भारतीय मानक

पहाड़ी क्षेत्र के लिए प्रतिधारक भित्ति हेतु मार्गदर्शी सिद्धांत

भाग 1 भित्ति के प्रकार का चयन

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 1 SELECTION OF TYPE OF WALL

ICS 93.020

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1998

Price Group 4

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hill Area Development Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

Retaining wall is a structure used to retain backfill and maintain difference in the elevation of the two ground surfaces. Retaining wall may be effectively utilized to tackle the problem of landslide in hill area by stabilizing the fill slopes and cut slopes.

From the initial construction cost considerations, one metre of extra width in filling, requiring retaining walls, costs much more than constructing the same width by cutting inside the hill. Similarly the cost of a breast wall is several times more than a non-walled cut slope. However, considering maintenance cost, progressive slope instability and environmental degradation from unprotected heavy excavations, the use of retaining walls on hill roads and terraces becomes essential. This standard (Part 1) is, therefore, being formulated to provide necessary guidance in selection of retaining walls for stability of hill slopes, the other parts of the standard being:

Part 2	Design of retaining/breast walls
Part 3	Construction of dry stone walls
Part 4	Construction of banded dry stone walls
Part 5	Construction of cement stone walls
Part 6	Construction of gabion walls
Part 7	Construction of RCC crib walls
Part 8	Construction of timber crib walls
Part 9	Design of RCC cantilever wall/buttressed walls/L-type walls
Part 10	Design and construction of reinforced earth retaining walls

In the formulation of this standard, considerable assistance has been provided by International Centre for Integrated Mountain Development, Kathmandu. Assistance has also been derived from Mountain Risk Engineering Handbook.

The composition of technical committee responsible for the 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.

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 1 SELECTION OF TYPE OF WALL

1 SCOPE

This standard (Part 1) covers the guidelines for selection of various retaining walls to suit the site conditions, for the purpose of imparting stability to the slopes in hill areas.

NOTE — The retaining walls are normally not intended to stabilize slope failures. They are mainly meant to support the active or passive earth pressure from the assumed failure wedge above the base of the wall. The stabilization of existing or probable failure planes caused by landslides, flows and falls require separate treatment and specific design approaches. Only the fill slopes and cut slopes could be stabilized/retained by retaining walls.

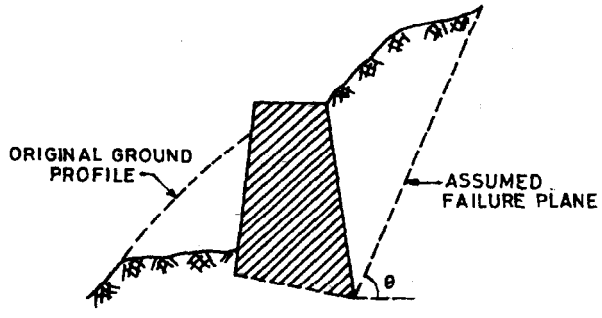
2 CLASSIFICATION

2.1 The retaining walls shall be classified on the basis of type of construction and mechanics of behaviour (*see* Fig. 1) as follows:

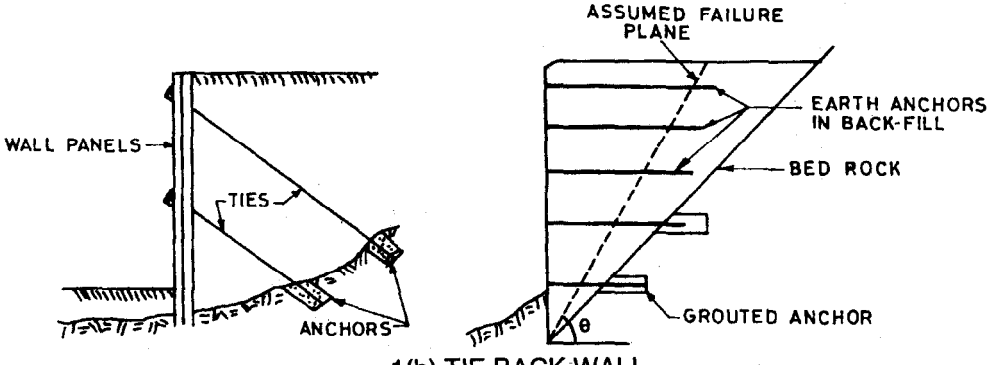
a) Gravity walls
b) Tie back walls
c) Driven cantilever walls
d) Reinforced earth walls
e) RCC walls

2.2 The classification of retaining walls with respect to their design and probable behaviour of construction medium may be as follows:

a) Bin walls
   i) Rectangular
   ii) Circular
   iii) Cross tied
b) Crib walls
   i) Concrete crib
   ii) Timber crib
c) Gabions walls and wire crated/sausage walls
d) Cement masonry walls
e) Dry stone masonry walls
f) Drum walls
g) Reinforced backfill walls

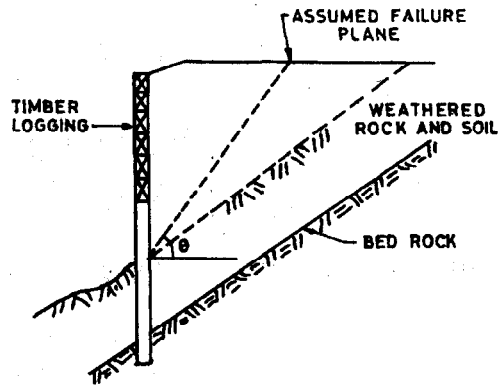


1(a) GRAVITY WALL

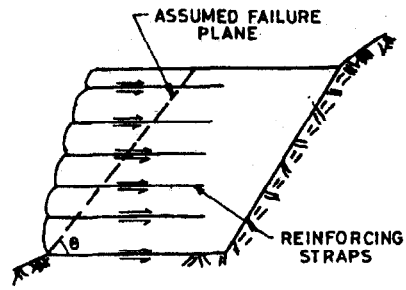


1(b) TIE BACK WALL

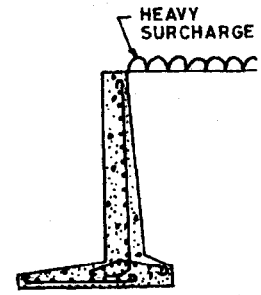
FIG. 1 DIFFERENT TYPES OF RETAINING WALLS — (*Continued*)



