TREATMENT AND REPAIR OF PARTIALLY DAMAGED RETAINING WALLS IN HILLS

By

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1. INTRODUCTION

In hills, stone masonry retaining walls are constructed on the principles of gravity walls. Where adequate study of soil rock, their behaviour in varying weather, stability of slopes etc. is not done, damages to the walls take place during rainy season. In normal practice, these retaining walls are dismantled and re-constructed. It will be much economical to repair and treat partially damaged or bulged retaining walls through appropriate measures.

2. POSSIBLE CAUSES OF DAMAGES OF RETAINING WALLS

The following are the possible causes of damages of retaining Walls.

2.1. Poor Drainage

Poor surface drainage near top of retaining walls may be noticed in most of damaged walls. A large quantity of water seeps through the back of retaining walls if there is no proper slope for quick surface drainage. This causes heavy back pressure. For quick drainage, top of retaining wall should have 1 : 25 to 1 : 36 slope. Preferably, top surface should be made impervious by fine soil, and stone boulders compacted in 0.3 to 0.5 m thickness. Excessive seepage of water is harmful on three accounts; first it causes heavy back pressure; secondly it degrades soil strength parameters; and thirdly it lubricates masonry stones at intermediate layers and at base.

2.2. Improper Workmanship

Poor interlocking of stones, improper masonry slope in dry stone masonry, and dumping of stones in retaining wall section and back filling are quite common. Weak mortar, lack of curing, use of very stiff and unworkable mortar are also common in case of masonry retaining walls.

2.3. Clogging of weep holes

Generally, size of weep holes provided is 15 cm × 10 cm for drainage. These get clogged and choked in very short time of six months to one year losing their utility. It is not easy to inspect and to clean them. Bigger scupper type drainage holes should be provided to overcome these drawbacks.

2.4. Inadequate design considerations

Quite often retaining walls are made of a single standard section in all sorts of soil and rocks irrespective of anticipated back pressure consideration. Normally adopted section consists of top width 0.6 m face slope 1 : 3 (1 horizontal and 3 vertical), and vertical back slope. Base is given 3 : 1 inward downward slope for keying it as shown in Fig. 1.

In normal practice, retaining walls upto 4 m height are constructed by dry stone masonry. Heights greater than 4 m are constructed in mortar masonary or dry stone masonry with 0.6 m wide masonry bands 3 m apart both in hori-

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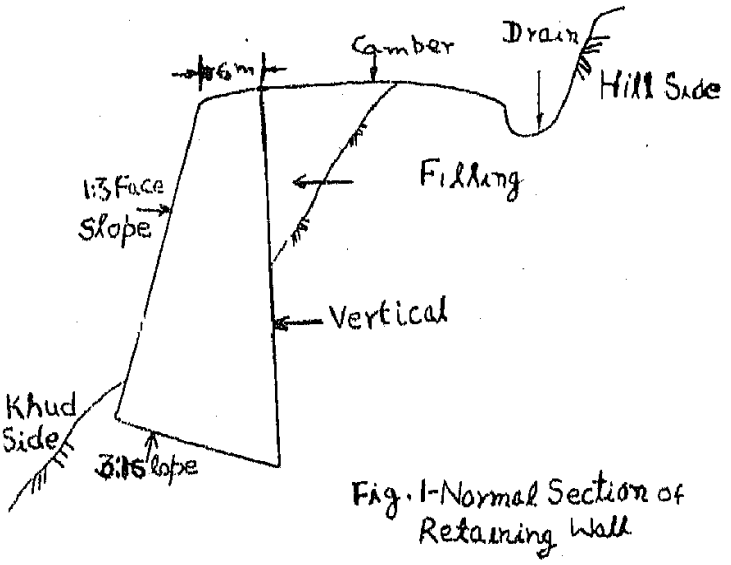


Fig. 1—Normal section of retaining wall

zontal and vertical directions. On many roads, retaining walls of height more than 4 m in dry stone masonry may be seen standing well since decades. At the same time many banded and mortar masonry retaining walls can also be seen damaged especially during rains due to reasons explained earlier.

