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Jawaharlal Nehru
“Step Out From the Old to the New”

Indian Standard

DESIGN AND CONSTRUCTION OF TUNNEL PLUGS — CODE OF PRACTICE

(First Revision)

ICS 93.16
FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Water Resources Division Council.

Diversion tunnels are constructed to divert water of a river during construction stage of a dam. These tunnels would need to be suitably plugged after the utilization of diversion works. The tunnel plugs resist the entire unbalanced water pressure and transfer it to the surrounding rock. The seepage/leakage is kept to a minimum manageable quantity.

To facilitate construction, adits are provided at one or more intermediate points of long tunnels. These adits have to be suitably plugged before commissioning of the tunnels.

This standard was first published in 1984. This revision has been taken up to include construction aspects of the tunnel plugs to make this standard comprehensive.

There is no ISO Standard on the subject. This standard has been prepared taking into consideration the practices prevalent in the field in India.

The composition of the Committee responsible for formulation of this standard is given at Annex A.

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 2:1960 'Rules for rounding off numerical values (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.
1 SCOPE

1.1 This standard covers design and construction aspects of tunnel plugs including keys, concreting, grouting and cooling of concrete.

1.2 This standard does not cover the criteria for suitability or otherwise of providing solid concrete plug or concrete plug with gated access for facilitating inspection.

1.3 This standard does not cover design of adit section, structural design of gate and its recess in the body of the plug.

2 REFERENCES

The following standards 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:

<table>
<thead>
<tr>
<th>IS No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>457 : 1957</td>
<td>Code of practice for general construction of plain and reinforced concrete for dams and other massive structures</td>
</tr>
<tr>
<td>5878 : (Part 7) 1972</td>
<td>Code of practice for construction of tunnels conveying water: Part 7 Grouting</td>
</tr>
<tr>
<td>14591 : 1999</td>
<td>Temperature control of mass concrete for dams — Guidelines</td>
</tr>
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</table>

3 MATERIAL

Plain and reinforced concrete/work shall conform to IS 456.

4 LOCATION

4.1 For permitting utilization of diversion tunnels as spillway tunnels, outlet tunnels, tail race tunnels, etc, the plugs shall be placed immediately upstream of the intersection point of the diversion tunnel with the vertical/inclined shaft, water conductor tunnel, etc. Additional concrete may be required to be placed for necessary hydraulic profile at the junction (see Fig. 1).

4.2 For plugging construction adits, solid concrete plugs shall be provided at their junctions with main tunnel. Gates if provided, shall be as close to the tunnel as possible to cause minimum hydraulic losses. It shall open inside the tunnel so that water pressure shall force closure and sealing of gates (see Fig. 2).

5 TYPES OF PLUGS

Plugs are mainly classified as:

a) Solid concrete plug (see Fig. 1); and
b) Gated plug (concrete plug with gated opening, see Fig. 2).

6 CONSTRUCTION FEATURES OF THE CONCRETE PLUG

6.1 Wedge shaped keys are generally provided for better plug action.

6.2 Keys shall be provided in rock/concrete interface and within concrete to ensure effective plug action by providing adequate bearing of the plug concrete on the tunnel lining or plug concrete/tunnel lining on the surrounding rock. The keyways in the tunnel lining may be filled up with lean concrete/wood packing/masonry to ensure smooth flow of water during diversion stage and this shall be removed prior to the concreting of the plug.

6.3 Keyways provided in the first stage plug concrete shall be designed for anticipated horizontal thrust. Keyways thus provided shall be filled up with the material given in 6.2 so long as the tunnel is used for restricted flow purposes.

6.4 The solid concrete plug may be provided in stages where required from operational/functional requirements for diversion tunnels (see Fig. 1). For ensuring proper bonding between existing and subsequent stages of concrete chipping/roughening of
FIG. 1 TYPICAL SECTION (SHOWING CONCRETE PLUG IN STAGES)
FIG. 2 PLAN SHOWING GATED PLUG

PLAN

C.L. OF TUNNEL
FLOW

C.L. OF GALLERY

LENGTH OF PLUG

GATE

C.L. OF ADIT

DRAIN

PLUG CONCRETE
(2ND STAGE)

INITIAL CONCRETE
(1ST STAGE CONCRETE)

PERFECT CONTACT
WITH 2ND STAGE
CONCRETE

GALLERY

DRAIN

ENLARGED
SECTION X - X
existing concrete should be carried out along with provision for suitable dowels.

6.5 The reinforcement of the tunnel lining shall be so placed that this does not get damaged and hinder during the chipping of concrete keys.

6.6 The length of concrete plug in the tunnel if provided, without keys will depend mainly upon frictional resistance offered by the surrounding initial concrete or rock and bearing on the rock depending upon shape of the plug.

6.7 Adequate provisions shall be made for dewatering during construction.

6.8 To facilitate grouting a gallery may also be left in the plug wherever required.

7 DESIGN OF PLUG

7.1 Design Head

7.1.1 Plugs in the tunnel are designed for the maximum reservoir level with no flow or minimum flow in the tunnel.

7.1.2 Allowance shall be made for increase in water head in reservoir due to any rare situations like wave build up, surge and water hammer effects, if applicable, in case of sudden stoppage of flow in the tunnel.