1(c) DRIVEN CANTILEVER WALL



1(d) REINFORCED EARTH WALL



1(e) RCC WALLS

FIG. 1 DIFFERENT TYPES OF RETAINING WALLS

i) Reinforced earth
ii) Fabric

h) Anchored walls
i) Horizontal sheet pile
ii) Vertical sheet pile
iii) H-pile, timber logged

j) RCC walls
i) Cantilever
ii) L-type
iii) Buttressed wall
iv) Frame retaining walls

3 SELECTION OF TYPE OF WALLS

3.1 In general, the choice of wall depends on local resources, local skill, hill slope angle, foundation conditions, slope of backfill, compatibility of materials and seismicity of the region (*see* Tables 1 and 2). However, the guidelines given in **3.1.1** to **3.1.14** shall be considered for selection of the type of retaining wall to be constructed for the purpose of imparting stability to the slopes in hill area.

3.1.1 For hilly roads, being of low volume, walls may not be designed for earthquake forces. It is economical to repair failed walls after earthquake.

3.1.2 Earthquake considerations lead to excessive wall dimensions. High walls may, therefore, be avoided by alternative geometric designs of roads and terraces unless justified by risk analysis. Walls with dip at the base towards hillside will reduce the base width in seismic areas.

3.1.3 Front battered retaining walls are many times more expensive than back battered walls in steep hilly areas.

3.1.4 A retaining wall on a thin talus slope may not be able to prevent the failure of entire talus slope during monsoon because of the quick rise of water table above the relatively impervious bed rock.

3.1.5 The construction of series of retaining walls one above another on an unstable or marginally stable slope shall be avoided as it adds more pressure on the lower walls destabilizing the slope contrary to the aim of stabilizing the slope. In such cases, unstable slope shall be stabilized by afforestation, surface/sub-surface drainage system, etc.

3.1.6 Improper backfill and poor drainage behind the wall involve complicated drainage conditions which are normally not considered in normal design. Proper drainage behind the walls shall, therefore, be provided.

3.1.7 The practice of undertaking wall construction after road/hill cutting poses the problem of disposal of excavated material and loss of top soil that could otherwise be used for vegetation. Hence during construction of retaining walls, the excavated material shall be disposed off at suitable identified sites.

3.1.8 Breast walls are more economical for cut slopes. Batter (negative) of the backfill side reduce base width of the wall significantly.

3.1.9 Dry stone retaining walls, breast walls and timber crib are economical but least durable, non-ductile structures. These are most susceptible to earthquake damages.

3.1.10 Gabion/wire crated walls shall be used in case of poor foundation or seepage conditions. These can take considerable differential settlement and some slope movement.

3.1.11 Banded dry stone masonry (height ≤ 6 m) and cement masonry walls are most durable but being non-ductile structures, are susceptible to earthquake damages.

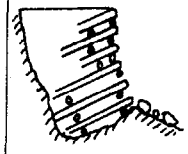
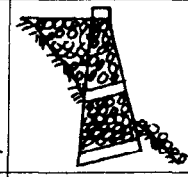
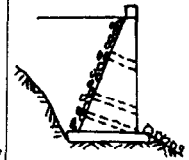
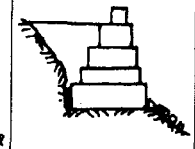
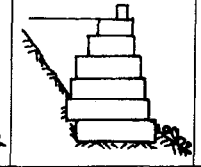
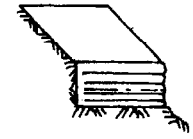
3.1.12 Reinforced earth is normally used as reinforced fill platform for road. Generally it is not used as preventive method of slope support.

3.1.13 Timber crib, dry stone masonry walls may be provided for hill slope angle less than 30° and, height less than 4 m in low volume roads. These are not suitable for terrace development because of short life.

3.1.14 Cement masonry, RCC walls, Gabion walls shall be considered for high volume roads, high cut slopes and terraces. These are also suitable for hill slope angles from 30° to 60°, where higher walls are needed.

Table 1 Selection of Retaining Walls

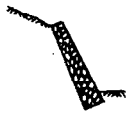
(*Clause* 3.1)

	Type	Retaining Walls						
		Timber Crib	Dry Stone	Banded Dry Stone/ Masonary	Cement Masonry	Gabion		Reinforced Earth
						Low	High	
	Diagrammatic Cross-section							
CONSTRUCTION NOTES	Top width	2 m	0.6-1.0 m	0.6-1.0 m	0.5-1.0 m	1 m	1-2 m	4 m or 0.7-0.8 m
	Base width	—	0.5-0.7 H	0.6-0.65 H	0.5-0.65 H	0.6-0.75 H	0.55-0.65H	4 m or 0.7-0.8 H
	Front batter	4:1	vertical	varies	10:1	6:1	6:1	3:1
	Back batter	4:1	varies	vertical	varies	varies	varies	3:1
	nward dip of foundation	1:4	1:3	1:3	horizontal or 1:6	1:6	1:6	horizontal
	Foundation depth below drain	0.5-1 m	0.5 m	0.5-1 m	0.5-1 m	0.5 m	1 m	0.5 m
	Range of height	3-9 m	1-6 m	6-8 m	1-10 m	1-6 m	6-10 m	3-25 m
	Hill slope angle	<30°	<35°	20°	35-60	35-60	35-60	<35
	Toe protection in case of soft rock/soil	Boulder pitching	Boulder Pitching					No
	General	Timbers 15 cm φ with stone rubble well packed behind timbers. 10% of all headers to extend into fill. Ecologically unacceptable.	Set stones along foundation bed. Use long bond stones. Hand packed stones in back fill.	Cement masonry bands of 50 cm thickness at 3 m c/c. Other specifications as for dry stone wall.	Weep holes 15 × 15 cm size at 1-2 m c/c. 50 cm rubble backing for drainage.	Stones to be hand packed. Stone shape important, blocky preferable to tabular. Specify maximum/minimum stone size. No weathered stone to be used. Compact granular back fill in layers (< 15 cm). Use *H* type gabion wall.		Granular back fill prefered. Use geogrid for H <4 m and tensur grid for H> 4 m. Provide drainage layer in case of seepage problems. Specify spacing of reinforcement grids.