Sometimes, successive retaining walls are constructed one over the other as shown in Fig. 2. This is a wrong practice as toe of upper wall causes heavy surcharge pressure on back of lower wall to which they may not stand. Such walls have been seen damaged most often if backing is of soil or soilmixed with stone boulders. Such successive walls may remain stable only when backing has a high percentage of stable rock, causing only a nominal back pressure.

3. DESIGN AND DRAINAGE ASPECTS

Proper design considerations, adequate study of foundation and backing soil, rock properties and its behaviour during adverse seasons are very necessary before taking up construction of a retaining wall. Quick drainage, good workmanship and proper quality control of work are very necessary for a stable retaining wall. In retaining walls of height more than 4 m size of weep holes should be about 0.6 m x 0.6 m to 1 m × 1 m scupper type as shown in Fig. 3. These are easy for inspection and cleaning. Moreover, it will reduce anticipated back pressure by quick drainage of seeping water.

4. REMEDIAL MEASURES

The remedial measures will depend on type, mode and profile of failure. It will also depend on stability of adjoining slope, and the type and behaviour of rock and soil lying at the base and in the backing. Possible remedial measures under different situations are explained in below paras.

4.1. Loss of few stones from the wall

Sometimes empty pockets are developed in the wall due to splitting away of few of the masonry stones. Such pockets enlarge in due course of time and ultimately result in the collapse of the retaining wall, fully or partially, if they are not treated in early stage as soon as it is noticed. Whole of the wall does not collapse till the arching action among the stones is able to bear the forces. In such case, stones should be placed in pockets tightly, so that they become well interlocked with parent masonry stones, Fig. 4. A proper toe

