gabions in highway construction

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This paper presents a short history of the use of gabions, especially in the State of Washington. Typical uses of gabions include stream control, retaining wall, and rockfall protection. Examples of each of these uses are given. Also presented is the development of Washington specifications for gabion use, and possible future modifications are discussed. Planned gabion use on I-90 at Snoqualmie Pass is discussed.

•A gabion, simply defined, is a basket of rocks! The earliest known use of gabions consisted of wicker baskets filled with stone that were piled up to form the desired structure. This evolved to the use of wire baskets (Fig. 1). There were some installations in Europe built in the last century that are still in service (Fig. 2). In this country, they have also been in use for some time but usually not under the name gabion (Figs. 3 and 4).

In Europe, gabions have been an established fact for quite some time (Figs. 5, 6, and 7). Their use in general construction is just catching on in the United States. Gabions are used primarily for two types of structures, one of which is a stream control structure such as weirs, groins, and bank protection (Figs. 8 and 9). For bank protection, gabions require much less depth and conform to local failures in the underlying bank without breach of the structure (Fig. 10). This type of structure, or a wall type of structure along a stream, should always use a fairly wide apron on the bed of the stream, as shown in Figure 10. "Mattress" types of gabions should not be placed on slopes steeper than about 2:1 because the stone filler tends to sag to the lower part of individual baskets (Fig. 11).

This brings us to the second main use of gabions, i.e., as gravity retaining walls. These are similar in application to metal bin walls but in some areas are aesthetically preferable.

The Washington Department of Highways first considered their use about 5 years ago, primarily through the efforts of Maccaferri Gabions of America. Since then gabions have been used for bank protection, retaining walls of various sizes (Fig. 12), and rockfall protection (Fig. 13). Although we have been generally pleased with their performance, we have not been pleased with their cost. This, I believe, can be attributed to two primary factors: (a) constantly revised specifications during their early development, breeding unfamiliarity among inspectors and uncertainty among contractors on what to expect; and (b) lack of construction experience, resulting in inefficient use of manpower and equipment on the part of contractors.

In regard to item a, the first available specifications (including those used by other states and the Forest Service) were those developed by Maccaferri, were quite general,

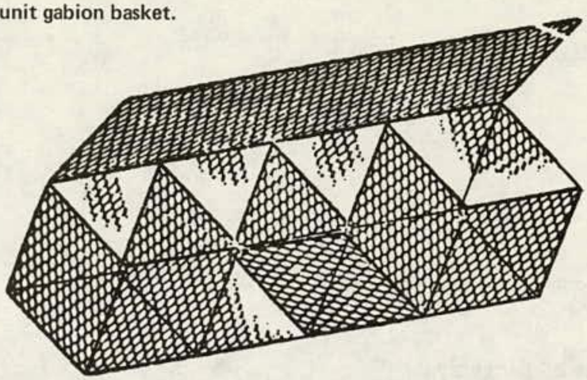


Figure 1. Typical four-unit gabion basket.

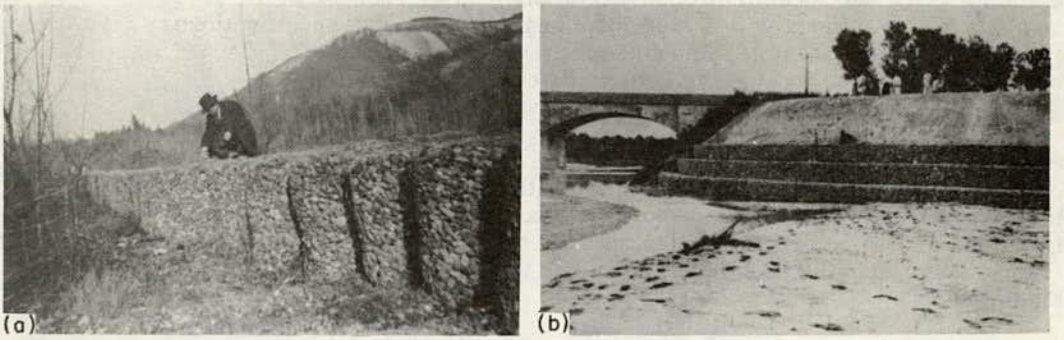


Figure 2. Installations (a) to close a breach in the bank of the River Reno built in 1893 and (b) on the River Santerno.

Figure 3. "Rock posts" in southeastern Washington.

Figure 4. A groin built of stone and hog wire about 1930.

Figure 5. Extensive use in retaining a highway in the Italian Alps.