<table>
<tr><td></td><td></td><td colspan="3">1. Foundations to be stepped up if rock encountered.
2. All walls require durable rock filling of small to medium size.
3. Drainage of wall bases not shown. Provide 15 cm thick gravel layer in case of clayey foundation.</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Application</td><td>Least durable</td><td>Most durable</td><td>Can take differential settlement and slope movement</td><td rowspan="3">Huge potential used more as stable reinforced fill platform for road rather than preventive method of slope support.</td></tr>
<tr><td colspan="2">Non ductile structure most susceptible to earth-quake damage</td><td>Very flexible structures</td></tr>
<tr><td colspan="3">1. Design as conventional retaining walls. Assume surcharge on road of 2T/m^2.
2. Used both as cut slope and fill slopes support. Breast wall is more economical for cut slope.
3. Choice of wall depends on local resources, local skill, hill slope angle, foundation conditions and also shape of back fill wedges as illustrated in diagrams and compatibility of materials.</td></tr>
</table>

Table 2 Selection of Breast Walls

(*Clause* 3.1)

Type	Breast Walls/Revetment Walls						Remarks
	Dry Stone			Banded Dry Stone Masonry	Cement Masonry	Gabion	Horizontal Drum Walls	
(1)	(2)			(3)	(4)	(5)	(6)	(7)
Diagrammatic cross-section								
Construction Notes: Top width	0.5			0.5	0.5	2	1	1. Wall construction requires special skills and practical labour. Curing of masonry walls generally not feasible in hills due to paucity of water.
Base width	0.29H	0.3H	0.33H		0.23H	2	1	2. The typical dimensions shown rely both on well-drained backfill and good foundation conditions.
Front batter								
Back batter	3:1	4:1	5:1	3:1	3:1	3 to 5:1	3:1	3. Detailed design is necessary in case of soil slopes and walls higher than 6 m and poor foundation conditions.
Inward dip of foundation	1:3	1:4	1:5	1:3	1:3	1:5	1:3	
Foundation depth below drain	0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	0.5-1 m	0.25 m	4. Gabion walls should be used in case of poor foundation/seepage conditions. They can take considerable differential settlement and some slope movement.
Range of height	6 m	4 m	3 m	3-8 m	1-10 m	1-8 m	2.2 m	
Hill slope angle	35-60			35-60	35-70	35-60	35	5. Other measures should also be taken, for example, check drains, turfing, benching of cut slopes in soft rocks, sealing of cracks, etc. All preventive measures should be implemented in one season. Total system of measures is far more effective than individual measures.
Toe protection in case of soft rock/soil	No pitching			No	No	No	No	
General	Pack stone along foundation bed. Use bond stones. Specify minimum stone size.			Cement masonry (1:6) bands of 0.5 m thickness at 3 m c/c.	Weep holes 15 × 15 cm at 1.5-2 m c/c and grade 1:10. Cement sand (1:6)	Step in front face 20-50 cm wide. Otherwise as for retaining walls.	Use vertical single drum for 0.7 m height. Anchor drum walls on sides. Fill debris material.	
	Revetment walls have uniform section of 0.5 m/0.75 m thickness for batter of 2:1 or more. Section shaped to suit variation and overbreak in rock cut slope.							
Application	Least durable/ economical			Little used	Most durable/costly	Quite durable/costlier or	Promising/most economical or	
	Non ductile structures most susceptible to earthquake damage.					Very flexible	Flexible	
	Revetments are used to prevent only major erosion, rock fall, slope degradation particularly where vulnerable structures are of risk.							

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Hill Area Development Engineering Sectional Committee, CED 56

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(*Continued on page* 8)

(*Continue from page* 7)

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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 latest issue of 'BIS Handbook' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc : No. CED 56 (5515).

Amendments Issued Since Publication

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भारतीय मानक

पहाड़ी क्षेत्र की रिटेनिंग दिवारें — रीति संहिता

भाग 2 रिटेनिंग/ब्रैस्ट दिवारों के डिजाइन

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 2 DESIGN OF RETAINING/BREAST WALLS

ICS 93.020

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Part 1 Selection of type of wall,
Part 3 Construction of dry stone walls,
Part 4 Construction of banded dry stone walls,
Part 5 Construction of cement stone walls,
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Part 7 Construction of RCC crib walls,
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Part 10 Design and construction of reinforced earth retaining walls.

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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.

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 2 DESIGN OF RETAINING/BREAST WALLS

1 SCOPE

This standard (Part 2) deals with design of gravity type structures used to support earth or other materials behind them which would otherwise not stay in that position. Other types of retaining structures are covered in Part 9 and Part 10 of this standard (*under preparation*)

2 REFERENCES

The Indian Standards listed in Annex A contain provisions which through reference in this text, constitute provision 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 in Annex A.

3 GENERAL

3.1 Gravity type retaining structures in hills are generally of two types:

a) Breast wall, and
b) Retaining wall.

3.1.1 Breast walls are normally stone masonry walls provided to protect the slopes of cutting in natural ground from the action of weather and cut slope failure but not from impact of snow avalanches. A toe wall cannot be used to stabilize an unstable slope.

3.1.2 Retaining walls are built to resist the earth pressure of filling and the traffic loads of the road. These are commonly used in hill roads when the road goes in embankment or partly cutting and partly filling (*see* Fig. 1). The retaining walls are also used extensively to develop sites for building complexes.