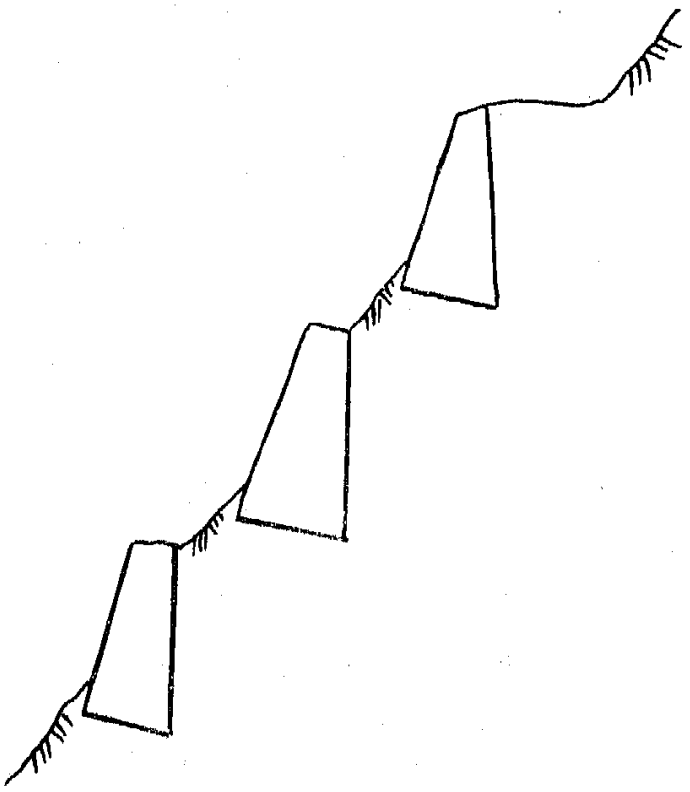


Fig. 2 –Successive retaining walls

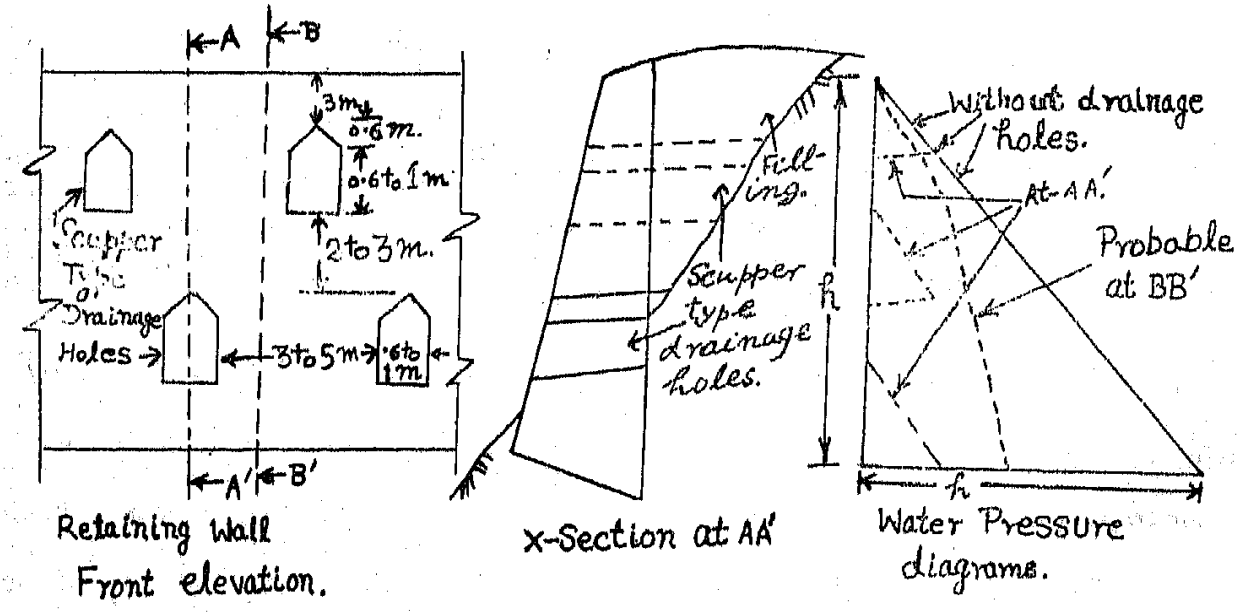


Fig. 3—Retaining walls with scupper type weep holes

wall should be constructed, if the failure occurs near the toe due to erosion of the base soil or rock, or due to base failure. Such erosion generally occurs during heavy rains. This type of remedy has been tried by the Authors for many retaining walls and found successful.

4.2. Slope failure

4.2.1. This may be of two kinds :

(i) Due to failure or sinking of base

(ii) Due to pressure on the foundation soil or rock exceeding the bearing capacity.

These failures occur only in rainy season, because soil strength parameters get degraded on wetting. If only partial damage occurs due to sinking, then it means that soil or rock lying below the base has gone to compression and consolidation. For such cases it will be better to make additional wall like toe wall in front of original wall as per details given in Table 1 and Fig. 5. The sunken depth may be filled up by hand-packed stones to get required original road surface.

The dimensions in Table 1 may be changed according to the failure condition and site requirements.

The damage brought out above can also be treated by surface grouting in case enough space is not available for toe wall i.e. wall standing on steep hill face. For grouting, 0.3 m X 0.3 m pits of 0.6 to 1 m depth should be dug at 1 to 2 m spacing. Fissures created due to failure may also be utilised for the purpose. Mixture of 1 part of cement and 1 part of water should be poured in the alternate pits or fissures till it is absorbed. Allow it to set for atleast 15 days and then pour the same mixture in rest of the pits. Fill up all the pits by soil and

