PROFORMA FOR ADOPTION OF DRAFT INDIAN STANDARD

BUREAU OF INDIAN STANDARDS

Subject: Approval of Draft Indian Standard

Sl. No.	Doc. No.	TITLE
1.	WRD/10/ 23313	Protection of Slope for Reservoir Embankment — Code of Practice (*Second Revision*)

In accordance with Part II, sub-rule (2) of rule 22 of BIS Rules 2018, I enclose a copy of the draft Indian Standard mentioned above finalized by the Sectional Committee WRD 10 and its Chairperson, in the light of comments received from important stake holders.

It is requested that this note and its enclosures may be returned to this office as early as possible recording your approval of the above draft Indian Standard.

Encl.: As above.

11/6/24

Dushyant Prajapati
Scientist 'F'/ Director and Head
(Water Resources Department)

दुष्यन्त प्रजापति/DUSHYANT PRAJAPATI
वैज्ञानिक 'एफ'/संयुक्त निदेशक एवं प्रमुख (जल संसाधन विभाग)
Scientist 'F'/Joint Director & Head (Water Resources Deptt.)
भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय
Ministry of Consumer Affairs, Food & Public Distribution
भारत सरकार/Government of India
9, बहादुरशाह ज़फर मार्ग, नई दिल्ली-110002
9, Bahadur Shah Zafar Marg, New Delhi-110002

Chairperson, Water Resources Division Council
BIS U.O. No. WRD 10/T– 08
Dated: 04/07/2024

APPROVED

(Chairperson)
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जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
Deptt. of Water Resources, RD & GR
भारत सरकार/Govt. of India
नई दिल्ली/New Delhi

भारतीय मानक

Indian Standard

IS 8237 : 2024

जलाशय तटबंध के लिए ढलाई का संरक्षण — रीति संहिता

(दूसरा पुनरीक्षण)

Protection of Slope for Reservoir Embankment — Code of Practice

(Second Revision)

ICS 93.160

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, ९ बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

May 2024

Price Group 6

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards after the draft was finalized by the Reservoirs and Lakes Sectional Committee and had been approved by the Water Resources Division Council.

Embankment slopes need to be protected against wave action, rain wash, wind action, velocity of flow or over-topping of embankments by reservoir water. Protection against erosion due to over-topping is provided by ensuring sufficient free board and spillway capacity and also by providing erosion resistant surface at top, turfing to the downstream slope, etc. Protection against erosion due to wave action, rainwash, wind action, or velocity of flow can be provided in many ways, such as cement concrete surface, flexible brick pitching, and riprap on the upstream slope and pitching or turfing on the downstream slope. Riprap is commonly used in India and is the only method covered in this code.

This standard was first published in 1976 and subsequently revised in 1985. The major changes incorporated in the first revision includes the following:

a) Extent of riprap has been defined with respect to minimum drawdown level (MDDL) instead of low water level (LWL).
b) Filter has been recommended to be provided in two layers; and
c) Criteria for fixing minimum weight of stones with respect to significant wave height has been replaced by relating quarried thickness of riprap to wave height.

This revision has been brought out to bring the standard in the latest style and format of the Indian Standards. In addition, the following changes have been made:

a) Definition of minimum draw down level (MDDL) has been updated in reference to IS 4410 (Part 6) : 2022.
b) Clause **5.2** has been introduced for choice of suitable stone to be used as riprap.
c) Clause **6.1.3** has been modified to include gradation requirements for the coarse filter material with respect to riprap material; and
d) Clause **8.2.2** has been updated to revise the criteria for maximum rock size

The composition of the Committee responsible for the revision of this standard is given in 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 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

PROTECTION OF SLOPE FOR RESERVOIR EMBANKMENT — CODE OF PRACTICE

(Second Revision)

1 SCOPE

1.1 This code covers design of protection of slope for reservoir embankments by riprap. Reference has been made to turfing and drainage arrangements for the downstream slope.

1.2 This code does not cover protection against damage due to velocity of flow for which additional pitching (or other measures) may be required.