4 BEARING CAPACITY

4.1 The allowable bearing capacity shall be calculated in accordance with IS 6403 on the basis of soil test data. In case of non-erodible rocks, the bearing capacity shall not exceed one-half the unconfined compression strength of the rock if the joints are

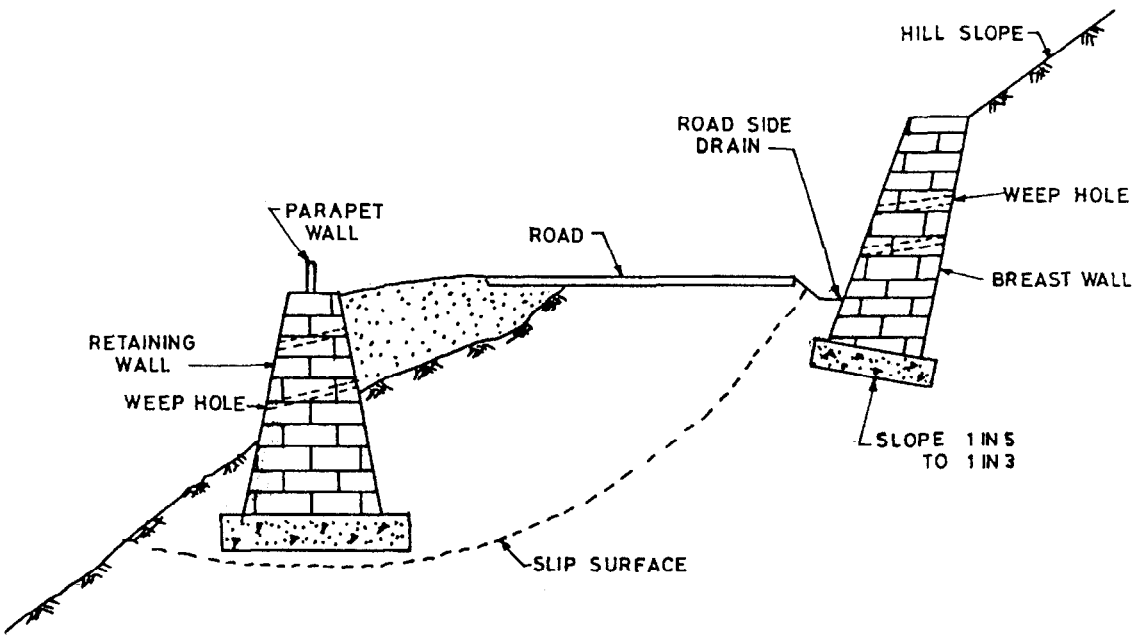

FIG. 1 TYPICAL ARRANGEMENT OF RETAINING WALL AND BREAST WALL IN A ROAD CROSS-SECTION

tight. Where the joints are open, the bearing capacity shall not exceed one-tenth the unconfined compression strength of the rock. Bearing capacity for weak and closely jointed rock shall be assessed after visual inspections supplemented as necessary by field or laboratory tests to determine their strength and compressibility. In the absence of soil test data, for preliminary design, the values given in Table 1 may be adopted. Bearing capacity of rocks may be determined in accordance with IS 12070. In case of erodible and weak foundations (clay, loose soil, etc) gabion walls shall be preferred as they can withstand high differential settlements.

Table 1 Safe Bearing Capacities for Different Types of Soil
(*Clause* 4.1)

Type of Bearing Material	Symbol	Consistency of Place	Recommended Value of Safe Bearing Capacity (t/m^2)
(1)	(2)	(3)	(4)
Well graded mixture of fine and coarse-grained soil, glacial till, hard pan, boulder clay	GW-GC, GC, SC	Very compact	100
Gravel, gravel-sand mixtures, boulder-gravel mixtures	GW, GP SW, SP	Very compact Medium to compact Loose	80 60 40
Coarse to medium sand, sand with little gravel	SW, SP	Very compact Medium to compact Loose	40 30 30
Fine to medium sand, silty or clayey medium to coarse sand	SW, SM, SC	Very compact Medium to compact Loose	30 25 15
Fine sand, silty or clayey medium to fine sand	SP, SM, SC	Very compact Medium to compact Loose	30 20 15
Homogeneous inorganic clay, sandy or silty clay	CL, CH	Very stiff to hard Medium to stiff Soft	40 20 5
Inorganic silt, sandy or clayey silt, varied silt-clay-fine sand	ML, MH	Very stiff to hard Medium to stiff Soft	30 15 5

4.2 When earthquake forces are included, the permissible increase in allowable bearing capacity shall be in accordance with **3.3** of IS 1893.

4.3 The value of cohesion 'c' and angle of internal friction 'Φ' vary for different backfill and foundation materials. These values shall be determined by experiment. However for preliminary design the values given in Table 2 may be used.

5 DESIGN CRITERIA

5.1 The design of a retaining structure shall consist of two principal parts, the evaluation of loads and pressures that may act on the structure and the design of the structure to withstand these loads and pressures.

5.1.1 Following forces shall be accounted for in the design:

a) Self weight of the retaining structure;
b) Live load and imposed loads, if any;
c) Earth pressure acting on the wall;

Table 2 Typical Strength Characteristics of Soil
(*Clause* 4.3)

Group Symbol	c (Cohesion of Soil) (t/m^2)		Φ' (Effective Stress Envelope) (degrees)	tan Φ'
(1)	(2)	(3)	(4)	(5)
GW	0	0	> 38	> 0.79
GP	0	0	> 37	> 0.74
GM	—	—	> 34	> 0.87
GC	—	—	> 31	> 0.60
SW	0	0	38	0.79
SP	0	0	37	0.74
SM	0.5	0.2	34	0.67
SM-SC	0.5	0.15	33	0.66
SC	0.75	0.1	31	0.60
ML	0.7	0.1	32	0.62
ML-CL	0.65	0.2	32	0.67
CL	0.9	0.15	28	0.54
MH	0.75	0.21	25	0.47
CH	1.0	0.1	19	0.35

d) Water pressure due to water table/subsurface seepage;
e) Water pressure due to water table on toe side, if any;
f) Seismic forces; and
g) Special loads, if any.

The self weight of the structure, and live and imposed loads shall be estimated in accordance with IS 875 (Parts 1 to 5). In the usual cases live load may be taken between 250 kg/m^2 to 500 kg/m^2 on the top width of the wall.

The earth pressures and other seismic forces on the retaining structure shall be estimated in accordance with IS 1893. For low volume roads, the walls may not be designed for earthquake forces. In case of retaining walls for roads earth pressure due to surcharge shall be in accordance with IRC Codes.

