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Indian Standard

CODE OF PRACTICE FOR TREATMENT OF ROCK FOUNDATIONS, CORE AND ABUTMENT CONTACTS WITH ROCK, FOR EMBANKMENT DAMS

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0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 29 August 1986, after the draft finalized by the Foundation and Substructures Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The treatment of foundations and abutments for embankment dams on rock foundations is an art of applying the knowledge of local geology and certain basic principle covering positive cut off extending to bed rock. It would not be practicable to prepare a rigid set of rules or stipulate standard procedures which would require to be enforced without leaving any latitude for the exercise of discretion by the site engineer. The aim of these recommendations is to summarize well-known and proved principles and to describe commonly used procedures, equipment and techniques in order to enable an engineer incharge to draft specifications for a specific case. The need for following an experimental approach and learning through trial is emphasized while providing guidelines which would permit a site engineer to use his discretion without compromising the overall design requirements.

0.3 This standard is to be read with:

IS : 4999-1968 Grouting of pervious soils

IS : 5050-1968 Code of practice for design, construction and maintenance of relief wells

IS : 6066-1984 Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*)

IS : 8414-1977 Guidelines for design of underseepage control measures for earth and rockfill dams

IS : 11293 (Part 1)-1985 Guidelines for the design of grout curtains: Part 1 Earth and rockfill dams

1. SCOPE

1.1 The scope of this standard is limited to earth and rockfill dams where the control of seepage is achieved primarily by a positive cutoff extending to bed rock so that the core is seated on rock all along the foundation as well as the flanks and abutments. The shell or casing zones may however rest on overburden.

1.2 Treatment of rock foundation for strengthening and stabilization of slopes is excluded from this standard. The scope is limited to treatment required for control of seepage.

2. ALIGNMENT OF THE DAM

2.1 Excessive skewness of the dam axis with respect to the valley alignment is to be avoided. Divergence of abutment contours with reference to the axis of the dam is to be avoided by choice of alignment, and the axis of the dam may be adjusted to avoid divergence of contours with reference to dam axis.

2.2 Despite these adjustments, because of irregularity of rock surface, there may still be areas of core contact where the rock contours have an undesirable orientation. Trimming of rock shall then be done to attain a maximum 90° angle with the axis on a horizontal plane (*see* Fig. 1). Such trimming should be accommodated with the core contact and transitions.

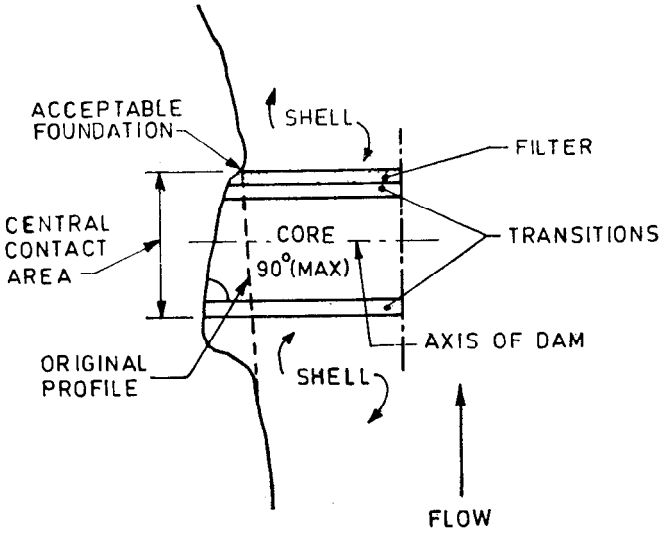


FIG. 1 PLAN OF ROCK CONTACT AT CENTRAL CONTACT AREA

3. ROCK PROFILE ALONG THE FOUNDATION

3.1 Rock profiles should be examined both along the axis and in the transverse direction. The behaviour of the core material and the cracking hazard is dependent on the pattern of stresses developed from the interaction of the rock and the core

material. In the following paragraph, guidelines are furnished stipulating requirement of rock profile along the axis and in the transverse direction. The consequence of rock geometry in the longitudinal and transverse directions creating zones of tensile stress in the core should be examined. These may require special consideration and adverse consequences of such geometries may be mitigated by filling with concrete in critical area and providing supplementary features as filters plastic concrete septums, etc.

