Chapter 2

AN INTRODUCTION TO TYPES OF VEGETATED SLOPES

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Abstract: *Many different types of natural and artificial slopes exist throughout the world, those that have the potential and suitability for stabilizing by vegetation include earthworks on transport infrastructure, forested and agricultural slopes. This chapter introduces the reader to the different types of natural and artificial slopes and breifly discusses the potential for stabilizing each type of slope with vegetation.*

Key words: earthworks, embankments, cut-slopes, terraces, vegetation

1. INTRODUCTION

Slopes are common features of the world around us, whether they are of a geological, geomorphological or human origin. In most instances, slopes are naturally unstable unless they have been stabilized through geological time. Unstable slopes create numerous management and engineering issues as we try to maintain order and prevent slope failures from affecting our transport infrastructure, leisure activities and human life. It is hoped that by careful planning and consideration, vegetation, as an ecotechnological solution, can assist in preventing slope failures. Different types of natural and artificial slopes exist (Figure 2.1), and those which are suitable for stabilizing by vegetation include earthworks on transport infrastructure, forested and agricultural slopes (Figure 2.2). The potential for stabilizing each type of slope with vegetation is discussed below.

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2. NATURAL SLOPES

Natural slopes (Figure 2.2) are formed usually over long periods of time, through many geological and geomorphological processes, e.g., mountain building, glacial activity, tidal and river activity. These slopes are only stable if the soil has sufficient strength to resist the gravitational forces on the potential sliding mass. Changes in pore water pressure conditions, slope geometry or engineering works may cause these natural slopes to fail (see Chapter 3). Failure planes are e.g., rotational, translational or complex, and occur at varying depths according to the different ground conditions present.

Vegetation is unlikely to have a significant impact on slope stability where slip planes are deep-seated, due to the shallow rooting nature of many species. However, vegetation may protect the ground surface from erosion by wind and water and prevent erosion at the toe of slopes where the slope is being undercut by wave action in water courses. The stability of the toe of a slope, stabilized by vegetation, may be sufficient to maintain the stability of the slope as a whole (Coppin and Richards 1990; Gray and Sotir 1996).

Hillsides and valley slopes in rural areas are commonly planted with woodlands and managed forests. In these particular areas, individual tree instability due to storms and gales (see Chapter 5), rockfall (see Chapter 7)

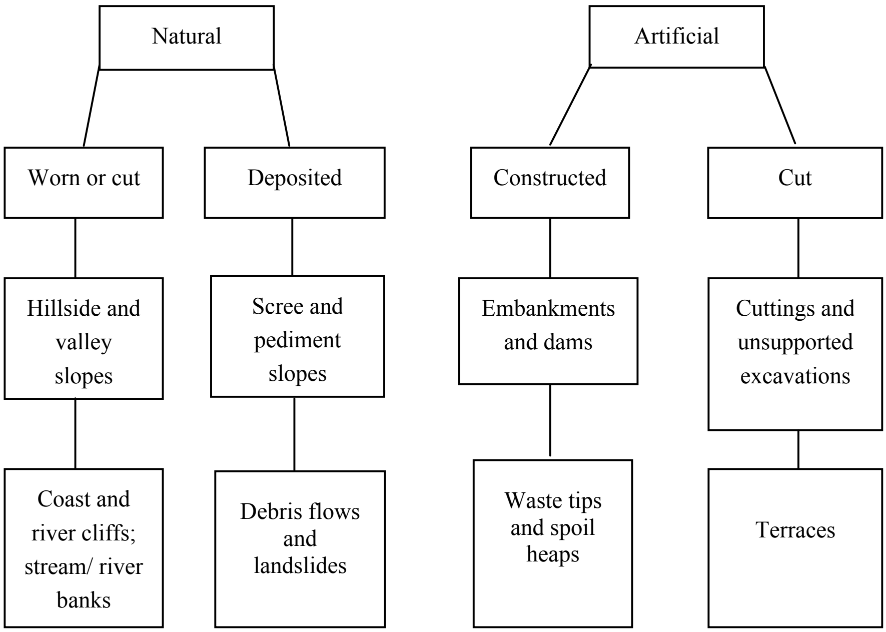

Figure 2-1. Different types of natural and artificial slopes (after Whitlow 2000).

Earthworks on transport infrastructure - railway embankment (Photo: J.E. Norris)

Highway cut-slope (Photo: J.E. Norris)

Forested slope (Photo: M. Genet)

Natural slope (Photo: L.H. Cammeraat)

Terraced slopes (Photo: Y. Chen)

Abandoned bench terrace (Photo: R. van Beek)

Figure 2-2. Examples of artificial and natural slopes.

or debris flows may be more of a problem than slope stability. Deforestation and wildfires on these types of slopes may also lead to increased soil erosion.