2 REFERENCES

The standards given 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 these standards are encouraged to investigate the possibility of applying the most recent edition of standards:

IS No.	*Title*
IS 4410 (Part 6) : 2022	Glossary of terms relating to river valley projects Part 6 Reservoirs (*second revision*)
IS 9429 : 1999	Drainage system for earth and rockfill dams — Code of practice (*first revision*)
IS 10635 : 2014	Freeboard requirement in dams — Guidelines (*second revision*)

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply:

3.1 Minimum Draw Down Level (MDDL) — It is the lowest level at which the full release towards meeting the specified purpose is physically possible and allowable under operating instructions (*see* IS 4410 Part 6).

3.2 Riprap — It is the protection to the embankment material against erosion due to wave action, velocity of flow, rain wash, wind action, etc, provided by placing a protection layer of rock fragments or manufactured material. Riprap may be placed on slope either by hand or it may be simply dumped.

3.2.1 *Hand Placed Riprap* — It consists of natural stones quarried laid flat or laid with projections boulders or specially manufactured material like cement concrete blocks and soil-cement blocks, carefully placed by hand in a more or less definite pattern with a minimum amount of voids, its top surface reasonably uniform and free of loose stones or alternately panel wise concrete slabs or precast concrete interlocking type blocks.

3.2.2 *Dumped Riprap* — It consists of boulders or blasted rock reasonably free from quarry fines and dumped in place by mechanical means.

3.3 Wave Action — It consists essentially the dynamic impact effect of the waves as they impinge on the slope and suction forces set up on the embankment face as the waves ride up and down.

3.4 Wave Height — The height of wave is reckoned as measured from the trough to the crest of the wave. For determination of wave-height, refer to IS 10635.

3.5 Wave Run-up — It is the difference (vertical height) between maximum elevation attained by wave run-up on a slope and the water elevation on the slope excluding wave action.

3.6 Turfing — It is a cover of grass grown over an area to prevent erosion of soil particles by rain wash.

4 GENERAL

4.1 Considerations for Adoption

4.1.1 The choice of type of riprap is governed mainly from the consideration of availability of suitable materials within reasonable distance and cost of placement.

4.1.2 Overall economics for riprap requires consideration of the fact that the wave run-up height on a slope with hand placed riprap for the same wave-height and embankment slope, is about 1.2 times to 1.5 times more than that for dumped riprap due to smoother surface in case of the former and also systematic placement and better workmanship in general.

4.2 Extent of Riprap

4.2.1 Riprap should be provided from an elevation 1.5 m or half of maximum wave height at MDDL whichever is more, below minimum drawdown level (MDDL) to the top of the dam. At sites where there is possibility of flow parallel to the embankment below the lowest water level and exigencies of drawing water below MDDL, riprap may be extended further below the MDDL as required.

4.2.2 Riprap should preferably be terminated at the lower end in a berm, provided in the embankment (*see* Fig. 1).

4.2.3 Where a berm is not provided, the riprap should be terminated duly keyed to a toe support (*see* Fig. 2). A similar support arrangement for riprap extending to ground level is shown in Fig. 3. The arrangement for riprap terminating at rock surface is shown in Fig. 4.

4.3 Site Preparation

Allowance shall be made in the constructed embankment to enable dressing of the outer slope to get compacted surface for laying filter layer(s) and then placing of the riprap over a compacted surface.