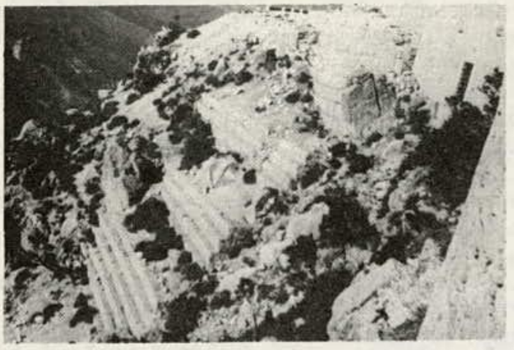


Figure 6. Installation on the River Arno.

Figure 7. Restoration of a small stream in Europe.

Figure 8. Channel protection at culvert exit.

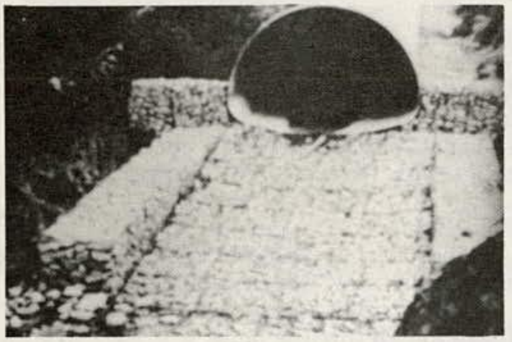
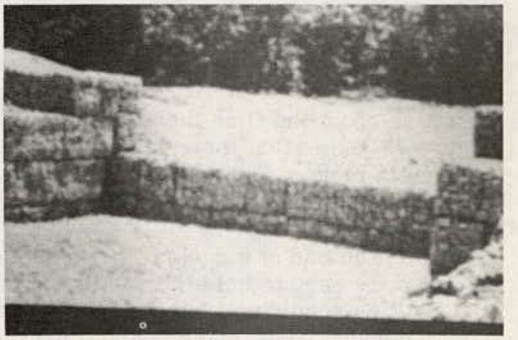


Figure 9. Typical weir installation.



and, understandably, were written around their product, tending to exclude competitors such as American Gabions of Browning, Montana. Examples of this are a requirement for a hexagonal triple twist mesh, wire specifications obviously written around a foreign product, and a load test that could not be met by a rectangular mesh. Maccaferri and Baekart gabions use a hexagonal mesh, whereas the American Gabion and project-fabricated gabions use a rectangular, nonclimbable fence mesh. Our interest, therefore, was to write a specification that was broad enough in certain areas to allow various methods of manufacture, yet ensure a satisfactory end product. This included reference to nonmetric measurements, a new load test, reference to standard federal wire specifications (QQ-W-461), and revision of some construction details. Also, our standard "no foreign product" specification had to be rescinded to allow the standard foreign gabion.

During this process, several gabion installations in neighboring Idaho (Fig. 14) and an extensive gabion operation in Colorado (Fig. 15) were visited. Much helpful information was gleaned on problems in Idaho and Colorado and suggested solutions. One of the big problems was cost, primarily because of the large amount of hand work in the then-accepted practice of hand-placing the stones at the face of the wall. We resolved to avoid this if we could. Another big problem was failure to specify a minimum density of the gabions or to determine the probable density of the material to be retained. This had, in at least one case, resulted in the failure of a wall because it was not heavy enough to hold the denser backfill in place. Colorado recommended a density specification, which we adopted. However, we enforced the specification by occasionally removing a completed gabion and weighing it. This is a somewhat difficult test to administer. We now allow basket filling from a container (truck) to be weighed before and after. We also recommend drastically reducing the number of these tests if satisfactory results are routine and as the inspector develops a "feel" for what a properly filled and compacted gabion looks like. Both states also strongly recommended angular stone in a retaining structure for better load transfer. This is now a part of our specification. It was, of course, recognized that this would not be necessary in a non-load-carrying structure such as bank protection. We also evolved a load test geared toward the conditions most likely to be encountered in a retaining structure. The initial specification was as follows:

A section of gabions with units having a minimum dimension of 3 feet and at least four units long shall be constructed and filled in the normal manner on a level platform having a removable center section at least 6 feet in length. The gabions shall be so situated that an end-to-end connection between units will be situated approximately over the center of the removable section. This section shall then be removed, leaving a clear span of the gabions of at least 6 feet. The gabions, including connection, shall show no sign of failure.

