Gabion Baskets: An Effective Means of Erosion Protection

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Takarau Gorge Road and Makara Road, located to the west of Wellington New Zealand are subject to regular erosion damage from adjoining streams.

The geotechnical hazards present along these roads include slips both above and below the road, degradation of the streambed, erosion of the stream banks and loss of fine materials from beneath the carriageway. A variety of retaining and erosion protection structures have previously been built to protect the carriageway. Following a 100-year return period storm event in February 2004 failures of slopes and retaining structures occurred.

Gabion basket walls have become a preferred option for carriageway protection as they are flexible and, if adequately designed and detailed, have the capacity to withstand differential settlements and scour.

1. INTRODUCTION

Wellington City Council is the roading authority responsible for the upgrade and maintenance of the roading network in the Wellington area. This includes two rural roads which follow the alignment of streams and are at constant risk of erosion. Due to the low traffic volumes of these roads major realignments of constraining of the streams are difficult to justify. Retaining structures and erosion protection works are used to protect the road at critical locations.

The two roads are Takarau Gorge Road and Makara Road, located to the west of Wellington city as shown in Figure 1. They adjoin the Ohariu and Makara streams respectively. Both roads, one in a gorge and one in a valley, are susceptible to damage after heavy storms. In February 2004 a 100-year return period storm occurred.

This storm caused major flooding and damage in the area. The damage occurred to many unprotected banks both above and below the road and to existing retaining and erosion protection structures.

These failures and ways to prevent them are discussed.

The merit of using gabion basket walls to protect roadways is also presented.

2. ROAD SETTING

The Ohariu and Makara streams are approximately 2m wide and 0.3m deep in normal flow conditions. The water levels can rise 2m or more during flood events. The adjoining road surface levels are 1m to 3m above the normal flow water level.

Takarau Gorge Road provides access to farming and forestry blocks. The narrow road winds through a steep sided gorge adjacent to the Ohariu Stream. The road has typically been formed as a cut to fill road. The stream is constrained by the narrow gorge and continues to degrade. The road is susceptible to erosion by undercutting and over steepening of the banks.

The Ohariu Stream joins the Makara Stream where it exits Takarau Gorge. Makara Road follows a relatively straight alignment to the small coastal settlement of Makara Beach. In the wider valley the stream is unconstrained and meanders across the valley floor. The road is at risk of erosion where the stream adjoins and cuts into the banks on the outside of bends.

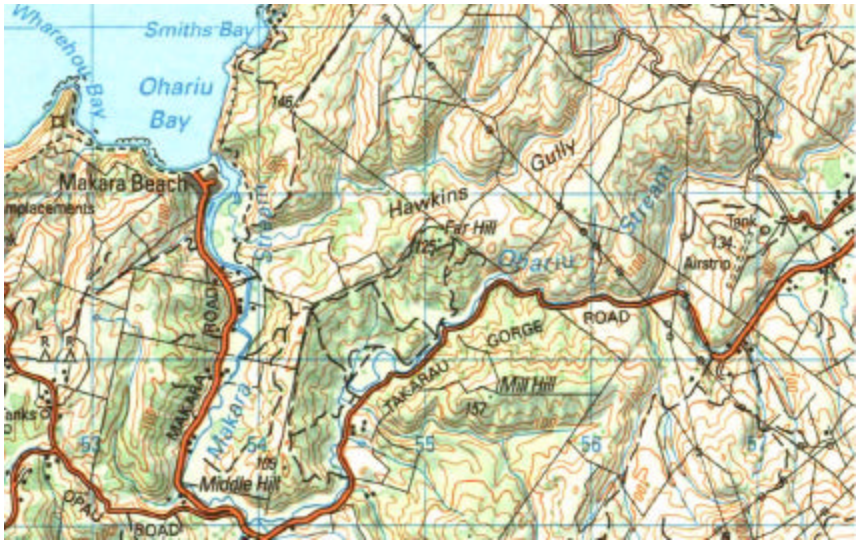


Figure 1 Map showing Takarau Gorge Road and Makara Road (TerraLink Ltd [1])

