CHAPTER 11. GEOTECHNICAL AND SLOPE STABILITY

11.1 INTRODUCTION

Geotechnical and stability related problems can occur on cut and fill slopes. These can be in the following forms:
- Subsidence resulting in slacks (depressions) in the road surface or differential movement at the interfaces between bridges and the road.
- Subsidence of fills due to poor compaction or overbuilding.
- Slip failures in the road prism, mainly in fills or in cuttings. Failure in the road usually occurs in the form of semi-circular open cracks close to the shoulder often with significant level differences. Progressive slips can result in dangerous conditions.
- Cut instability on steep cuts where loose rocks fall into the side drain or road or when significant quantities of cut material slide onto the road.
- Cut and fill erosion where cut slopes or embankment fill material is eroded by weather action (rain, wind and natural weathering) resulting in material falling into and blocking the side drain.
- Failure of lateral support ( gabions, retaining walls).
- Expansive, collapsing or failing soft soils which result in deformation of the road.

11.2 SLOPE MANAGEMENT SYSTEM

Because of the importance of managing cut and fill slopes, SANRAL has introduced a Slope Management System to address slope stability. The Management System comprises three steps:

Inventory
An inventory list of all cut or fill/embankment slopes higher than 5m, known problem slopes as well as all retaining structures (anchored cut faces, reinforced earth walls, gabion walls, concrete block retaining walls, etc) must be compiled. An example of an inventory list is contained in Appendix E.

The inventory list should contain the following information:
- Route and section details;
- Kilometre information at the start and end of each cut or fill/embankment and the side (L or R) of the road where these are located. GPS co-ordinates can be provided as well;
- The approximate maximum vertical height of the cut or fill;
- The approximate slope of the cut or fill in degrees or batter (horizontal to vertical);
- Brief details of known previous problems;
- Brief details of known historical remedial works;
Descriptions of existing retaining structures or lateral supports, even where these are less than 5m in height.

Slope Stability Monitoring Form
The Monitoring Form included in Appendix E must be completed and submitted for every significant stability-related incident occurring at any of the cuts, fills or laterally supported facility. The purposes of the form is to enable a record to be kept of the slope-related incident and the actions taken to identify and remedy the problems;

Maintenance Contract Feedback
The Route Manager must report on the condition of the slopes recorded on the inventory list on an annual basis or after heavy rains.

11.3 RESPONSE

Some of the problems such as subsidence in the road surface and cut erosion can be addressed using routine maintenance actions. All significant problems must be brought to the immediate attention of SANRAL, either through the completion and submission of the Slope Stability Monitoring Form where appropriate or by contacting SANRAL directly. Actions required immediately to address the problem must be agreed with SANRAL.

Because of the danger of progressive failure of slips, immediate action might be necessary which could include closing off an adequate portion of the road. Similar action should be taken where rockfalls occur which could block the road or cause damage to vehicles or people. As soon as the Route Manager becomes aware of such problems, he should arrange for the erection of suitable warning signs, contact the IMS Central Communication Centre (CCC) and the traffic police. On contracts where there is the potential for such incidents, the necessary signage should be kept on site for use when required.

11.4 SOIL/ROCK PROBLEMS

The failure of road embankments (fills), cuttings and lateral support can have severe consequences such as closure of the road, damage to property and injury or loss of life. By being aware of and monitoring the condition of problem areas the Route Manager can assist in ensuring that remedial actions are carried out in good time or, in disastrous circumstances, prevent damage, injury or loss of life.

Apparently stable slopes can become unstable for a variety of reasons. Failure can take place within hours or over a long period of months or even years. Little can be done to prevent failure triggered by events such as abnormal downpours, floods, natural disasters or burst water pipes. However, many failures can be
prevented by proactively maintaining and/or reinstating the upper catchwater drain along the crests of cuttings, by monitoring typical indicators of instability and where appropriate instigating remedial measures. The Route Manager needs to take the lead in these actions.

The Route Manager will have to exercise discretion as to whether observed signs require immediate reaction but he should as soon as possible in conjunction with SANRAL decide whether specialist assistance is required. The rate of change of certain signs such as crack widths and deformation can give a good idea of impending failure. Vegetation often plays an important role in stabilizing slopes and a number of failures have occurred after the removal of bushes and/or trees.

Photographs in conjunction with the SANRAL Slope Monitoring forms can provide a useful record and give an indication of change particularly over long periods. Most failures are either caused or accelerated by water. Therefore suspect areas should be checked after any unusual rainfall and at the start of each wet season.

The following are regarded as indicators of the development of possibly unstable conditions. Initially only one indicator may be observed. In general the more indicators that become visible, the more likely it is that failure will occur.

