6 COLLIERY SPOIL HEAP STABILITY

Chapter contents

6 COLLIERY SPOIL HEAP STABILITY

6.1 Introduction

The characteristics of existing colliery spoil heaps vary widely depending on the nature of the spoil and the method of deposition (see Chapter 5). Old tips were generally formed in an uncontrolled manner by loose tipping, often by mechanical means. The tips so produced were conical or irregular in shape with a high profile in relation to the local topography.

Little attention was paid to the subject of tip stability until tip failures began to occur. Most tip failures resulted from errors in design, construction and operation or from poor maintenance. Often failures resulted from action being taken without recognition of the dangers involved. High moisture contents or water seepage are associated with most failures in spoil heaps and lagoon banks.

The problem of tip stability was brought into focus by the disaster at Aberfan, South Wales, UK in 1966 when a serious flowslide occurred and thousands of tonnes of liquified spoil swept down the mountainside into the village below killing 144 people[5, 158] (see Photograph 1.1). The events at Aberfan led to the introduction of the Mines and Quarries (Tips) Act, 1969, and the more detailed Mines and Quarries (Tips) Regulations, 1971, which now govern the design, construction and management of tips in the United Kingdom. A considerable amount of work was carried out by the United Kingdom National Coal Board following the Aberfan disaster and a technical handbook was produced[169] which is the source of some of the information in this chapter.

After Aberfan the stability of many tips was investigated and where necessary precautionary or remedial works were carried out. These measures usually involved regrading slopes and improving drainage.

With new tips, where modern engineering and management practices have been introduced, the likelihood of these tips becoming unstable has been virtually eliminated.

Where sites are being reclaimed or redeveloped, it is therefore important to investigate any tips which are to remain and establish whether or not an adequate factor of safety exists against failure, and whether any remedial measures are necessary to ensure long-term stability.

The main responsibility for the design, construction and management of tips lies with engineers, and many fields of expertise in addition to civil engineering are called upon, such as soil mechanics, geology, hydrogeology and hydrology. In addition, since the long-term behaviour of earth structures can be influenced by the vegetation which they support, disciplines other than engineering, such as soil science, ecology and horticulture, need to be involved. However it is essential that practical experience is also taken into account. The design and construction of large scale earth structures is not an exact science and the interpretation of local conditions, an understanding of which is vitally important to the successful completion of any project, must be given full regard.

6.2 Spoil and tip characteristics

The effect of the mechanisation of mining and spoil deposition methods on spoil heap characteristics is described in Section 5.1.

The various methods of tip construction and the characteristics of these methods are discussed in Box 6.1. Typical tip configurations for older tips are shown in Figure 13.1.

Box 6.1: Common tipping methods

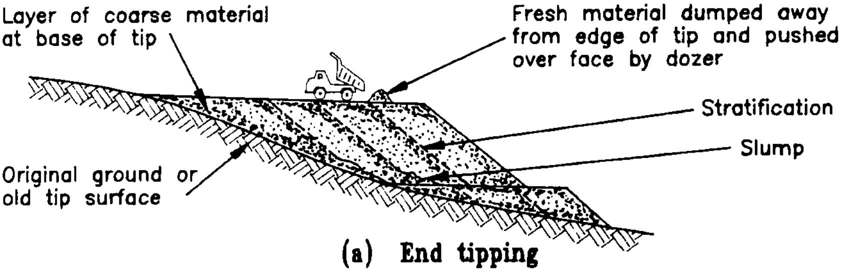
Dry materials end tipped over high faces.
Where tips are formed of dry material tipped over high faces, the slopes generally form at the angle of shearing resistance of the loose material *i.e.* at the angle of repose (see Figures 6.1(a) and 6.1(c)). The water table in the tip is generally low or absent, except where the tips have been built over springs or where surface water is allowed to flow into the tip. Many tips in this category are partially or completely burnt.

Wet material tipped over high faces.
Where heaped tips are formed of wet materials such as washery discards, the slopes formed are generally irregular with the upper parts of the slopes steeper than the lower parts. Periodic slumping may occur leaving steep slopes near the crest of the heap and shallower slopes considerably less than the angle of shearing resistance near the base. The wet material in the shallower slopes may be subject to prolonged creep and bulging. Perched water tables are often found within these tips with localised seepages emerging from the lower slopes. Many tips of this type are partially-burnt, but generally to a lesser extent than dry tips.