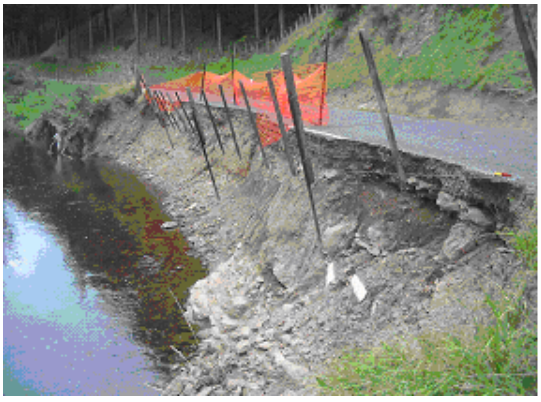
3. GEOTECHNICAL HAZARDS

Takarau Gorge and Makara roads are susceptible to a number of geotechnical hazards. These are

- High cut slopes above the road
- Bank erosion
- Flood damage to the carriageway
- Internal erosion of fine material

Above the roadway there are cut slopes up to 10m high. The cuts are in rock, residual soils and colluvium and can have slopes of up to 60^{o}. These often become unstable during heavy rainfall and slip debris can block the road. Large trees with shallow root systems on steep banks can become unstable during heavy rainfall events. Fallen trees can block the carriageway and also trigger larger slips.

Below the roadway unprotected stream banks are often eroded during flood events due to the flow patterns of the respective streams. The erosion leads to localised slipping and the loss of sections of carriageway. Photograph 1 shows a slip below the road that has been caused by the undercutting of the bank.



Photograph 1 Slip below road caused by undercutting of stream bank.

In Takarau Gorge the flood waters can flow over the road and cause localised scour, damage to unsealed shoulders and deposit flood debris.

Internal erosion can occur due to the migration of fine material with floodwaters. This can eventually cause severe damage to the pavement as illustrated in Photograph 2.

4. ROAD PROTECTION WORKS

Structures built to protect Takarau Gorge Road and Makara Road have usually been constructed as a reaction to damage caused by floods and slips.

Photograph 2 Damage to pavement due to the migration of fine material.

Large slips above the carriageway are not cost effective to prevent, however the carriageway can be protected from further damage by scaling works or promoting vegetation growth. Large slips that had occurred prior to the February 2004 storm and were remedied in this way showed no further signs of slipping during the storm event.

In both stream environments road protection structures are required that can withstand heavy traffic loads due to logging and stock trucks and allow for the other hazards described. The walls also need to be cost effective, relatively easy to construct in a streambed and be sympathetic to the surrounding environment.

The types of existing structure protecting the road from stream damage include:

- Rock revetments
- Pole walls
- Gabion basket walls

4.1 Rock Revetments

Revetments are a rock armour type protection. They consist of rocks stacked against the bank. The failure mechanisms observed in existing revetments along Takarau Gorge Road and Makara Road include the displacement of inadequately sized rock armour, localised scour at the end of revetments where there is a sharp transition between the natural bank and the revetment, and the loss of fine materials from behind the wall.

The advantage of revetments is that they are easy to construct below water level and are cost effective. They also have a natural look as they are made from natural materials and suit the rural environment.

Based on the observed damage the design of rock revetments need to consider the following:

- Armour rock large enough to resist movement
- Layers of filter rocks or a geotextile filter fabric to limit the movement of fines.
- A smooth transition from the natural bank to the rock structure to reduce scour at the ends of the structure.

4.2 Pole walls

Pole walls consist of posts, for example timber, railway iron or concrete, with timber lagging. The failure mechanisms observed in existing poles walls following storm events include overturning failures where the poles had been inadequately embedded into the underlying rock and undermining of the wall.

Photograph 3 shows a railway iron wall where localised scour has occurred beneath the wall. This has caused the backfill material to slump forming a hole. Localised scour can also occur at the end of the wall.

Based on the observed damage the design of pole walls need to consider the following:

- Potential scour depth to minimise the risk of undermining.
- Adequate founding depths for the poles.
- A geotextile filter fabric to limit the movement of fines.

Photograph 3 Undermined railway iron wall with loss of backfill material.