3.1.1 Abrupt changes in section, for example, benches on the abutment slopes, should be avoided to minimize the hazard of transverse cracking because of differential settlement between the deep and shallow portions of the dam. If a site with a bench on the abutment is to be developed, trimming or rounding of the bench should be considered.

3.1.2 Necessary crimming or excavation of the abutments should be done very carefully. The line of excavation should be presplit or cushion blasting used to minimize damage to the rock beyond the excavation line. Surfaces against which material is to be placed commonly are excavated to a slope not steeper than ½ horizontal to 1 vertical (*see* Fig. 2). Flatter slopes or rounding may be necessary, particularly in upper portions of the abutment.

3.1.3 Changes in slope should be limited to 20° and the number of changes in slope should be minimum. This can be achieved by excavation of rock or placing concrete against the rock.

3.1.4 Removal of overburden materials under the upstream and downstream shells may not be necessary. Removal of overburden may however be required if excessive settlement of the shell sections would develop under their weight, if overburden materials are so weak as to result in slides, or if seepage passing through the core or through the foundation materials cannot be controlled and discharged safely with the overburden in place.

3.1.5 The hazard of slides in either overburden materials or rock during excavation for the core, spillway, or shells shall be given careful consideration in planning and in the layout of the dam.

4. ROCK PROFILE ACROSS CUT-OFF TRENCH

4.1 The excavated slope of the cut off trench should be 1:1 or flatter irrespective of the slopes required for stability of excavation. Adequately designed filter, single or multiple layer, should be provided against the downstream face of the cut-off trench. The filter should be capable of preventing internal erosion of core material and satisfy the filter criteria. The consequences of the loosening of the rock due to construction operations should be examined while establishing filter requirements for the downstream rock face.

4.2 Alternatively, excavated surface through weathered rocks may be treated with shotcrete. Where loosening of the rock by excavation may create open voids, low pressure pack grouting should be done of the rock contact.

4.3 The minimum width of the core trench should be larger than 4 m or 10 percent of head. If it is not possible to accommodate a cut-off trench of top width detailed as above within the core width, consideration should be given to use the plastic concrete diaphragm in part of the cut-off depth.

5. FOUNDATION PREPARATION

5.1 Basically, the surface under the entire core and under a portion of the upstream filter and downstream transition zone shall be completely excavated to such rock as will offer adequate resistance to erosion of fines in the core.

All loose or semi-detached blocks of rock should be removed. The quality of rock shall be judged in terms of the characteristic of core material. Rock of 'Lugeon' values in percolation test within 10 (Ten) will generally be free of cracks larger than