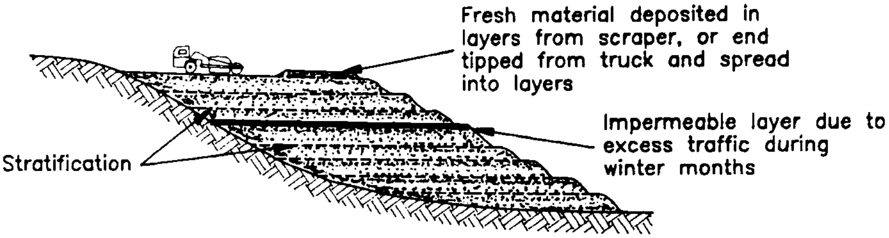
Thick layer tips.
Where a tip has been formed of dry materials placed in thick layers, each layer will have similar characteristics to those described above for end tipped dry material. With wet material slumping may occur. In general the wetter and more clayey the material and the thicker the layer, the greater the probability that slumping will have occurred. Stratification usually takes place, and perched water tables often occur at the junctions between the layers (see Figure 6.1(b)). In addition, some such tips may have been subject to combustion.

Thin layer tips.
More recent construction practice is to place material in layers approximately 300mm thick and compact the material either randomly using construction plant or systematically using rollers. The side slopes are usually formed to less than the angle of shearing resistance of the tip material. Such tips are less permeable than tips of the same material built by other methods, and the water table is slower to respond to changing weather conditions. Tips of this type are not liable to spontaneous combustion.

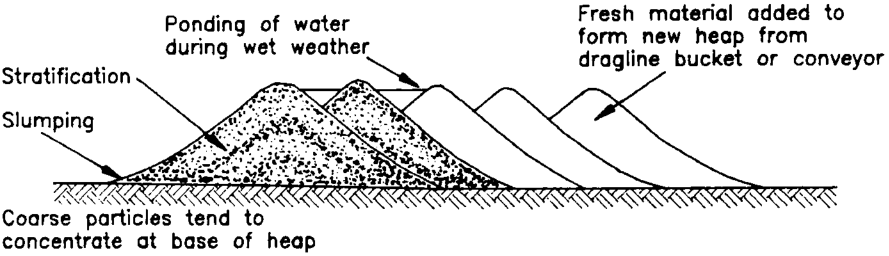
Lagoon banks.
Most old lagoon banks were built by thick layer tipping with steep outside slopes approaching the angle of shearing resistance of the tip material. Heightening of the banks was often carried out 'fir tree fashion' by an additional bank of spoil placed partly on the existing bank and partly on the lagoon deposit (see Figure 6.1(d)). Perched water tables often occur at each of the layers, and seepage may emerge on the outside slope of the bank. Recently built lagoon banks are generally of coarse discard placed in thin compacted layers with outside slope gradients of less than 1 in 2. Drainage provisions within or below the banks prevent seepage water from the lagoon deposits emerging on the outside slopes.



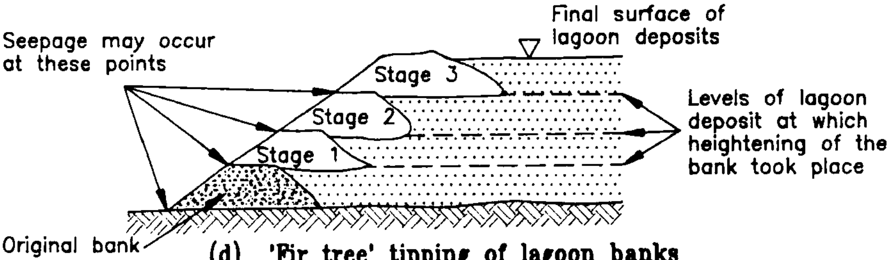
(a) End tipping



(b) Layered tipping



(c) Heaped tipping



(d) 'Fir tree' tipping of lagoon banks (may be subject to instability)

Figure 6.1: Some examples of construction methods for tips and lagoons (after Geoffrey Walton Practice, 1991[100] redrawn with the permission of the Controller of HMSO)

6.3 Factors affecting stability

Although the tip may appear stable this should not be taken to indicate that the tip has an adequate factor of safety against failure and will therefore remain stable. The factor of safety is the ratio of the disturbing forces over the resisting forces. Existing tips originally formed by tipping over high faces but which stand with slopes less than about 20° (1 in 2.75) are likely to have been unstable at some time in the past, and may still be unstable.

A number of factors may serve to reduce the stability of an existing tip by increasing the disturbing forces or reducing the resisting forces present in the tip or its foundations (see Box 6.2). Water in the tip can adversely affect stability in a number of ways, as follows:

- by reducing the strength of the material in the tip or the material on which the tip is founded;
- by increasing the weight of tip material thereby providing additional disturbing forces;
- by generating water pressures in the tip thereby reducing the effective shear strength of the tip material;
- by generating seepage pressures leading to piping (internal erosion; see Box 6.2).