4.3 Gabion Baskets

Gabion baskets are usually 1m by 1m by 2m wire mesh baskets laced together and filled with very coarse gravel and cobbles. Gabion baskets are very flexible and can accommodate settlement of soft founding materials and erosion. To further protect against erosion they can be constructed on reno mattresses. Reno mattresses are approximately 0.25m thick and constructed in the same way as the baskets. They extend under the wall and at least 1m in front. If the toe is eroded the reno mattress is flexible enough to form to the new bed contours and resist further erosion.

Despite this flexibility damage can occur to gabion walls during flood events. Photograph 4 shows a gabion wall that has been inadequately constructed. The wall was originally founded at streambed level. The stream has degraded, undermining a section of the wall and causing the wall to rotate. The design of gabion walls is discussed in the following section.

Photograph 4 Gabion wall where the middle section has been undermined and rotated.

5. DESIGN OF GABION WALLS

Gabion walls have become a preferable option for support of the Takarau Gorge and Makara Road carriageways adjacent to the Ohariu and Makara streams. These walls are cost effective and can be designed to accommodate significant settlement and scour. However the walls need to be designed for stability and correctly detailed so that they are not damaged during significant flood events.

5.1 Wall Stability

Gabion walls must be designed for stability in the same way as any gravity type retaining structure. This involves designing the wall to resist:

- Overturning
- Bearing
- Sliding
- Global stability

All design loads need to be considered. In this case large logging and stock truck loads need to be applied.

In gravity retaining structures the weight of the wall resists active soil and applied pressures. The walls along Takarau Gorge and Makara Roads can be up to four baskets high (4m). Often the desired carriageway width and the close proximity of the stream edge require the gabions to be steeply stacked.

To increase overturning stability a second layer of gabions can be incorporated into the design or a grid reinforcement system can be used in the backfill to increase the stability of the wall.

The wall should be founded in dense materials of adequate bearing capacity. A subsurface investigation will determine the depth of soft sediments below stream level. This allows the wall to be founded on dense materials and lessens the likelihood of differential settlements. This often results in the wall being founded below the current stream level. The flexible nature of the baskets means that they can withstand some differential movement and still remain fully functional.

Frictional and cohesive resistance along the base of the wall must be greater than the applied forces to resist sliding. A grid reinforcement system can also be used at the foundation level to increase sliding resistance.

The global stability of the wall design must be checked to ensure that the wall has a sufficient factor of safety against circular slip failures extending below the toe of the wall.

5.2 Detailing of Gabion Walls

In a stream the wall must also be detailed to resist:

- Scour beneath and at the ends of the wall
- Migration of fines from behind the wall
- Corrosion

There are two types of scour that must be allowed for in the design of gabion basket walls, the general scour caused by flow patterns in the stream and localised scour caused by the structure.

A hydrological assessment is required to assess flood levels and scour depths. In the case of Ohariu and Makara streams a scour depth of typically 1m has been assessed for design. To date gabion basket walls that have been embedded 1m below the existing streambed level, or 0.5m below streambed level where the toe of the wall has been protected by a reno mattress, have been found to be adequate in large flood events.

Abrupt changes at the upstream and downstream ends of the wall can generate areas of localised turbulence and scour. A survey is often needed to determine the alignment of the new wall. This allows the curvature of the stream and the desired carriageway width to be incorporated into the design. Scour at the ends of the walls can be minimised by angling the end gabions back into the bank to create a smoother transition.

Filter fabrics are important to limit the migration of fines from the material behind the structure.

Gabion walls in aggressive environments such as the coastal location of Makara Road need to be protected from corrosion. The wire used to manufacture the baskets can be galvanised and coated with PVC.

6. CONCLUSIONS

Takarau Gorge and Makara roads are subject to damage from stream erosion.

Following a major storm event failures of slopes and retaining structures occurred. These failures illustrate the importance of design and detailing in a stream environment.

Gabion basket walls have become the preferred solution to protect the carriageway from erosion. This is due to their flexibility and ability to accommodate settlement. If reno mattresses are also used the wall is further protected from scour of the toe. Good design practices should include a detailed investigation of the ground conditions, a stability assessment of the wall and detailing to allow for the stream environment.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. TerraLink Ltd, “MapWorld TopoMap NZ V2.0.61”, 2000.