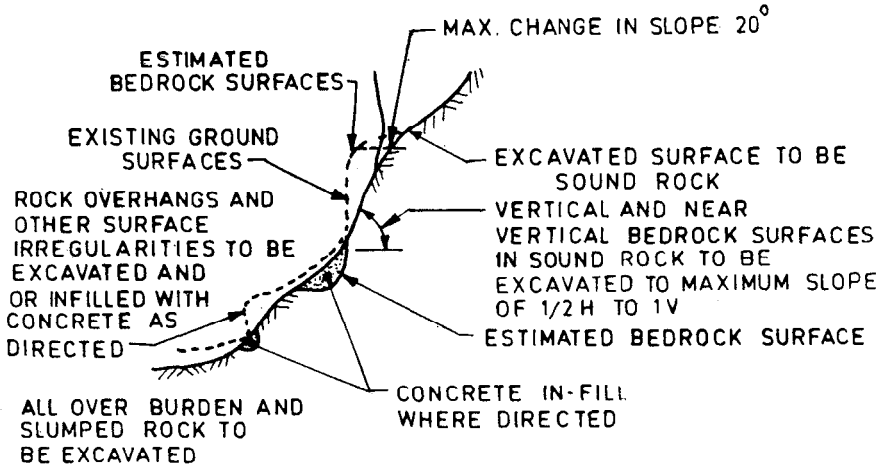


FIG. 2 TYPICAL CORE ABUTMENT EXCAVATION DETAIL

0·025 mm. Erosion of fines from core materials commonly used would not occur through such cracks. Grouting may be necessary to bring down 'Lugeon' values to above allowable limits in the contact zone.

5.2 The amount of care required in treating the rock suface is controlled by the character of the core material. If the core material is resistant to piping, especially if it contains considerable coarse material with adequate proportion of sand, surface treatment is less demanding than if the core material is susceptible to piping; for example, a fine silty sand and very lean clays. In the latter case, extreme care should be taken and the core material should be placed only after very careful inspection of the treated surface. For dispersive clays, special precauutions, such as protection by filter fabric or plastic concrete may be required.

5.3 Blasting should be kept to the minimum practical in order not to open up joints or otherwise disturb the rock surface, and no blasting should be done on surfaces that have been grouted or slush-grouted.

5.4 All knobs and overhangs should be removed by barring and wedging or by light blasting. Cracks and joints that are exposed in these operations should be cleaned (usually to a depth of not less than three times their width at the surface) using air and water, picks, or other tools, as necessary, to remove completely soil or weathered rock which would be subject to erosion. Such joints and cracks should then be filled with grout under a small gravity head, say, of 3 m. Wherever possible, a pipe should be set to the bottom of the joint or crack and grout pumped in until the joint or crack is completely filled. Grout should then be broomed and brushed across the top of the joint to ensure that the contact with the core material will be tight and non-erodible. In the absence of gravity grouting, slush grouting alone may not be effective because complete filling may not be assured. Grout used for this purpose should be highly plastic buttery. The maximum size of sand for the slush grout used for filling cracks should not exceed one-third the width of the crack to be filled.

5.5 Concrete with admixtures of approved quality and sufficient water to achieve a slump of 100-150 mm may be easily compacted by hand and used for backfilling of irregularities such as depressed areas, holes and potholes.

5.6 Small ribs and similar irregularities should be filled with plastic concrete to produce slopes not steeper than about 1:1 where the difference in elevation is a few centimetres to a metre or so. Surface treatment in this fashion should extend upstream to approximately the mid-point of the upstream filter and downstream at least 0·6 to 0·9 m beyond the downstream edge of the fine filter. In particularly adverse situations, such as where there are joints wider than the coarser particles of the filter, surface treatment as described may be necessary under the entire transition zone.

5.7 The final rock surface should have smooth contours against which soil can be compacted by heavy equipment. Hand compaction is generally unsatisfactory and it is advisable to place plastic concrete in core contact areas of conduit trenches and other irregularities transverse to the dam axis for a width at least 0·5 H or preferably 1·0 H.

5.8 Surface treatment as described may be difficult to accomplish on steeply sloping abutments. In this case, gunite may be used for filling depressions after the cracks and joints have been cleaned and sealed. If there is extensive jointing, especially if the joints slope upward away from the face, adequate sealing of the joints may require constructing a concrete slab, which is dowelled to the rock, and then grouting through the slab.

5.9 The depth of excavation necessary in weathered rock is difficult to establish during initial design. The depth of weathering is usually very irregular, being controlled by minor variations in joint spacing and rock type. Abrupt changes in elevation of the surface of 'groutable rock' probably will be found. Overhangs, some of large size, should be anticipated.