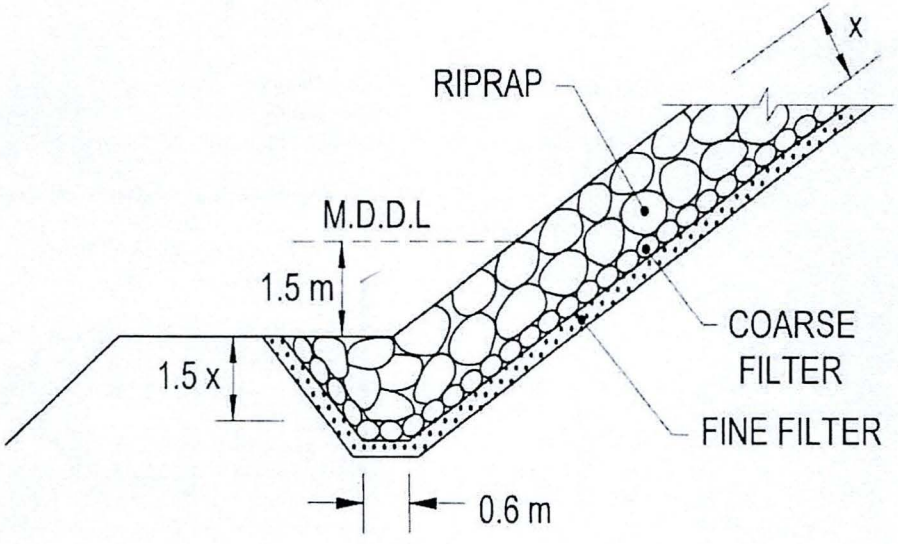

FIG. 1 PITCHING WITH BERM BELOW MDDL

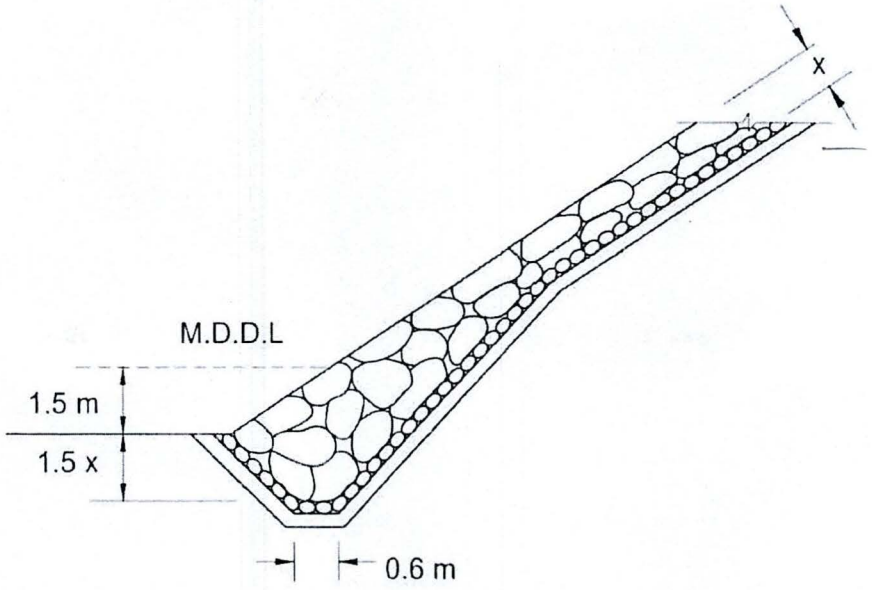

FIG. 2 PITCHING WITH NO BERM BELOW MDDL

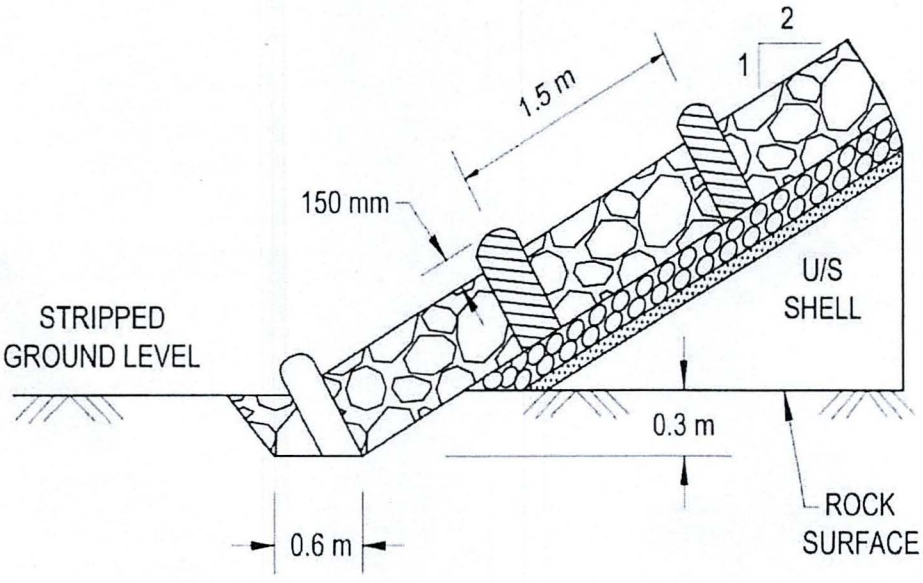

FIG. 3 PITCHING TERMINATING AT ROCK SURFACE

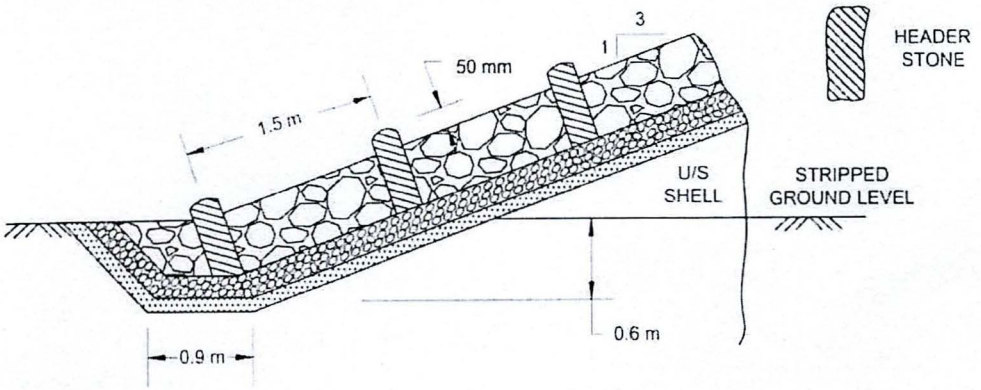

FIG. 4 PITCHING AT STRIPPED GROUND LEVEL

5 REQUIREMENTS FOR ROCK USED AS RIPRAP

5.1 Stone for riprap shall be hard and durable and shall not crumble on long exposure to water, frost and air.

5.2 For the first choice of suitable material, the most important criterion is adequate piece size. In comparing different sources, durability is next consideration. Where materials are of similar piece size and durability, preference should be given to those pieces with higher mass density, more equi-dimensional shape and rougher surface texture.

6 FILTER

6.1 Provision of two layers of filter (coarse and fine) is usually necessary under riprap to prevent the waves from eroding and washing out the underlying embankment material. Further as the riprap is generally poorly graded due to predominance of one size material, the provision of adequate filter is essential.

6.1.1 The thickness and number of layers of filter are mainly governed by considerations of intensity of wave action, gradation of riprap, gradation of embankment material and ease of construction.

6.1.2 Thickness of each of the two layers shall not be less than 150 mm under hand placed riprap and 200 mm under dumped riprap.

6.1.3 Gradation requirement for the coarse filter material with respect to riprap material should conform to the criteria given in IS 9429. The two layers of filter shall also satisfy these criteria with respect to each other. Where the embankment material satisfies these criteria with respect to coarse filter, fine filter could be omitted.

6.2 Filter material for the riprap shall consist of gravel/metal/crushed rocks or sand of medium to coarse sizes. They shall satisfy the required gradation criteria. Filters with large percentage of fines are not desirable.

7 HAND PLACED RIPRAP

7.1 Procedure for Placing Riprap

The hand placed riprap shall consist of one main stones laid on edge. Starting at the bottom of the slope the stones shall be laid compactly with staggered joints and so matched and inter-locked that they shall be keyed together with a minimum joint space. Rock fragments and spalls shall be driven into interstices to wedge the riprap in place. The wedging shall be done with the largest chip practicable, ensuring that each chip is firmly driven into place using a hammer, so that no chip can be easily removed by hand. Very irregular projections shall be knocked off so that the riprap presents a reasonably uniform surface free of loose stones.