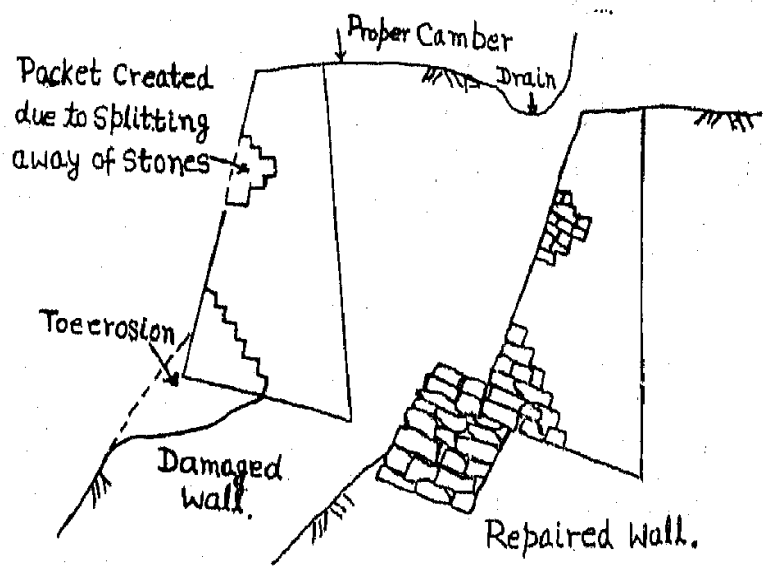


Fig.—4 Repair of retaining wall affected by erosion or loss of stones

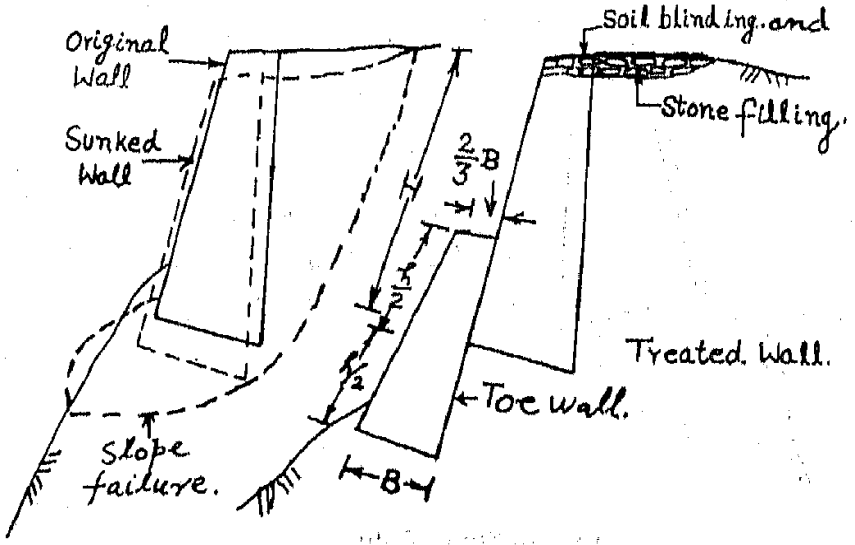


Fig.—5 Repair of wall subject to sunking

TABLE—1 : DETAILS OF TOE WALL

Height of retaining Wall 'H' (metre)	Height of toe wall 'h' (metre)	Width of Toe wall 'B' (metre)
1	—	—
3	1	0.6
4	1.2	0.8
5	1.5	1.0
6	1.8	1.2
7	2.1	1.5
8	2.4	1.8
9	2.7	2.1
10	3.0	2.4

stones and compact properly. In case of fine soil beds, mixture of 1 part of unslacked lime and 3 parts of water should be poured instead. The mixture should be thin enough so that it may seep in soil voids and fissures.

The quantity of cement water or unslaked lime water mixture may be assessed to be 5 to 10 per cent of soil quantity to be strengthened. The requirement of cement may be 1 to 5 bags per running metre length of the retaining wall depending on depth and width of failure.

4.2.2. Slope failure resembles spheroidal or parabolic shape. A wide crack or gap may develop on the surface as failure progresses. It becomes only a partial failure, if base soil or rock is able to bear weight of departed masses at any lower level as shown in Fig. 6. Such cases may be treated by construction of a toe wall or by grouting as explained in para 4.2.1. It would be better if grouting is done along the fissures or the gaps developed. This would result in a honeycombed solid mass.