While the gabions are in the above condition, a single mesh wire at the bottom and near the center of the clear span will be cut, and the gabion units must still exhibit no sign of failure.

This was about the time the American Gabion people consented to try the load test. Figure 16 shows that their gabions performed beautifully. They later consented to perform a more stringent test to approximate a several-tiered wall; this test produced very good results.

A problem in one of our earlier contracts arose because we failed to specify the number of ties to be used to hold the various components together. It was decided at that time that the ties should equal the strength of the mesh; it has since been decided that this is overly conservative, inasmuch as load tests have shown that the units will hold up with most of the wires cut. The amount of mesh is, after all, more a function of the size of opening necessary to contain the filler. Our latest specification is as follows:

Gabion baskets shall be securely fastened to all adjacent gabion baskets to the satisfaction of the engineer. It is not intended that the fastenings to adjacent gabions equal the strength of the baskets themselves.

Figure 10. Typical riverbank installation showing ability to conform to changes caused by erosion.

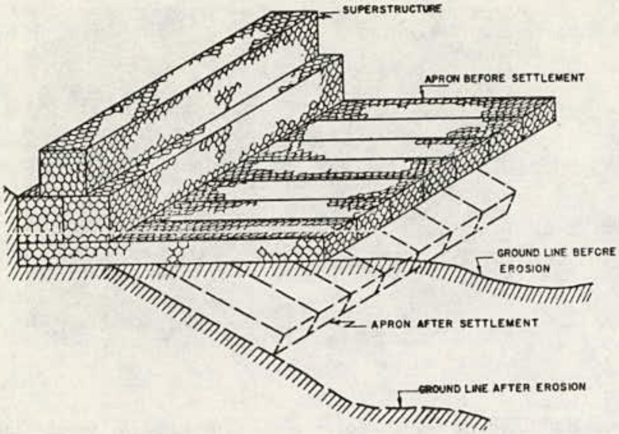


Figure 11. Results of using mattress type of gabion on too steep a slope.

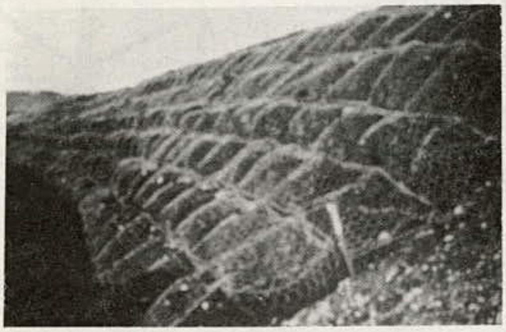


Figure 12. Wall to contain fill at bridge abutment on the Snoqualmie Pass.

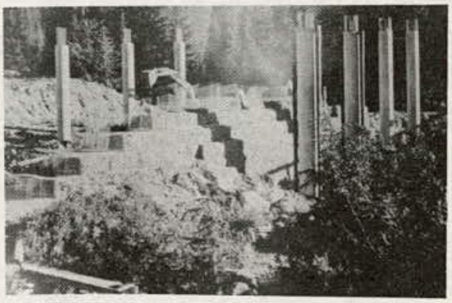


Figure 13. Protection against rockfall on Wash-12.

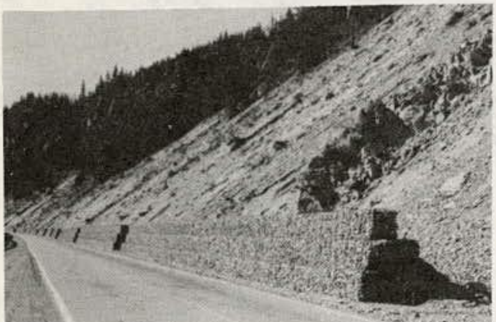


Figure 14. Gabions supporting US-95 near Whitebird, Idaho.

Figure 15. Gabion construction near Glenwood Springs, Colorado.

Figure 16. Initial test by American Gabion.

Figure 17. Artist's conception of (a) standard cantilever wall retaining a portion of I-90 near Snoqualmie Pass and (b) same location using a gabion wall.

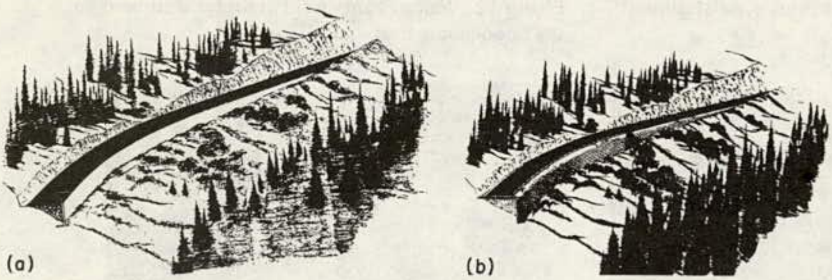


Figure 18. "Quick-Klip" joins rolls of fence wire to form gabions.