6.4 Modes of tip failure

6.4.1 Introduction

The main types of slope failure in spoil tips and lagoon banks are shown in Figure 6.2 and are discussed in the following sections along with other more localised failure modes.[100]

Box 6.2: Factors which may cause a reduction in tip stability

Additional loading on the top edge of a slope by further tipping, vehicle loading or water seepage into the tip;

Steepening of the slope due to excavation, or erosion due to uncontrolled drainage. Mining subsidence beneath the toe of the slope could also lead to marginal slopes becoming unstable;

Removal of support at the toe of the slope by excavation or water erosion. Wave action in a lagoon may cause undercutting of a bank;

Increase in water level (pore pressure) within the tip or its foundation leading to a reduction of effective shearing resistance along potential failure surfaces. This may occur due to surface water seepage, lack of drainage provisions for springs, seepage from lagoon deposits, blocked culverts, or due to the effect of mining subsidence. Freezing of the surface of a slope may also lead to a build up of seepage water;

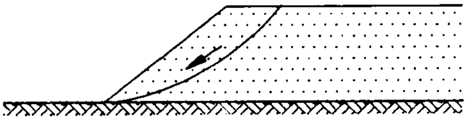
Disturbance of the tip or its foundations which may reduce effective stresses between particles with a consequent rise in pore pressure. Sudden disturbances may be caused by: vibration e.g. from blasting or pile driving, mining subsidence, impact loading from tipping, or the effect of slippage in an adjacent part of the tip;

Piping, which is internal erosion within the tip due to the passage of water, thereby forming voids and reducing stability;

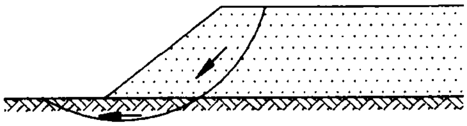
Softening or swelling due to the effects of water seepage or ponding may lead to a localised reduction in stability, and any resulting slippage could affect the overall stability of any adjacent tip or its foundations;

Rapid drawdown by the removal of wet deposits or water retained within a lagoon may lead to a rotational slippage of the lagoon bank;

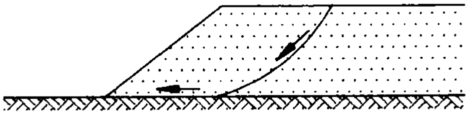
Spoil heap combustion may cause the formation of voids which could result in a localised collapse, although sometimes burning may improve stability by an increase in the shear strength or by the fusing of spoil material.



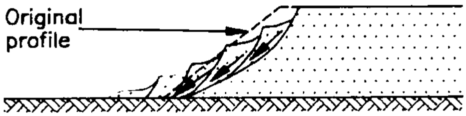
(a) Circular failure in cohesive spoil



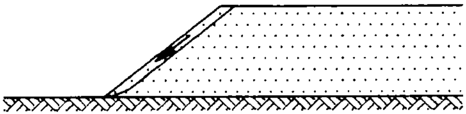
(b) Spiral failure through spoil and foundation



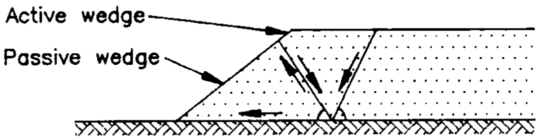
(c) Curvilinear failure controlled by sliding on weak planar surface at tip/foundation interface



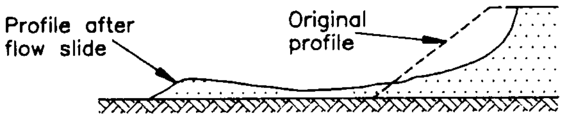
(d) Multiple rotational failures in oversteep weak material



(e) Surface sliding in granular materials



(f) Biplanar failure controlled by base of spoil or top of foundation stratum



(g) Flow slide in silty saturated weak material

Figure 6.2: Modes of tip failure (after Geoffrey Walton Practice (1991),[100] redrawn with the permission of the Controller of HMSO)

6.4.2 Rotational slips

In rotational slips, movement takes the form of rotation about an axis which is generally outside the slope itself. The shape of the failure surface varies depending on the characteristics of the material in the tip (see Figures 6.2(a) to 6.2(d)). The first sign of slippage is usually a tension crack in the spoil above the failure surface, sometimes accompanied by slumping of the spoil in front of the crack (see Photograph 6.1). The rate of failure is generally relatively slow *i.e.* developing over a period of hours to days.

6.4.3 Surface slips

For surface slips the failure surface is parallel to the front face of the tip (see Figure 6.2(e)). Such slides generally take place in dry, cohesionless, granular material tipped at or above the angle of repose, and may occur as the surface layer dries out and any temporary cohesion is lost. Surface

Photograph 6.1: Example of a rotational slip failure (source: I.G. Brown)

slips may also occur where the strength of the surface layer has been reduced by weathering or water action, or following the removal of the toe of the tip by excavation or erosion.