Whole of the grouting should not be done in one day or in one operation, as the fluid grout may exert a high back pressure and lubricate the mass which may cause complete collapse of the wall. Only 5 per cent length should be grouted on each day in first 5 days. Then a gap of 15 days should be given for curing and strengthening of grouted mass. Whole of the remaining grouting may be completed on 16th day and onwards. After completing 10 per cent length, the mixure may be changed to 1 part cement, 1 part medium sand and 1 to 1.5 part water. If the fissure is wider than 10 cm, after completing the first 10 per cent length, grouting mixture may be changed to 1 part cement, 1 part sand, 2 parts of 10 to 20 mm size grit or river shingle, and 2 parts water. Grouting should never be done when the ground is saturated. Dry ground would allow quick soaking or

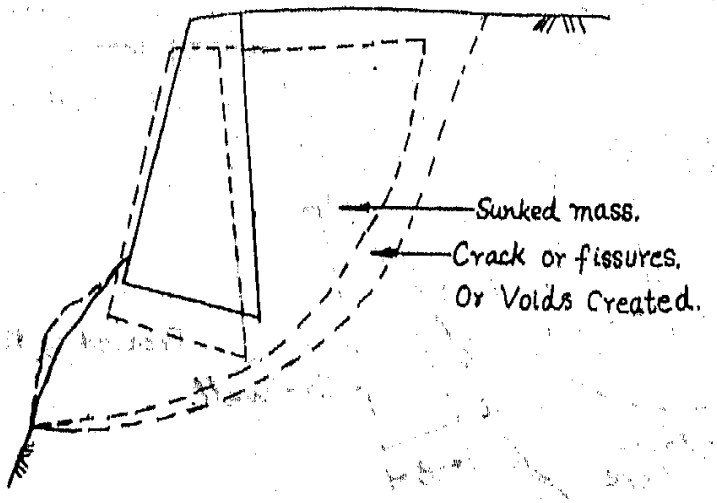


Fig. 6—Slope failure

seepage of grout mixture all around the fissures.

Such grouting has been used successfully for rectifying a slope failure, and strengthening a collapsed old breast wall and a old bulged wall at Govt. Girls Inter. College, Pauri building site. This has been cheaper by about Rs. 20,000 than the construction of a new 7 m high 15 m long retaining wall.

4.2.3. **Sinking of a big part of hill surface or road** : Such failures occur due to excessive ingress of surface water and or by soil erosion near foot of a hill face, specially near rivers and streams. Remedy lies in strengthening by surface grouting as explained in para 4.2.1. using unslaked lime or cement, or by proper toe wall. Turfing or making surface impervious by pitching of stones etc. may also prove very helpful.

4.2.4. **Bulged retaining walls** : This type of failure resembles a column failure in building or shearing as shown in Fig. 7. This may be treated by construction of a suitable toe wall, or by grouting, or both. Sometimes enough space for toe wall may not be available. In such case, surface grouting may only be a reliable solution.

4.2.5. **Slope failure combined with toe failure** : This may be treated as explained in paras 4.2.1. and 4.2.2.

5. CASE STUDY FOR SOME TREATED RETAINING WALLS

5.1 Toe of a 7.5 m high mortar masonry retaining wall was seen eroded forming large pockets as shown in photo 1 soon after the first rainy season of their construction. This was due to fall of rain water from top and heaving of soil lying below toe on Pauri-Kholachori road, km. 2. The pocket was filled up tightly and a toe wall was constructed in dry stone masonry by maintenance gang as explained in Fig. 4. It has functioned well for last four years, saving the wall from complete collapse. Similar treatment has been done to dozens of other retaining walls on a number of roads in district Pauri Garhwal (U.P.).