The consideration of full water pressure behind the wall may lead to quite heavy section. Adequate arrangement for release of this water pressure shall be made. Atleast 30 percent water pressure shall always be considered even in case of provision of good efficient pressure release system.

5.2 Retaining walls and breast walls shall be designed as rigid walls, using following criteria:

a) Factor of safety against overturning: > 2.0 (static loads); > 1.5 (with earthquake forces) *(see also* IS 1904)

b) Factor of safety against sliding: > 1.5 (static loads); > 1.0 (with earthquake forces)

NOTE — The live loads and imposed loads adding to stability of the structure shall not be considered in working out the factors of safety given in **5.2**(a) and **5.2**(b).

c) Maximum base pressure: ≤ q_a (allowable bearing capacity); ≤ 1.33 q_a (during earth-quake)

d) Minimum base pressure > 0 (zero)
e) Factor of safety against floatation > 1.25
[see also IS 4247 (Part 3)]

f) In case of steep hills, the factors of safety for slip surface below foundation shall be greater than 1.5 and 1.0 in static and seismic conditions respectively.

The design of wall foundations shall meet the requirements of IS 1080 and IS 1904.

5.3 Sometimes, to achieve the minimum factor of safety given in **5.2**(b) and thereby resist sliding it may be necessary to increase the base area or to add concrete keys monolithic with foundation slab or to provide piles.

5.4 It is generally not possible to design each and every wall along the entire length of a road. Standard designs as given in Table 3 may be adopted for walls less than 8 m in height and 120 m^2 area in a low hazard zone provided the allowable bearing capacity is more than the maximum pressure indicated in the table.

6 OTHER DETAILS

6.1 Depth of Walls

The depth of retaining wall and breast wall below ground level or terrace level shall be at least 500 mm below side drain within soil or highly jointed rock and foundation shall be on natural firm ground. All multiple breast walls shall be taken to the firm rock surface.

6.2 Stepping of Base of Wall on Rock Slope

If the retaining wall is made on rock slope, the foundation shall be stepped as shown in Fig. 2. In case of steep slopes (>35°), retaining walls with front face nearly vertical and back-face inclined shall be used as it will reduce the height of wall considerably.

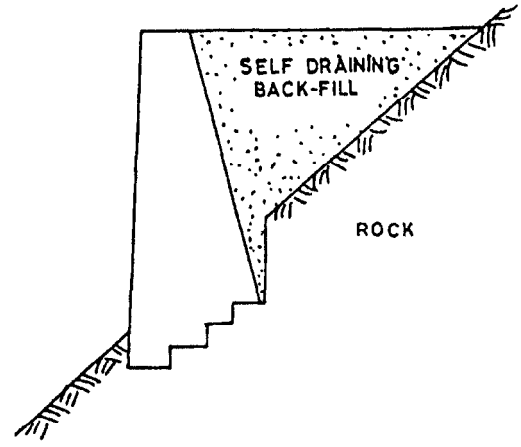

FIG. 2 STEPPING OF FOUNDATION OF WALL ON ROCK SLOPE

6.3 Dip of the Base of Wall Towards Hillside

A dip of the base of wall towards hillside to the extent of 3 : 1 (horizontal : vertical) proves very economical in seismic conditions (*see* Fig. 3). It increases factor of safety against sliding significantly.

6.4 Negative Batter of Backside of Breast Wall

Breast wall with negative batter (*see* Fig. 3) on cut-slope side reduces earth pressure significantly. So even nominal section of breast wall stabilizes cut slopes in soil, provided breast wall is founded on rock or firm natural ground. Negative batter of upto 1 : 3 (horizontal : vertical) is recommended.

Table 3 Standard Design of Cement Masonry and Dry Stone Masonry Retaining Walls

(*Clause* 5.4)

Back Fill Type	Particulars	Cement Masonry														Dry Stone Masonry								
		Ht 3M			Ht 6M			Ht 8M			Ht 10M			Ht 3M			Ht 6M			Ht 8M			Ht 10M		
Good Back-fill	Top width in m	0.65	0.70	—	0.75	1.00	1.00	0.80	1.00	1.00	0.90	1.00	—	0.70	—	—	0.75	0.95	1.00	0.85	1.00	1.00	0.90	1.00	—
Full Drainage	Base width in m	1.91	2.01	—	3.92	4.78	8.41	5.23	8.10	10.96	6.64	13.57	—	2.01	—	—	3.92	4.32	8.50	5.33	6.89	11.81	6.64	14.58	—
GW, GP SW, SP	Foundation pressure in t/m^2	14.00	13.00	—	25.0	20.00	13.00	33.00	20.00	17.00	40.00	21.00	—	11.00	—	—	22.00	20.00	17.00	29.00	20.00	13.00	36.00	16.00	—
Fair Back-fill	Top width in m	0.60	0.75	—	0.90	1.00	1.00	0.95	1.00	1.00	1.00	1.00	1.00	0.75	—	—	0.85	1.00	—	1.00	1.00	1.00	1.00	1.00	1.00
Low pore Water pressure	Base width in m	1.81	2.11	—	4.12	4.47	4.88	5.53	6.59	8.14	6.94	9.90	14.03	2.11	—	—	4.12	4.42	—	5.63	6.49	6.94	6.94	8.50	10.26
GM, SM SM, SC	Foundation pressure in t/m^2	15.00	13.00	—	25.00	22.00	20.00	32.00	25.00	20.00	39.00	25.00	11.00	11.00	—	—	22.00	20.00	—	28.00	22.00	20.00	34.00	25.00	20.00
Poor Back-fill	Top width in m	—	—	—	—	—	—	—	1.00	1.00	1.00	1.00	1.00	—	—	—	—	—	—	1.00	1.00	1.00	1.00	1.00	1.00
High pore Water pressure	Base width in m	—	—	—	—	—	—	—	6.49	7.89	8.50	7.79	11.01	—	—	—	—	—	—	6.54	8.65	8.70	7.84	10.11	11.97
GC, SC ML	Foundation pressure in t/m^2	—	—	—	—	—	—	—	22.00	20.00	19.00	29.00	23.00	—	—	—	—	—	—	22.00	20.00	16.00	25.00	20.00	18.00

NOTES

1 Wall Geometry : Front face vertical back, face inclined, base inclined with hill.

2 Back Fill Top : Horizontal with surcharge 1.5 t/m^2.

3 Select wall dimensions such that allowable bearing capacity is greater than the foundation pressure.

4 The base width for dry stone masonry wall is slightly less for cement masonry wall because wall friction angle is likely to be equal to angle of internal friction of back fill in the case of dry stone masonry.