7.2 Hand placed riprap should preferably be laid in one course such that the layer thickness is same as the stone size. However, at least 80 percent of the area of riprap should have stones weighing more than 45 kg. Such stone should be spread uniformly in the area. Where such stones are not sufficient to cover the entire thickness of riprap, the same may be laid in two layers.

7.2.1 If two layers of stones are used, header stones extending through both layers and spaced at about 1.5 m as shown in Fig. 5 shall be used. Also, among the two layers, the top layer shall be of larger stones. The size of the smallest side of the header stone shall not be less than 150 mm and its length shall be equal

to the thickness of the riprap plus 150 mm so that the header stone would project above the general top surface of the riprap by about 150 mm. Such a projection will break the wave force and would also facilitate easy identification of the header stones. If header stones of full length are not available from the quarry, concrete blocks of the necessary size, length and shape may be manufactured for the purpose.

7.2.2 In case stone of requisite size are not available and smaller stones/boulders locally available are required to be used, the riprap should be laid in panels formed by constructing profile walls. A portion of the area between the panels may be grouted by pouring fluid cement mortar worked into the riprap.

7.2.3 Hand placed ripraps may be laid flat or laid with projections (needles).

7.3 Thickness of Riprap

7.3.1 The minimum thickness of hand placed riprap measured normal to embankment slope shall be as shown in Table 1. It shall not be less than 300 mm in any case.

7.3.2 The maximum wave height may be calculated in accordance with the procedure prescribed in IS 10635. For effectively saving in the cost of riprap, the wave height in convenient reaches and different suitable elevations may be calculated, and then fixing thickness of riprap accordingly.

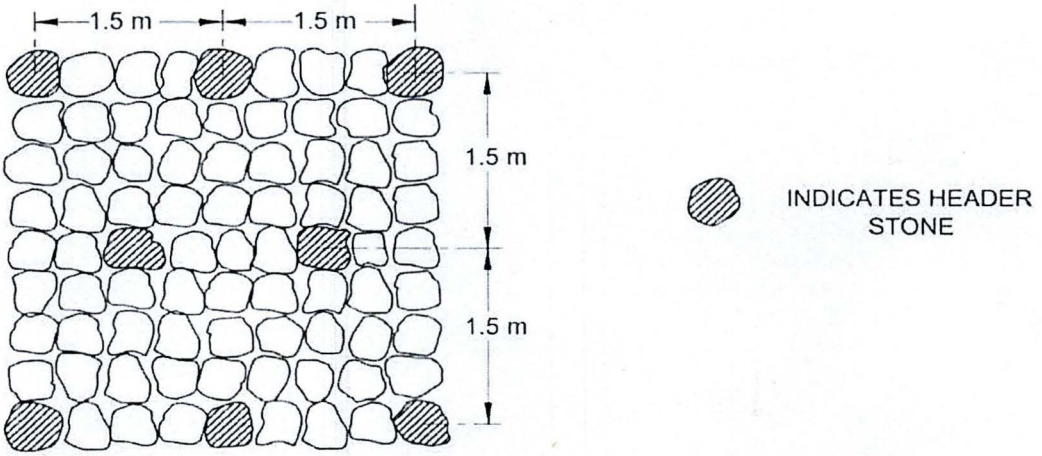

FIG. 5 ARRANGEMENT OF HEADER STONES IN HAND PLACED RIPRAP

Table 1 Minimum Thickness of Hand Placed Riprap

(*Clause* 7.3.1)

Sl No.	Maximum Wave Height m	Minimum Riprap Thickness mm	Minimum Thickness of Filter Layer mm	
			Finer	*Coarser*
(1)	(2)	(3)	(4)	
i)	0 to 1.5	300	150	150
ii)	1.5 to 3.0	450	150	150
iii)	Over 3.0	600	150	150

8 DUMPED RIPRAP

8.1 Procedure for Placing Riprap

Dumped riprap shall consist of boulders or blasted rock fragments. It shall be dumped in place mechanically on a properly graded filter layer. It shall either be dumped over the upstream face from the embankment level as the embankment is being raised up or after the embankment had been completed. When placed during construction, the

riprap layer should be kept a few meters lower than the construction surface when placed after the embankment is completed, the rock should be taken to the crest of the dam in trucks and then lowered down the slope by suitable mechanical device. The rock shall not be allowed to drop down the slope in a chute or be pushed down the slope, since these operations result in excessive segregation. After dumping, the rock should be worked manually with bars or other equipment to achieve a well packed and tidy surface.