7.2 Plug Length

7.2.1 The length of the plug shall not be less than the excavated diameter of the tunnel. The overall length of the plug may be increased to keep an allowance for seals at the near ends. The plug length may be calculated based on any of the following formulae as applicable:

\[
\text{Length of the plug} \geq \frac{\text{Hydrostatic force on the plug due to water head}}{\text{Permissible average shear stress} \times \text{Perimeter of tunnel section}}
\]

\[
\text{Length of the plug} \geq \frac{\text{Hydrostatic force on the plug due to water head}}{\text{Frictional resistance per unit length of the plug}}
\]

\[
\text{Length of the plug} \geq \frac{\text{Frictional resistance of plug and shear resistance of anchors per unit length of the plug}}{\text{Hydrostatic force on the plug due to water head}}
\]

NOTES

1 Value of permissible average shear stress/shear friction between the plug and surrounding concrete/rock shall allow for any imperfections in contact grouting between the plug and the tunnel lining. Conservative values with ample safety factors shall be considered.

2 Values of permissible shear and frictional resistance shall be validated where required at site.

7.2.2 It is preferable to provide the whole length of plug in one block without any construction joint.

8 DEPTH OF KEYWAYS

8.1 Key in Concrete/Rock

The depth of key may be calculated from the average bearing stress in concrete/rock from the following formula. The permissible stresses in concrete shall be in accordance with IS 456. In many cases the stresses in concrete will govern as rock would be generally stronger than concrete.

\[
\text{Average bearing} = \frac{\text{Hydrostatic force on the plug}}{\text{Effective projected bearing area}}
\]

NOTES

1 Effective projected bearing area shall be assumed 75 percent of the total projected bearing area of the keys to allow imperfections in grouting.

2 The depth of any key where feasible shall not be less than 450 mm.

9 GROUTING

9.1 General

9.1.1 Grouting is required to improve the quality of the rock by filling the fissures/voids of the rock surrounding the plug. This shall also be done to ensure better shear friction.

9.2 Types of Grouting

9.2.1 Following are the two types of grouting:

a) Consolidation grouting, and

b) Contact grouting.

9.2.1.1 Consolidation grouting is done to improve the quality of bearing rock in the vicinity of plug and to reduce leakage at that location. In poor rocks, consolidation grouting is done to make good any fissures in the rock which may either be existing previously or caused during tunnel driving. Consolidation grouting also reduces the possible leakage through the rock. Consolidation grouting of the rock surrounding the plug shall be done prior to the placement of the plug (see Fig. 3).

9.2.1.2 Contact grouting is low pressure grouting through shallow holes. Contact grouting shall be done to fill any cracks developed at the interfaces on account of shrinkage of concrete and to ensure better shear friction and prevent excessive leakage along the contact of plug concrete and rock/tunnel lining. It shall be done
from the outer ends of the plugs by means of system of supply, return and vent headers embedded in the plug concrete. Contact grouting shall be done after 6 weeks of concreting the plug (see Fig. 4).

9.2.1.3 In case of gated plug, contact grouting may also be done by direct holes from the gallery.

9.2.1.4 Grouting of rock surrounding the plug shall conform to IS 5878 (Part 7).
9.2.1.5 In case of excessive leakage grouting using micro cement and/or chemical grout shall be done to achieve the desired result.

10 COOLING OF CONCRETE

10.1 Plug concrete shall be placed at temperatures to be determined based on cooling studies for concrete (see IS 14591 and other specialist literature). In absence of such studies plug concreting can be done at a placement temperature of 13°C. In case precooking of concrete is not possible, then post-cooling may be done by circulating chilled water through coils of thin tubing installed on top of each lift of concrete (see Fig. 5).

10.2 Special care shall be taken at lift joints to ensure adequate shear resistance.

10.3 In case of gated plugs, cooling of concrete may not be required, if concreting is done in stages to reduce the thickness of concrete. Keys shall be provided in first stage concrete for transferring the water head which is acting on the second stage of concrete.

11 ANCHORAGE OF MAIN TUNNEL LINING IN PLUG CONCRETE

11.1 In case of gated plug, full circular shape of lining gets broken by the access opening through the plug. The main tunnel lining would have to be supported with suitable arrangements. The lining may be supported on portal and concreting of this frame shall be done monolithic with the lining of main tunnel. Fig. 6 shows main tunnel lining of the plug access portion (supported on the rectangular frame around the access through plug).

11.2 In the portion, where main tunnel lining gets broken by the access opening through the plug, the tunnel invert and overt shall be anchored to the existing rock, as shown in Fig. 6, so that the loads acting on the straight leg between invert and portal, and overt and portal are not transferred to the tunnel lining.

12 BLOCKOUT FOR GATE

12.1 Blockouts for embedments of gate shall be suitably anchored into the plug concrete.

12.2 Double water seals shall be provided in the blockout to check leakage of water through the joints between the plug concrete and blockouts.

13 CLEARANCE OF SILT IN GATE CHAMBER

13.1 In case of gated plugs with access through the plug, there are chances of silt deposits in gate chamber behind the gate. This deposited silt needs clearance to avoid any difficulty in operation of the gate.

13.2 Suitable arrangements shall be provided to remove the anticipated silt. This may be done by injecting air/water jet under pressure through the access of plug.

![Fig. 5 Typical Section (Showing Cooling Arrangement)](image-url)
FIG. 6A  PLAN AT JUNCTION OF H.R.T. WITH ADIT
FIG. 6B Anceorage of Main Tunnel Lining
## ANNEX A

### (Foreword)

**COMMITTEE COMPOSITION**

Water Conductor Systems Sectional Committee, WRD 14

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