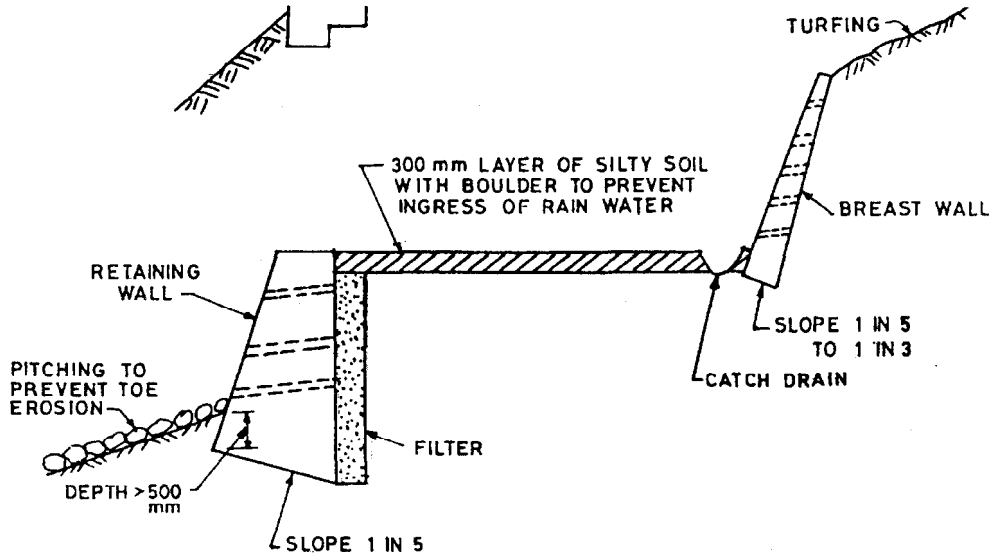

FIG. 3 TERRACE DEVELOPMENT FOR BUILDING COMPLEXES WITH RETAINING WALL AND BREAST WALL

6.5 Drainage Plan

6.5.1 Inverted filter shall be provided behind retaining walls to drain off ground water table or rain water seepage.

6.5.2 Weep holes shall be provided in cement stone masonry walls at spacing of about 1.5 m centre-to-centre in either direction. The size of weep holes shall be 100 mm to 150 mm PVC (flexible) pipes and shall be embedded at 10° down from the horizontal towards valley side to effectively drain the water from ground.

6.5.3 Impervious silty soil layer or back-fill of about 300 mm thickness shall be provided on the top to prevent seepage of rain water in the back-fill or into the foundation of buildings on terraces (*see* Fig. 3). However, the back-fill shall be of self-draining material (coarse sand, gravel and boulder), free of fines.

6.5.4 Natural gullies shall be diverted away from the building site so that flow of rain water does not cause erosion of breast walls on topmost terrace. Grass turfing shall be laid on the ground slope to prevent erosion.

6.5.5 Catch water drains shall be avoided near the top of the breast walls as they allow seepage of water in unmaintained conditiions into the cut slope and destabilize it. If necessary, catch water drains may be provided far away from breast walls for above reasons. A catch water drain shall be provided at the toe of the breast wall to collect water from weep holes and surface runoff of the slope.

6.6 Erosion Control of Toe of Retaining Walls

The rain water flows at a high speed from high retaining walls (>3 m). This may lead to toe erosion of soft rocks (shale/sand rock/conglomerate, etc) at the foundation. So dry stone pitching may be done as shown in Fig. 3. Stones of 150 mm size may be laid on slope for a distance of 1 m below the toe of retaining walls.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
875	Code of practice for design loads (other than earthquake) for buildings and structures:
(Part 1) : 1987	Dead loads — Unit weights of building material and stored materials (*second revision*)
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 1987	Wind loads (*second revision*)
(Part 4) : 1987	Snow loads (*second revision*)
(Part 5) : 1987	Special loads and load combinations (*second revision*)
1080 : 1986	Code of practice for design and construction of shallow foundations on soils (other than raft, ring and shell) (*second revision*)
1893 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
4247 (Part 3) : 1978	Code of practice for structural design of surface hydel power stations: Part 3 Substructure (*first revision*)
6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
12070 : 1987	Code of practice for design and construction of shallow foundation on rock

ANNEX B

(Foreword)

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(*Continued from page 7*)

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पहाड़ी क्षेत्र की रिटेनिंग दिवारें — मार्गदर्शी सिद्धान्त

भाग 3 शुष्क पत्थर की दीवार का निर्माण

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 3 CONSTRUCTION OF DRY STONE WALLS

ICS 93.020

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 1998

Price Group 3

FOREWORD

This Indian Standard (Part 3) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hill Area Development Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

Retaining wall is a structure used to retain backfill and maintain difference in the elevation of the two ground surfaces. Retaining wall may be effectively utilized to tackle the problem of landslide in hill area by stabilizing the fill slopes and cut slopes.

From the initial construction cost considerations, one metre of extra width in filling, requiring retaining walls, costs much more than constructing the same width by cutting inside the hill. Similarly the cost of a breast wall is several times more than a non-walled cut slope. However, considering maintenance cost, progressive slope instability and environmental degradation from unprotected heavy excavations, the use of retaining walls on hill roads and terraces becomes essential. This standard (Part 3) is, therefore, being formulated to provide necessary guidanace in construction of dry stone retaining walls for stability of hill slopes, the other parts of the code being:

Part 1	Selection of type of wall
Part 2	Design of retaining/breast walls
Part 4	Construction of banded dry stone walls
Part 5	Construction of cement stone walls
Part 6	Construction of gabion walls
Part 7	Construction of RCC crib walls
Part 8	Construction of timber crib walls
Part 9	Design of RCC cantilever wall/buttressed walls/L-type walls
Part 10	Design and construction of reinforced earth retaining walls

The present practice in various Government departments is to construct retaining walls up to 4 m height in random rubble dry stone masonry. Retaining walls more than 4 m height are constructed either in lime or cement mortar masonry or in dry stone masonry panels separated by 0.6 m wide mortarred masonry sleepers laid 3 to 4 m apart both in horizontal and vertical directions. The specified norms prescribed by the respective departments usually do not give sufficient weightage to the nature and properties of the soil or rock below the wall base and at the back of the wall, or the weather conditions. It is normally assumed that the mortarred masonry or bands give sufficient strength to the wall for added stability and confines local failure, if any. In actual practice it has however been observed that a number of dry as well as banded or fully mortarred walls do collapse during rains without offering much resistance as such these walls are used only as a temporary measure. This part, therefore, gives definite guidelines to the field engineers for construction of dry stone retaining walls.