8.2 Thickness of Riprap

8.2.1 The minimum thickness of dumped rock riprap and average rock size shall be as shown in Table 2. The thickness of riprap shall not be less than 450 mm in any case.

Table 2 Minimum Thickness of Dumped Riprap

(*Clauses* 8.2 *and* 8.2.2)

SI No.	Maximum Wave Height	Minimum Average Rock Size (D_{50})	Minimum Riprap Thickness
	m	mm	mm
(1)	(2)	(3)	(4)
i)	0 to 1.5	300	600
ii)	1.5 to 3.0	400	750
iii)	Above 3	700	1 000

8.2.2 The most important criteria in Table 2 is the minimum average rock size (D_{50}) of riprap. For example, for waves of 2 m in height, the riprap should be composed of rocks, half of which by weight are equal to or larger than more or less equidimensional rock with average diameter of 400 mm. The rock used for riprap shall be well graded from a maximum rock size roughly equal to 1.5 times the average size to 50 mm or 0.125 times of D_{50} (whichever is higher).

8.2.3 The full thickness of dumped riprap shall be dumped in one layer.

9 DOWNSTREAM SLOPE PROTECTION

9.1 Prevention from Erosion by Rain Wash

Protection by riprap or pitching to the downstream slope of the earth dam from top to toe against erosion by rain wash in particular, is uneconomical and generally not warranted. However, the slope should be protected in accordance with provisions in **9.1.1** to **9.1.3**.

9.1.1 Turfing shall be provided and maintained on the entire downstream face.

9.1.2 Where turfing cannot grow on downstream slope of embankment, for proper growth of turfing selected soil layer may be provided or alternatively 300 mm thick hand placed riprap without filter layers may be provided.

9.1.3 A system of open paved drains (chutes) along the sloping surface terminating in the longitudinal collecting drains at the junction of berm and slope shall be provided at 90 m centre-to-centre to drain the rain water. The spacing may be reduced based on regional climatic conditions and type of slope protection. The drains may be formed of stone pitching or with precast concrete sections (*see* Fig. 6). The longitudinal drains shall be provided with 150 mm diameter pipes laid at a slope of 1 : 50 for discharging the collected water to the downstream. If cross drains are provided, the lowermost sloping drains shall drain into the cross drains, otherwise the sloping drains shall be connected to the toe drain.

9.2 Prevention of Erosion by Tail Water

9.2.1 Hand-placed riprap of 300 mm thickness over proper filter layers shall be provided up to 1 m above the maximum tail water level. If due to non-availability of adequate size of stones, riprap is required to be provided in two layers, header stones running through the entire thickness of the two layers shall be provided. These header stones need not project above the surface. Where internal drainage arrangements have not been provided in the body of the dam or in cases where rock is readily available from compulsory excavation, rock-toe of 0.2 H (where H is the hydraulic head) should be considered. The maximum and minimum height of rock toe shall generally be 6 m and 1.5 m. In case the maximum tail water is expected to rise above the crest of rock-toe, 300 mm thick hand-placed riprap with proper filter shall be provided from crest of rock-toe to an elevation 1 m above maximum tail water level.