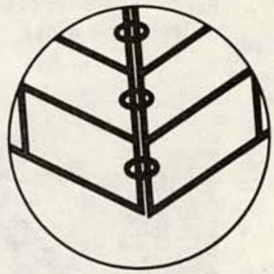
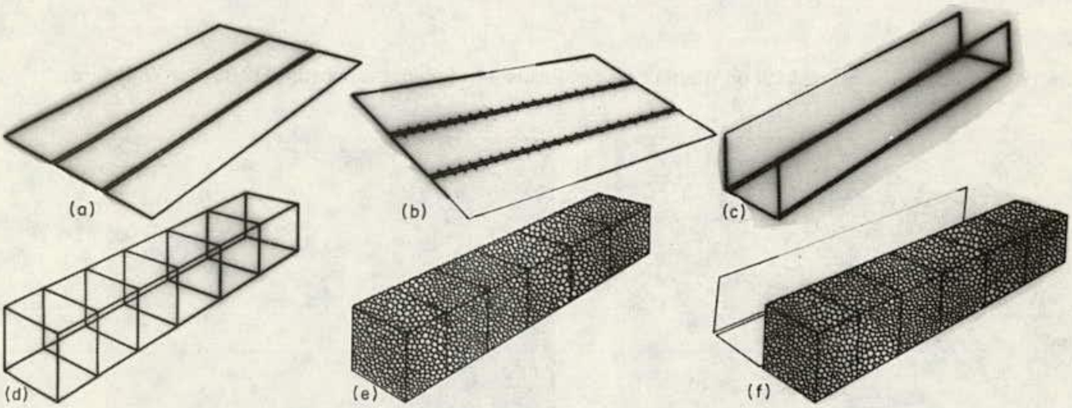


Figure 19. Fabrication of gabion: (a) roll out fence wire; (b) clip together; (c) raise sides; (d) add diaphragms; (e) fill with stone, and add lid; and (f) roll out next row.



We learned on one of our first retaining wall jobs that our design density of 115 pcf was difficult to obtain with the following usual open gradation.

Sieve	Percentage Passing
8-in. square	100
6-in. square	75
4-in. square	≥10

We therefore specified additional fines to increase density.

Sieve	Percentage Passing
8-in. square	100
6-in. square	70 to 80
4-in. square	5 to 20
¼-in. square	≥2

This has not resulted in any appreciable loss of material and has helped to attain needed design density. If a conflict develops between unit weight and gradation in a retaining wall project, the unit weight must always prevail, as long as the filler remains granular and porous. However, we are now designing walls from 105 to 110 pcf, which is not too difficult to attain.

As noted earlier, we have not required hand placing of any filler material. We have had some trouble with misshapen gabions because of this, but it can be controlled with proper care, particularly if design density is not too hard to reach. We feel that the neater appearance possible with hand placing is not worth the extra cost. There certainly could be some exceptions to this, particularly in areas requiring more attention to aesthetics. Regarding aesthetics, we have found gabion structures more desirable than their concrete counterparts in areas of rugged terrain and high natural beauty, such as forest and mountain settings. In general, we will choose this type of structure over a less expensive design that does not blend so well into the natural terrain (Fig. 17).

Most recently, a project was completed for numerous rockfall barriers along Wash-12 at White Pass by using a novel gabion fabrication method developed by a mesh supplier. Essentially, it consists of fabricating the gabions in place from rolls of fence wire by using common intermediate diaphragms and specially developed stainless steel clips (Figs. 18, 19, and 20). The tedious task of installing tie wires is eliminated by increasing the number of diaphragms and adding additional diaphragms at the wall ends. There is a considerable saving on both materials and labor when this method is used, and it may help to bring gabion costs back in line with riprap and bin walls. We are still evaluating this method and intend to modify our specifications to allow this type of construction.[1]

Our most ambitious design has been for the I-90 crossing of Snoqualmie Pass in the Cascades. It has been difficult to fit a six-lane freeway into rugged terrain with minimum damage to the environment. The highway will make use of about 55,000 cubic yards of gabions, mostly retaining walls. Figure 21 shows one talus area where three lanes will be supported by a two-tiered wall (Fig. 22). This is also an area of heavy snowfall and frequent avalanches. Although other measures have been used to minimize avalanche hazard, forces due to avalanches had to be considered in the design.