5.10 Usual practice is to select material, preferably a plastic soil, for the first lift over the rock surface. If plastic soils are limited, the most plastic soil available should be used. Gravel or stone exceeding about 50 mm in size should be removed or excluded from the material placed in this first layer over the rock to improve compaction at the contact. The surface on which the core material is placed should be moist but free of standing water, and the material when placed should be wet of optimum. In dry climates or during dry weather, difficulty may be experienced with this first lift becoming excessively dry where it feathers out on a gentle to moderate slope. In such a case the edge of the fill should be sloped slightly downward toward the contact with the rock. Against steep rock faces or adjacent to concrete structures, sloping the fill slightly upward near the contact is desirable to provide better clearance and better compaction at the contact.

6. FOUNDATION CLEAN-UP

6.1 All foundation areas should be dewatered for final inspection after clean-up prior to the placement of core material. The prepared rock surface in the central contact area should be free of water at the time when embankment material is placed and for foundation treatment measures, such as slush grouting and crack-grouting.

6.2 Where existence of deep depressions and occurrence of springs complicate the clean up, special provisions should be made to dry up the foundation in preparation for placing embankment fill. Gravel filled drains channellizing the water from the springs to central sumps and submersible pumps or pneumatically operated sump pumps (placed inside the sumps) have been found to be

effective. A cover of polythene should be placed over the gravel to prevent contamination of the gravel by the fill material. Stand pipes should be provided for discharge of water from the sumps. The top of stand pipes should correspond to the static head.

6.3 Where rock is friable and subject to cracking by exposure and drying, coating of asphalt emulsion or slush grout comprising a workable mix of cement, sand and bentonite is desirable.

6.4 To prevent cracks from developing in surfaces already prepared, all necessary excavation requiring blasting should be completed before starting grouting and surface treatment and clean up.

7. TREATMENT OF ROCK DEFECTS AND DISCONTINUITIES

7.1 In evaluating and planning for excavation and seepage control measures, special attention shall be given to discontinuities such as faults and relief (sheet) joints, which may extend for long distance as nearly plane surfaces. Relief joints may exist naturally or may open during excavation. They are most likely to occur in deep, steep-walled valleys, specially in brittle rocks, or where high modulus rock is underlain by low modulus rock. Since they are roughly parallel to the valley wall, they may cause slides during construction. Openings of several centimetres have been observed. Control of seepage through such joints becomes a major problem. Installation of concrete cutoffs across particularly bad joints may be warranted or extensive grouting may be necessary. Drainage from such joints shall be provided.

7.2 When seams are filled with silt, clay, etc, or in faults with gauge, it is essential to excavate and backfill the seam and gauge zones in the entire core contact zone. It is advisable to excavate and backfill a further length on the upstream for a distance equal to the reservoir head and backfill it with concrete. On the downstream side the seams should be excavated and backfilled with a well designed and adequate filter again for a distance equal to the reservoir head.

8. GROUTING

8.1 There are three main objectives in the grouting programme (*see also* IS : 6066-1984*). These are as follows:

a) To reduce the seepage flow through the dam foundation;

b) To prevent possible piping or washing of fines from the core into cracks and fissures in the foundation; and

c) To reduce the hydrostatic pressure in the downstream foundation of the dam. The latter is generally a problem only for dams on fairly weak foundations and critical abutment configurations. This is usually accomplished in conjunction with an abutment drainage system.

8.2 To prevent possible piping of the fine core material through the foundation, blanket grouting is accomplished as determined by the rock conditions. If the core foundation of the dam consists of closely fractured and jointed rock, a blanket grout pattern is used with holes spaced at 3 m to 5 m with depths of 6 m to 10 m. If the foundation rock is massive, no blanket grouting is done. Localised area consisting of faults, fissures, or cracks are generally grouted upstream of the cutoff and sometimes downstream.

