficient data to enable them to plan the programme of remedial treatment. The subsurface explorations are carried out

by means of pits and trenches, if the depth to be explored is shallow, say up to 5 m, and by drill holes and drifts, if the depth to be explored is greater than 5 m.

4.3.4 The unstable zones around the reservoir rim, specially those close to the dam sites in tight gorges, should be explored in detail by means of drifts, pits and trenches so that the likely planes of failures are located with precision. The physical properties including angle of internal friction and cohesion of representative samples of the material along which movement is anticipated should be determined. The above information would enable the designers to work out details for preventive measures, for example, it may be possible to unload the top of the slide area or to load the toe of the slide with well drained material, within economic limits.

NOTE — For conducting laboratory tests, reference should be made to SP 36 (Part 1).

4.3.5 Sub–surface explorations by drill holes, drifts, pits and trenches should be carried out at possible locations of check dams and at the locations of other preventive structures proposed to restrict the flow of silt into the reservoir. These studies would enable the designers to assess the feasibility of such proposals.

4.3.6 Detailed plans, regarding the economic mineral deposits within the zones of influence of the reservoir should be finalized during this stage by the concerned agencies. The seepage investigations in the quarries and mines within the zone of influence of the reservoir should be continued.

4.3.7 The seismotechtonic studies should be further intensified and continued for several years even after the impoundment of the reservoir or till it is established for certain that the impoundment of the reservoir will not have any effect on the seismic stage of the area. The detailed seismotechtonic investigations should be carried out for reservoirs of capacity more than 500 cubic meter and dams of height greater than 60 m.

4.4 Construction Stage

4.4.1 It is likely that major discontinuities of pervious formations/zones etc. located at the periphery or in the reservoir basin may extend upto the dam alignment. In such cases the dispositions of features established during the investigation stage, by sub-surface exploration, can be confirmed during foundation excavation and can be studied more precise visually. The weak features which were missed during the various stages of investigation may get exposed during excavation of the foundation. The implication of such features on the competency or stability of the reservoir rim should to be studied and remedial measures be undertaken accordingly.

The compilation and evaluation of various geological reports and drawings prepared during various stages of investigations should be done. The compilation should also contain details of remedial measures taken for the treatment of weak features present in the reservoir basin, rim and foundation of the dam, having relation to the stability of the reservoir rims, storage of the reservoir and seismic aspects etc.

4.5 Post-Construction Stage

4.5.1 The object of post-construction geological investigations is to monitor the critical problems encountered during all the stages of investigation of the project and the effectiveness of treatment provided to the weak features. For example, monitoring the critical areas susceptible to landslides or to keep a watch on the areas which requires special treatment, such as against leakages, so that necessary action can be taken on time, if required. Monitoring of the seepage in mines and quarries within the zones of the influence of reservoir, precision geodetic repeat surveys across fault planes or in slide prone areas and evaluation of microseismic and seismic data from the network of seismological observatories should be continued for a sufficiently long time till adequate reassurance is achieved.