Dry stone masonry retaining walls generally fail due to construction of grossly inadequate section of walls. Good supervision is, therefore, the key to better quality of construction of dry stone masonry walls. Strict supervision is essential for longer life of these type of walls. It shall be ensured that skilled labour is used in construction of dry stone masonry walls.

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

Indian Standard

RETAINING WALL FOR HILL AREA — GUIDELINES

PART 3 CONSTRUCTION OF DRY STONE WALLS

1 SCOPE

This standard (Part 3) deals with the construction aspects of dry stone retaining walls.

2 REFERENCES

The Indian Standard IS 1123:1975 'Method of identification of natural building stones (*first revision*)' contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the edition indicated was 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 edition of the standard indicated above.

3 GENERAL

3.1 A hill road masonry retaining wall is a gravity wall which shall be considered safe under the expected conditions of loading, if following conditions are satisfied:

a) it shall be safe against overturning,

b) shearing stress shall be less than shearing strength available, and

c) the pressure at the toe shall remain less than the safe bearing capacity of the foundation material.

It may be, however, assumed that there is adequate frictional bond between the stone layers from face to back and from top to base so that the entire section of the retaining wall acts as one unit. This may be very easily achieved by using stones of rectangular shape with sufficient overlap on each other enabling proper interlocking. The top width of the retaining wall shall be taken as 600 mm.

3.2 The stability of the retaining wall mainly depends upon the allowable bearing pressure of the foundation, particularly under the toe as compressive strength of properly constructed masonry section is usually adequate. Sliding at the base depends on the coefficient of friction between the wall base and the foundation soil. The total earth pressure above any level along the height of the retaining wall reduces parabolically from base upward, whereas the wall thickness reduces linearly. Therefore in most cases the critical section in the wall is at the base.

3.3 It cannot be asserted with any degree of certainty that fully mortarred masonry wall or a panelled masonry wall shall give a better performance than a dry stone retaining wall, on account of the following:

a) The value of bonding material or mortar is only from the point of view of making the wall an integral unit. However it is not assured in the case of hill roads and site development in hills; due to lack of supervision, non-availability of skilled labour, improper mixing of mortar, lack of post-construction, curing, etc and also sometimes paucity of water in the area.

b) Since both types of wall are not supposed to bear any tension, the strength of a dry stone masonry wall having the same section and similar soil conditions as a fully mortarred masonry wall, shall be adequate. The compressive strength of properly packed dry stone masonry is likely to be more than that of foundation soil on the hill slope.

c) For sliding at the base, coefficient of friction between the wall base and the foundation soil being same in both types, the behaviour shall not be different. Thus there is no particular utility of bands or mortar and the strength of a properly constructed dry stone masonry retaining wall shall be quite sufficient. On account of its flexibility, a dry stone masonry retaining wall may be expected to behave better than a fully mortarred masonry wall under seismic conditions.

d) Dry stone walls are easy to repair when it fails.

3.4 The design of dry stone masonry retaining wall shall be in accordance with Part 2 of this standard. A suitable computer program may be used for the design.

4 MATERIAL

Stone, the main material required for the construction of dry stone masonry retaining wall, is available in large quantity in hills. To select and utilize them for their satisfactory performance, it shall be necessary to know the various properties which can be determined according to relevant Indian Standards. The strength of rocks depends on its mineral constituents which form the basis of classification and identification of rocks. Identification of stones may be done in accordance with IS 1123.

5 BASE SLOPE

An inward slope provides good keying of the wall

in the hill face and also reduces the toe pressure, besides greatly increasing the sliding strength of the wall at base. Therefore, the base shall preferably be at right angles to the face of the wall. A minimum inward slope of 1 (Vertical) in 6 (Horizontal) shall be provided and it shall not be more than 1 (Vertical) in 3 (Horizontal). Base slope is very effective in seismic stability of walls.

6 STONE WORK

6.1 Rough flat stones shall be preferred as they give better contact and friction at joints. There shall be no dumping of stones. Stones shall be placed well interlocked at close proximity with each other. Size of stones below 225 mm × 100 mm × 75 mm (with mass of about 5 kg) shall not be used. The maximum size of stone shall be 600 mm × 200 mm × 300 mm with mass of about 45 kg. The largest dimension, that is, the length shall be placed across the length of the retaining wall for maximum stability as with this arrangement the wall face will not easily separate from the hearting. It shall result in greater unity and interlocking among the stones placed around it.

6.2 In dry stone masonry it shall be necessary to spread broken stone dust, stone chips, soil (gravelly or sandy soils) and soil mixtures, after placing each layer of stones to fill the voids. Filling of voids prevent filling of cavities by mud which is injurious to the wall as it makes it impervious to the flow of water. Fine grained soils and smooth river shingle shall not be used as these may lubricate the joint decreasing the frictional resistance. Only coarse angular particles shall be made use of. If available in the vicinity, water may also be sprinkled to moisten the filler material. Some ramming shall also be preferred. This helps in spreading the load of the overlying stones more evenly and increasing the weight of the wall and in turn increases the strength of the wall. Fig. 1(a), Fig. 1(b) and Fig. 1(c) represent bad construction practices liable to damage or cause failure of wall and shall be avoided.