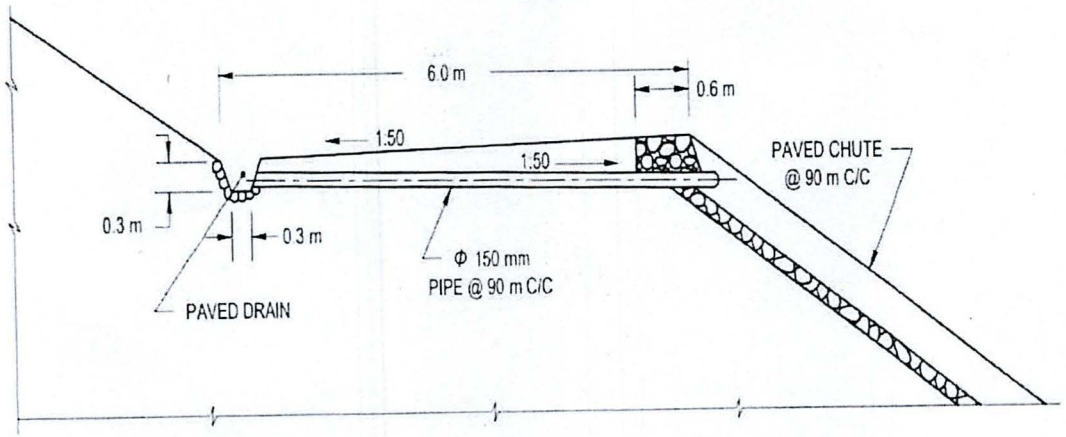

FIG. 6 TYPICAL DOWNSTREAM SURFACE DRAINAGE ARRANGEMENT

9.2.2 In the case of standing tail water due to back water of lower reservoir, the slope may be protected either by riprap or by combination of riprap and rock-toe (*see* IS 9429), to suit the site condition. The thickness of riprap and its extent on slope shall be governed by wave heights in the lower reservoir considering maximum/normal water level conditions.

10 TOLERANCE

The tolerance on the nominal thickness of riprap enforced on the performed profile shall be ± 10 percent.

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Reservoirs and Lakes Sectional Committee, WRD 10

Organization	*Representative(s)*
National Institute of Hydrology, Roorkee	DR M. K. GOEL (***Chairperson***)
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Central Water Commission, New Delhi	SHRI MD FAIZ SHRI AMITHABH MEENA (*Alternate*)
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Indian Institute of Technology, Roorkee	PROF ARUN KUMAR PROF SUMIT SEN (*Alternate*)
Irrigation Research Institute, Roorkee	SHRI DINESH CHANDRA SHRI SHANKAR KUMAR SAHA (*Alternate*)
J&K Lakes and Water Way Development Authority, Srinagar	EXECUTIVE ENGINEER
Ministry of Irrigation, Sardar Sarovar Construction Advisory Committee, Vadodara	SHRI K. V. RATHOD SHRI N. K. BHANDARI (*Alternate*)
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Organization	*Representative(s)*
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University Visvesvaraya College of Engineering , Bengaluru	PROF INAYATHULLA M.
Water and Power Consultancy Services Limited, New Delhi	DR A. K. SHARMA SHRI A. STEPHEN LEO (*Alternate*)
Water Resources Department, Govt of Andhra Pradesh, Vijayawada	SHRI A. SURI BABU
Water Resources Department, Govt of Madhya Pradesh, Bhopal	SHRI B. C. PURANDARE SHRI S. R. UIKEY (*Alternate*)
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Wetlands International South Asia, New Delhi	DR RITESH KUMAR SHRI HARSH GANAPATHI (*Alternate*)
In Personal Capacity (*514 IVA, Paschimabad Multistorey JNU, New Delhi - 110067*)	DR A. L. RAMANATHAN
In Personal Capacity (*55/2 Amod Path, IIT Roorkee Campus, Roorkee – 247667)*	PROF M. L. KANSAL
In Personal Capacity (*Panya Sadana 173, 3rd A Main D Block, Vijaya Nagar 3rd Stage Mysuru – 570030)*	DR JAGANNATHA V.
BIS Directorate General	SHRI R. BHANU PRAKASH, SCIENTIST 'E'/DIRECTOR AND HEAD (WATER RESOURCES) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

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SCIENTIST 'B'/ASSISTANT DIRECTOR
(WATER RESOURCES), BIS

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: WRD 10 (23313).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices:		*Telephones*
Central	: 601/A, Konnectus Tower -1, 6th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002	2323 7617
Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	265 9930
Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
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Published by BIS, New Delhi