5.2. Treatment as explained in 4.2.1. and 4.2.4. has been done to a about 8 m. high cribbed stone masonry retaining wall in Km. 6 of Mundaneshwar-Bausal road in district Pauri Garhwal in December 1980. The hill zone consists of hard steep rock underlying 1 to 3 m thick loose soil and boulder deposits. Whole of the soil deposit alongwith the retaining wall sunk by 1.0 m and got moved away for 15 cm. The retaining wall got bulged. However, the top 4 m of retaining wall remained intact. A toe wall of dry stone masonry 3 m high and 2.5 m wide at base was constructed. Gap at the top was filled up by stone and soil to proper camber. The retaining wall remained intact and stood the rains of

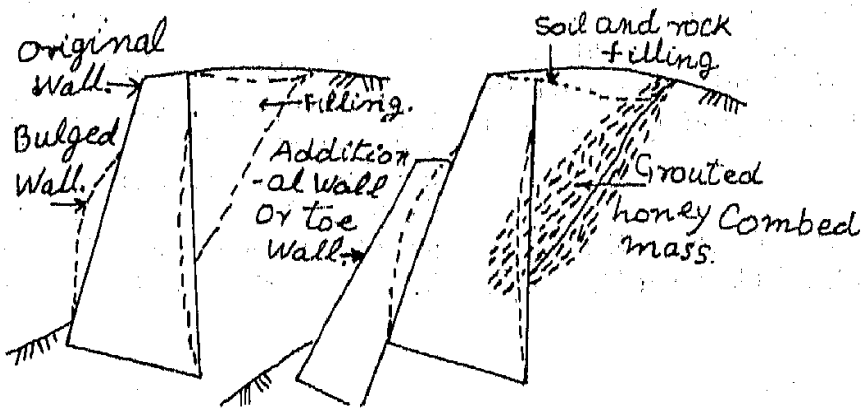


Fig. 7—Bulged retaining wall

1981 well. Similar treatment is being given to a 6 m high bulged retaining wall in Km. 18 of Almora-Shaharphatak road.

5.3. Excavation and cutting in hill rock and soil was done in 22 m length 11 m width, 5 m height for construction of two numbers three-roomed quarters at Govt. Girls Inter College Pauri in early 1979. A 3 m high banded masonry breast wall was constructed to protect cut slope which consisted of fractured, highly weathered rock as shown in Photo 2. On the upper side of cut slope, there is a building at about 3 m above and 5 m away from top of breast wall. During rains of June-July 79, the hill slop upto toe of breast wall slided, sank by 30 cm. and moved away for 15 cm, damaging the apron constructed around the building very badly. The building came to a dangerous situation as it could collapse at any moment. The slope failure may be seen in Photo 3. It was not easy to construct a masonry or other retaining wall to support the detached hill mass as the whole of the detached mass along the building could have fallen down during the excavation of rock and soil for making the foundation of retaining wall. Moreover it could not have stopped ingress of rain water percolating in the fissures or voids of the failed layer. It was therefore thought that filling of voids and fissures by cement and water mix by grouting could only be the reliable and safe remedy. It was actually done. The slope and the building have been found to be safe so far. It required only 80 bags of cement, and the total cost amounted to Rs. 1600 only while cost of a new retaining wall would have been about Rs. 20,000.

5.4. In km. 75 of Pauri-Kotdwara road in district Pauri Garhwal U.P., one high retaining wall of height about 7 m collapsed many times though constructed in cribbed and banded masonry. In October 1980 it was reconstructed with 1 m opening scupper type drainage holes as explained in Fig. 3. This retaining wall is intact even today. Similar drainage holes of width 0.6 m have been provided in 9 m high dry stone masonry retaining wall in km 22 of Sungerhal-Sikukhal-Jwalpa Devi road in district Pauri Garhwal in April 1981, and 8 m high dry stone masonry retaining wall in km 1 of Chharonj-Chalnichhina road in Almora district. These have been found successful and the walls have not shown any sign of collapse. Similar drainage holes are being provided in several other retaining walls.