**Instability Indicators: Embankments**

- Longitudinal/semi-circular cracks with level differences. Particularly where level differences are large immediate action is necessary (see Active Cracks - Longitudinal Cracks in Chapter 8).
  **Action:**
  Seal the cracks immediately to prevent the ingress of water.
  Monitor the position, extent and direction of the cracks and displacement at suitable intervals. Should further movement or failure appear imminent particularly in wet weather such measurements could be at hourly intervals and would help to decide whether further or total road closure is necessary.

- Lateral and/or vertical displacement of guardrails, kerbs or road edge markings.
  **Action:**
  Note position, extent and direction of movement and monitor at suitable intervals. Check for cracking and/or displacement in the road surface.

- Circular depressions in the road surface or on the fill slopes indicating sinkhole development (chimneying) generally caused by void formation within or below the embankment.
  **Action:**
  Note position and size of depression, check for cracks, inspect toe of fill and any nearby drainage
structures for collapse or open joints. Monitor daily if the embankment is high and inform SANRAL immediately. Bulging of slope or displacement at the toe of the fill.

- Bulging of slope or displacement at the toe of the fill
  
  **Action:**
  
  Note position and extent and monitor to see if any enlargement occurs with time.

- Road surface heave or settlement indicating possible deep-seated foundation problems.
  
  **Action:**
  
  Note position and extent and monitor.

- Seepage out of the slope or at the toe (often shown by greener areas or reeds) especially where there is a regular (perennial) flow.
  
  **Action:**
  
  Note position, check for signs of movement such as cracks and bulging in the slope and also check the road pavement for signs of structural distress.

- Trees and shrubs that are not vertical indicating movement of the slope.
  
  **Action:**
  
  Note position and check slope for other signs of movement such as bulging, cracks and seepage.

- Culvert deformation or collapse and, in prefabricated culverts, open joints.
  
  **Action:**
  
  Note position and monitor. A collapsed culvert must be repaired as soon as possible to prevent stormwater causing further damage to the road structure.

**Instability Indicators: Cuttings**

- Boulders, rocks and soil in the side drain, at the base of protective nets and on the road surface.
  
  **Action:**
  
  Note the position and monitor the frequency and quantities of debris removed to determine the extent and severity of the problem. Where rocks and boulders fall directly onto the road surface SANRAL should be informed immediately. Warning signs should be erected and interim protective measures taken such as the erection of guardrails or gabion baskets, the deepening of side drains where they are unlined and the construction of a catchwater drain above the cut.

- Weathering debris blocking the side drain. Where harder rocks like sandstone overlie degradable rocks such as mudstones and shales there is a possibility of undercutting and toppling failure.
**Action:**
Note the position, evaluate the possibility of toppling and inform SANRAL if there is a likelihood of serious failure. Monitor these features on the cutting face. Keep a photographic record.

- **Tension cracks above or in the cut slope.**
  **Action:**
  Note the position, length and monitor daily if movement is taking place. Seal the cracks to prevent water getting in. Inform SANRAL.

- **Open joints in rock slopes.**
  **Action:**
  Note the position and width of joints. Monitor to determine whether the joints are opening further and check for signs of seepage and fines being washed out. Assess whether there is any danger of sliding or falling rock as a result of the cracks and if this is likely inform the road authority.

- **Trees and shrubs that are not vertical indicating movement of the slope.**
  **Action:**
  Note position and check for other signs of slope movement including tension cracks and bulging.

- **Bulging or toe kick often accompanied by seepage.**
  **Action:**
  Note position, extent and check for other signs of movement such as tension cracks. Monitor and if movement continues or accelerates inform the road authority immediately.

- **Seepage, especially if high flows of water are noted at specific locations (as opposed to widespread seepage along the toe).**
  **Action:**
  Note the position and describe flow. Check for open tension cracks, depressions where ponding can take place (eg blocked catchwater drain) or where piping is evident. Monitor the position for any deterioration.

- **Erosion concentrating water flow and wetting up of the slope.**
  **Action:**
  As soon as possible take preventative action such as constructing an additional catchwater drain, repairing the drain and reinstating the eroded area with vegetation or gabions.

**Instability Indicators: Lateral Support**
Lateral support to road embankments and cuttings can be provided by several means. Because of the consequences of failure of lateral support systems, if there is any indication of a problem SANRAL should be informed immediately. Indicators of distress for the common forms of lateral support are:

- **Gabion retaining walls - displacement, deformation or corrosion and collapse.**
  **Action:**
  Note position and describe condition.
- Concrete retaining walls - bulging, tilting, cracking or damage.  
  **Action:**  
  Note position and describe condition.

- Proprietary block walls - bulging/movement.  
  **Action:**  
  Note position and describe condition.

- Anchored slopes and walls - corrosion or damage to anchor heads or thrust plates.  
  **Action:**  
  Note position and describe condition.

Cut face being stabilised