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[1]Possible revised specifications were included in the original manuscript of this paper. They are available in Xerox form at cost of reproduction and handling from the Transportation Research Board. When ordering, refer to XS-50, TRB Special Report 148.

Figure 20. Completed gabions.

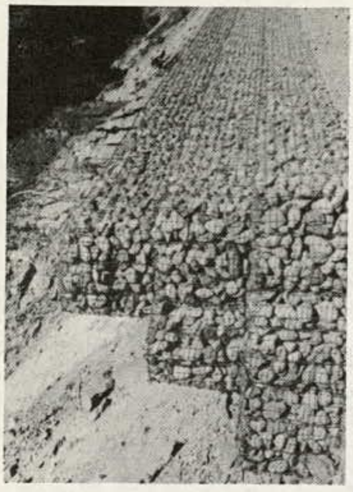


Figure 21. Talus area west of Snoqualmie Pass.

Figure 22. Preliminary design of walls for area shown in Figure 21.

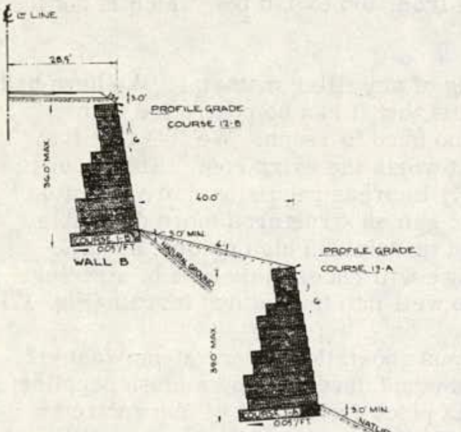


Figure 23. Avalanche chutes above I-90.

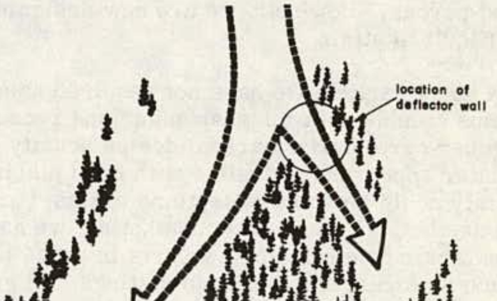
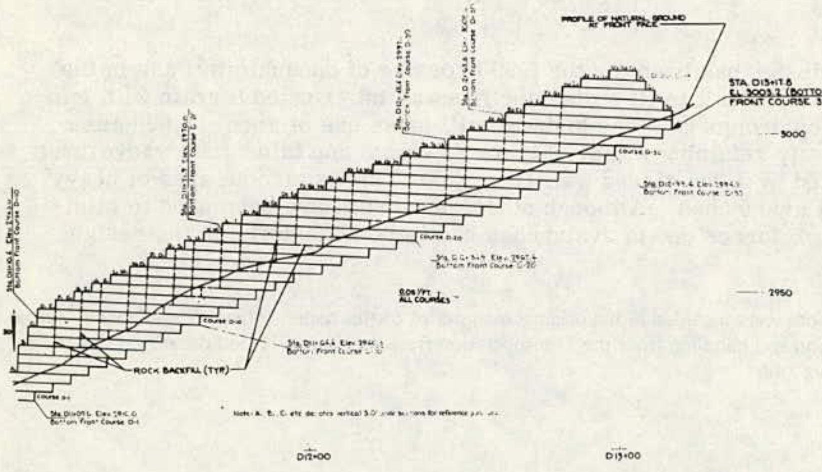


Figure 24. Profile of avalanche deflector wall.



Another unique use of gabions in this area will be as an avalanche deflector. Figure 23 shows an avalanche chute that splits above the highway, sending debris in two directions. The left leg is bridged to allow the avalanche to pass safely under the highway. A deflection wall will be constructed at the division point to contain the avalanche in this left chute (Fig. 24). This wall, of course, is designed to withstand considerable avalanche forces.

In summary, we feel that gabions do, indeed, have a place in highway construction, particularly in areas where natural-appearing structures are desirable. It appears that, with the development of newer methods and with more familiarity by the contracting fraternity, the cost of this type of construction will be competitive with other, more conventional designs.

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The views and conclusions expressed in the report are strictly the author's and do not necessarily reflect the position of the Washington Department of Highways.