Many drainage channels exist on hillslopes and in valleys. The streams and rivers that meander and flow down these slopes may undercut the hillslopes and cause bank instability. Ground bio-engineering is an accepted engineering technique for stabilizing bank erosion and instability caused by fast flowing water, and as such is not specifically covered in this book. The reader is therefore referred to published texts for advice on river bank stability (e.g., Schiechtl 1980; Gray and Sotir 1996; Schiechtl and Stern 1996, 2000).

Eco-engineering methods are particularly suited to natural slopes, where management is generally long-term and the site is large-scale.

3. ARTIFICIAL SLOPES OR EARTHWORKS

Artificial slopes or earthworks are either cut into natural rock or soil or built up to form embankments, dams, waste tips or spoil heaps. Vegetation could be used for stabilizing cut slopes in soil, soil embankments, waste tips, spoil heaps and terraced slopes. It is less likely to be of value in dams where engineering stability is critical and vegetation could affect soil permeability. Ground bioengineering methods are commonly used on artificial and terraced slopes, as this fast and effective solution can be considered during slope construction and remediation.

3.1 Embankments

Embankments typically occur along highways, railways and canals (Figure 2.2) and are made from materials such as soil or rock excavated from elsewhere and placed on natural ground. The changes in condition of these materials with time and rate of deformation have critical influences on the safe and efficient operation of the transport system. Embankment stability is dependent on soil material; presence of water; shrink and swell cycles induced by seasonal moisture changes and vegetation; slope geometry, angle and height; construction method and type of foundation, and age. External factors such as vandalism, erosion and burrowing animals can cause loss of embankment performance (Perry et al. 2003a).

Slope failure can either be in the form of small-scale shallow translational slides, where the failure is contained entirely within the embankment side slopes and maximum depth of rupture does not exceed 2.0 m, or deep rotational slips that run from the crest through the embankment to the underlying foundation material to emerge beyond the toe. The type of slope failure is different for each transport sector due to the variation in construction methods, soil materials, drainage provision and function. Slope failure in embankments during and after construction is sometimes associated with the interface between the natural ground and the fill material. Pore water pressures and seepage within the embankment and natural ground may exacerbate slope failures. Where the original topsoil was left in place, a potential rupture surface may be formed (Coppin and Richards 1990; Greenwood et al. 2001; Perry et al. 2003a).

A suitable combination of vegetation types, e.g., shrubs and trees, and ground bio-engineering solutions, e.g., willow poles, can help to stabilize embankments that may be prone to the shallow translational slide failure (Coppin and Richards 1990; MacNeil et al. 2001; Marriott et al. 2001; Operstein and Frydman 2000; Steele et al. 2004; Norris 2005). Vegetation may help to stabilise the toe of deeper slips but generally deep rotational slips at depths greater than 2.0-3.0 m would be out of the zone of influence of many tree roots. For deep-seated slides, a combination of geosynthetics and vegetation may be more appropriate.

3.2 Cut-slopes and cuttings

Infrastructure cuttings and cut-slopes (Figure 2.2) are excavations in existing ground with side slopes and a trafficked surface, providing passage for road, rail and canal traffic across natural ground to maintain vertical alignment. The change in condition of the soils with time and the rate of deformation of the cutting again affect the safe and efficient use of the transport corridor (MacNeil et al. 2001; Marriott et al. 2001; Perry et al. 2003b).

The stability of a cut-slope can be affected by a reduction in the strength or stiffness of the soil through which the cut is made; a change in the external disturbing static and dynamic forces acting on the soil structure; change in geometry and the presence of water. Slope failures on cut-slopes occur in a similar manner to failures on embankments, therefore, the application of vegetation on cut slopes may be applied in the same way as for embankments, i.e., by using a combination of vegetation types to intercept shallow translational failures and by placing vegetation at the toe of slopes.

3.3 Terraces

Terraced slopes (Figure 2.2) are common features in many parts of Asia (Storey 2002) as well as Mediterranean regions, built to conserve soil and water on steep slopes for a variety of agricultural uses. However, if traditional methods are used but not implemented correctly through lack of training, care or resources, soil loss can be rapidly increased. For example, if hill terraces for the cultivation of crops are poorly constructed or maintained, topsoil erosion and slope instability will be exacerbated through water collecting on oversteepened terraces (Sidle et al. 2006). If the terraces collapse, breaches will focus surface runoff leading to gully formation and increased sediment transport downslope (McConchie and Ma 2002). Furthermore, changes in agricultural practice have led to wide scale abandonment of terraced slopes. Abandonment of terraces can result in the loss of vegetation and root reinforcement thus leading to an increase in the rate of soil erosion (Goudie 2000; Cammeraat et al. 2005; van Beek et al. 2005).

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