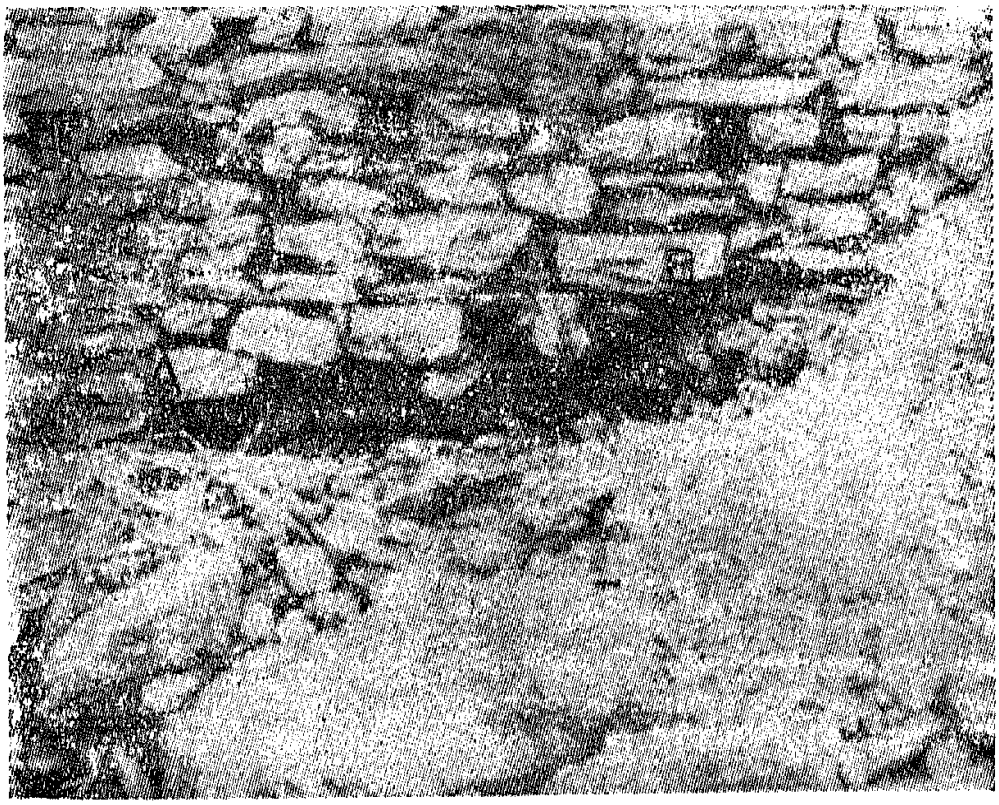
5.5. Photo 4 shows a partially failed retaining wall due to bulging and loss of stones at km 20 of Almora-Pandhar road. This was repaired by packing the voids tightly with stones and constructing a supporting toe wall, see Photo 5.

6. CONCLUSIONS

With the above explanation and study, it may be concluded that appropriate remedial measures will be much cheaper and better than reconstruction of partially damaged retaining/breast walls. The treatment will however vary depending on the type of failure, type of wall, site conditions etc.

ACKNOWLEDGEMENTS

Authors are thankful to Shri N.K. Mittal, Superintending Engineer, P.W.D., Uttarkashi, who had approved remedial measures at Government Girls Inter College, Pauri and other sites. Authors are also thankful to other staff for carrying out work in field.