7 PLACEMENT OF BACKFILL

No dumping of stones shall be done. The backfill shall preferably be done by hand packing to achieve the maximum angle of internal friction. The width of backfill shall be at least 500 mm. The backfill material shall be non-cohesive and as free draining as possible except the top layer of 300 to 500 mm thickness which shall be made as impervious as possible to minimize ingress of water from top surface.

8 DRAINAGE

8.1 The dry stone masonry retaining walls have the advantage that the masonry remains quite permeable to the flow of water and pressure normally does not build up. However, efficient drainage system above the top of the retaining wall is most essential. The top layer of backfill shall be laid at a proper camber and shoulder slope. The water flowing in the hill side drain shall be drained off through scuppers of appropriate design at regular intervals. The retaining wall top shall be kept slightly lower than the shoulder sloping outward so that water runs over the wall instead of seeping into the backfill. For site development, a 300 mm thick impervious soil layer (properly compacted) with boulders shall be laid above the top surface and backfill to prevent ingress of drain water. Typical sketch showing best retaining wall with good filling is shown in Fig. 1(d).

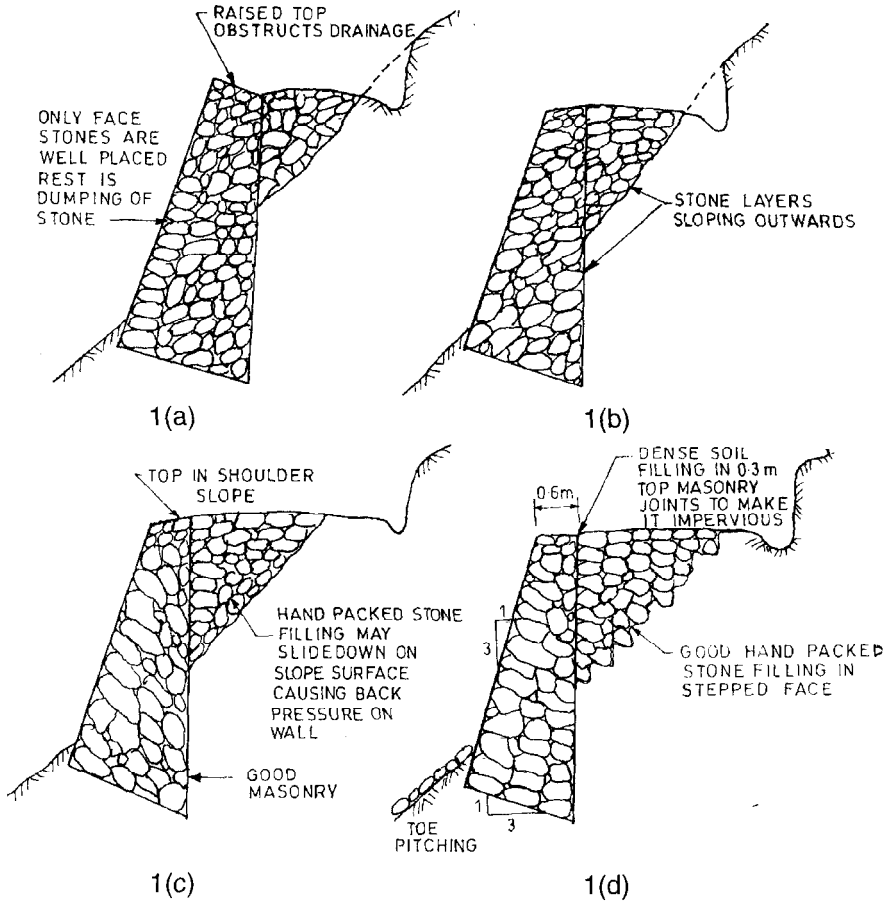
8.2 Excavated material from foundation if dumped by the side of the toe obstructs drainage. It must be sloped down below the top level of the toe projection.

9 TOE PROTECTION

The water coming out at high velocity from top of retaining wall can cause soil erosion at the toe and even below it by back erosion of soft rock or shale. Toe protection shall always be provided particularly in walls having height more than 3 m except where the toe rests on hard non-erodable rock.

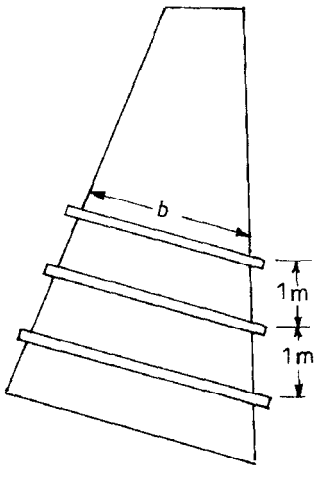
10 RCC BONDING ELEMENT

In thicker wall sections and tall retaining walls, say greater than 3 m, special duly staggered bonding elements through the masonry, going from earth face of the wall to its front face at regular spacing along the length and height, shall be used. The bonding elements shall be spaced at 1 m interval along the length of the wall. These elements may consist of with overlapping bond stones (scissor bond stones), wooden ballies or bamboos but considering the durability these may consist of reinforced concrete member of square cross-section of 75 mm × 75 mm or 100 mm × 100 mm and having a length equal to the thickness of the wall plus 150 mm so that it may project out of wall by 75 mm on both sides for easy checking as shown in Fig. 2.



1(a) RETAINING WALL OF VERY SMALL STRENGTH
1(b) RETAINING WALL OF POOR STRENGTH
1(c) GOOD RETAINING WALL BUT UNSTABLE FILLING
1(d) BEST RETAINING WALL WITH GOOD FILLING

FIG. 1 TYPICAL CONSTRUCTION DETAILS FOR DRY STONE MASONRY WALL



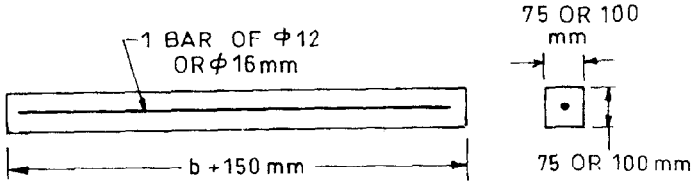


FIG. 2 RCC BONDING ELEMENTS

ANNEX A
(Foreword)

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(*Continued on page* 5)

(*Continued from page 4*)

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