8.3 If the rock does not respond to cement grouting and post grouting 'Lugeon' values remain above 10 (Ten) locally, the nature and size of cracks should be carefully examined. When the high 'Lugeon' values are attributable to fine cracks, closely spaced, cement grouting may not be effective in reducing the permeability. In hard inerodible rocks, such fine cracks may be permitted. In other cases such as gauge zones supplementary measures should be resorted to for prevention of internal erosion (*see* IS : 6066-1984*).

9. DRAINAGE

9.1 Galleries or tunnels are sometimes excavated into abutments and foundations to provide access for drilling drain holes and grout holes into the foundation or into the embankment foundation contact. Drilling from these tunnels after filling of the reservoir is subjected to the hazard of uncontrolled 'blow in' under high heads. If tunnels are provided, the elevations should be judiciously chosen so that the hazard of 'blow in' can be prevented by lowering the reservoir before undertaking the drilling operations for corrective grouting or drainage.

9.2 Relief wells and drainage trenches are often used at downstream toes of dams on pervious overburden to provide relief of seepage pressure and to control seepage discharges without permitting piping. Installation of relief wells and their monitoring shall be done as per IS : 5050-1968†. When drain holes are installed in rock containing fines the drain should be protected by a filter system as shown in Fig. 3.

9.3 On projects where the foundation is such that seepage could cause migrati n of particles from the foundation materials, the drainage blanket shall be filter graded with respect to the foundation. Drain pipes may be included in the blanket to ensure ample discharge capacity.

*Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*).

*Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*).

†Code of practice for design, construction and maintenance of relief wells.

9.4 It is essential to ensure continuity of filter system from the drain to the core contact on the downstream side of cutoff trench as shown in Fig. 4.

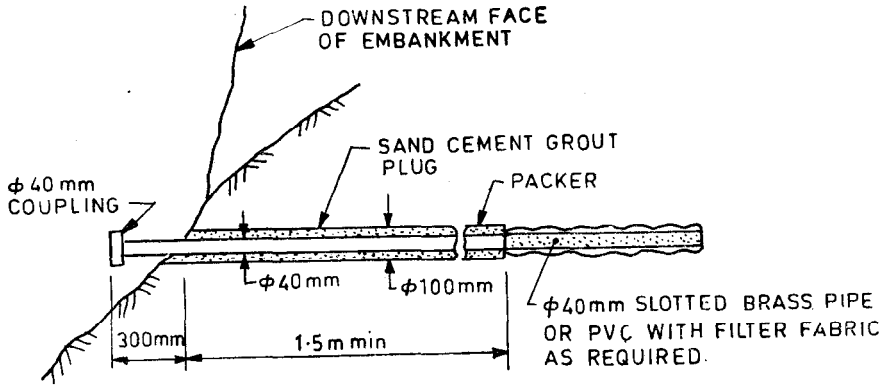
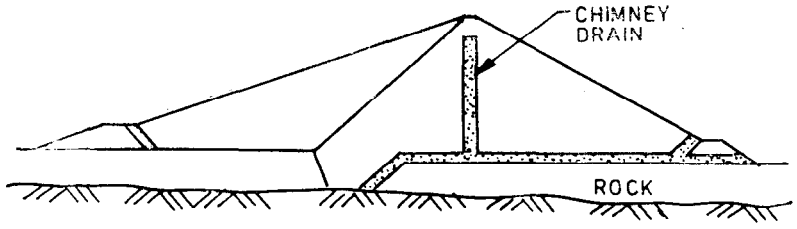


FIG. 3 INSTALLATION OF HORIZONTAL DRAIN IN ABUTMENT OF HIGH EMBANKMENT DAM



NOTE: CONTINUOUS FILTER SYSTEM FROM CHIMNEY DRAIN TO DOWN STREAM SLOPE OF CUTOFF TRENCH FILTER TO BE EXTENDED TO BOTTOM OF CUTOFF TRENCH.

FIG. 4 FILTER SYSTEM FOR CUTOFF TRENCH