Photo—1. Loss of stones and formation of pockets in retaining wall because of water erosion

Photo—2. Highly fractured rock zone with excessive fissures and voids

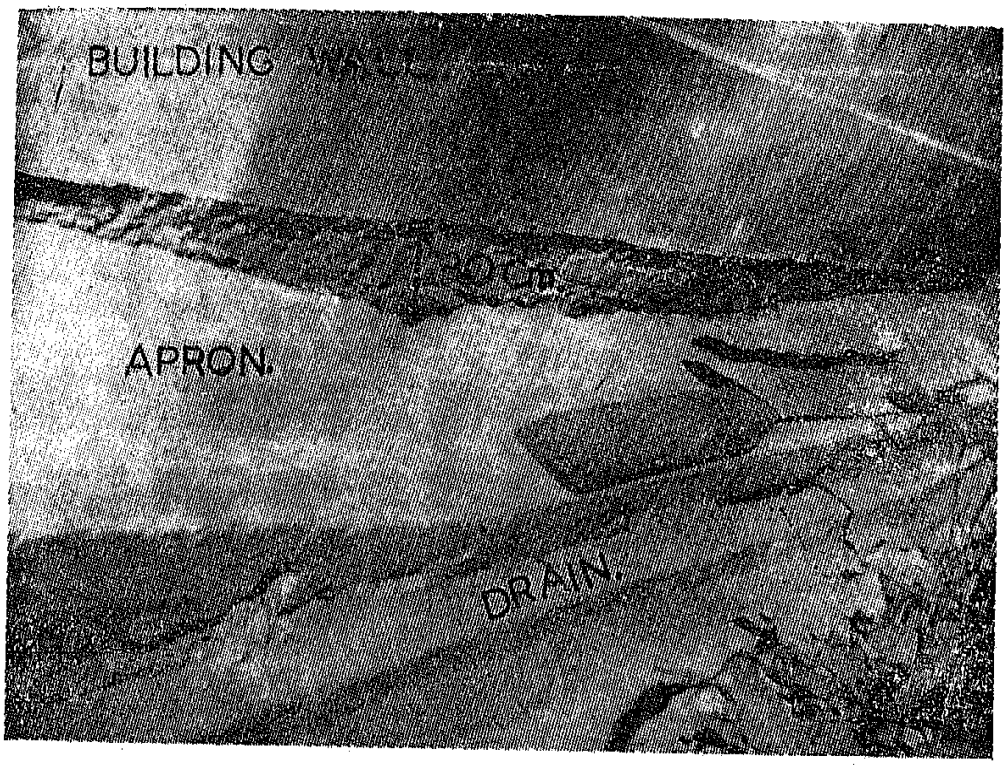
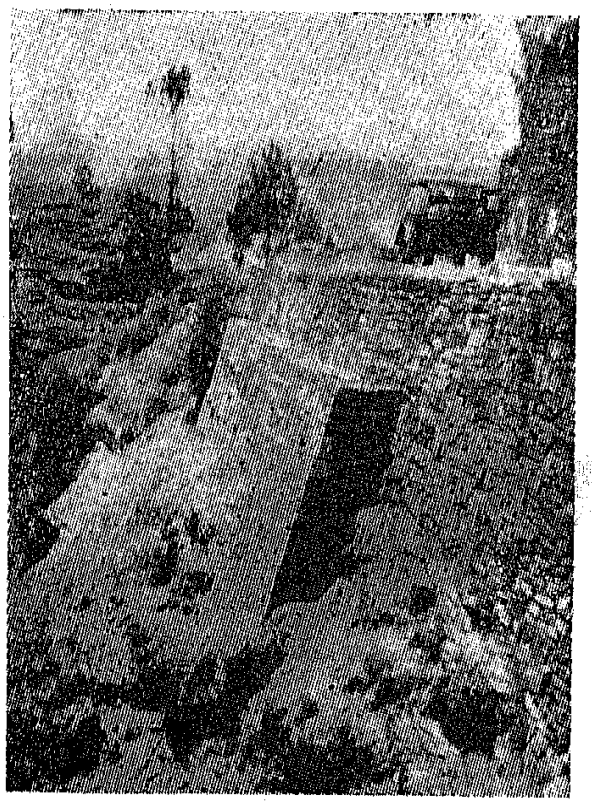


Photo – 3. Close view of a hill cut slope failure

Photo 4. A retaining wall subjected to bulging and loss of stones



Photo—5. The wall in photo 4 after repairs. The voids were tightly packed with stones and a toe wall built for support