6.4.4 Biplanar slips

Biplanar slips involve shearing along two planes of differing orientation, with the formation of an upper active wedge of material and a lower passive wedge (see Figure 6.2(f)). The upper wedge displaces the lower wedge and shearing occurs at the tip foundation. Such failures are common in tips where the foundation material is soft and weak.

6.4.5 Flow slides

Flow slides occur when the soil mass in transformed into a liquified state as a result of disturbance following saturation. Disturbance may occur due to rotational failure, mining subsidence or vibration from earthquakes, blasting or heavy plant, Collapse of the soil structure takes place, but closer packing of the grains of spoil material is prevented by the viscosity of the water, and liquefaction occurs allowing the spoil to flow downhill as a slurry. Flow slides typically occur in poorly compacted or saturated spoil heaps consisting of sand or silt sized material, and are a common failure mode in lagoon materials following breaching of the lagoon bank. Flow slides occur rapidly and material can travel significant distances.

6.4.6 Piping failure

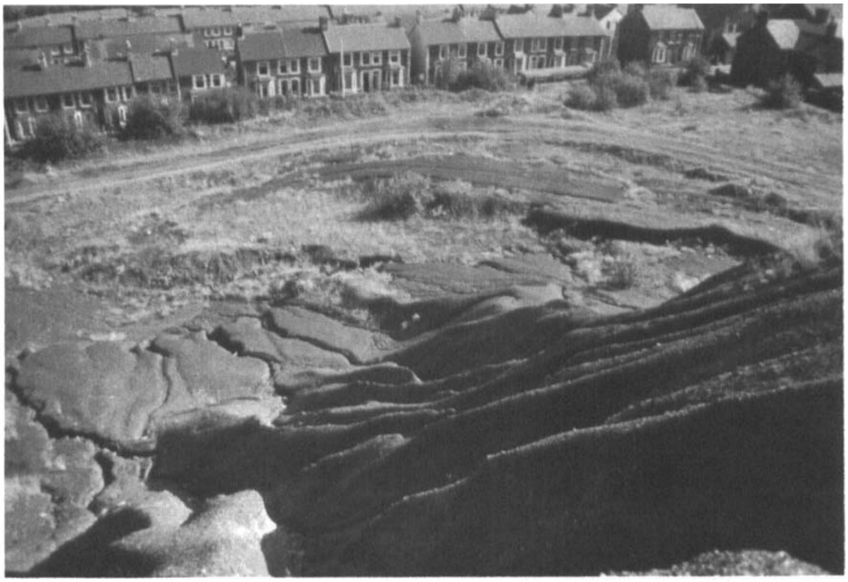
Piping is a localised failure caused by internal erosion within the tip as soil particles are washed out by the passage of water. Collapse due to piping may sometimes trigger other forms of failure.

6.4.7 Cavitation collapse

This is a localised collapse of underground voids resulting from events such as piping, collapsed culverts or underground combustion. General tip stability is not usually affected, except sometimes for lagoon embankments, although sudden collapse may be a source of danger to persons at the surface.

6.4.8 Mud runs

A mud run is a localised failure caused by a rapidly moving flow of water-borne soil having the consistency of mud. This is brought about following heavy rainfall by flows or issues of water eroding gulleys in the side slopes and forming mud runs at the base of the tip (see Photograph 6.2).



Photograph 6.2: Example of water erosion forming surface gulleys (source: Welsh Development Agency)

6.4.9 Settlement and heave

Settlement and heave may occur to varying degrees within different parts of a tip, sometimes giving rise to differential movement.

Settlement occurs as a result of loading due to self weight or imposed loads. Collapse settlement may sometimes occur as a result of a reduction in strength of a material following saturation.

Heave may take place for a variety of reasons, such as:

- rotational failure;
- shear failure of weak material in the tip foundations;
- upward seepage pressures;
- following removal of surcharge loading *e.g.* when a tip is removed;
- chemical changes of the tip materials;
- the action of frost;
- rehydration of desiccated clay *e.g.* following the removal of trees.

6.5 Investigation and stability analysis

6.5.1 Introduction

Stability analysis plays an important part in the process of reviewing tip stability, particularly in situations where conditions affecting the tip are to be altered, or have already been altered. The investigation and stability analysis should be carried out by specialist engineering or geotechnical consultants with experience of slope stability problems.

Investigation and assessment of slope stability is discussed in the following sections.

Investigations will be required on an existing tip if:

- the appearance of the tip suggests that failure might occur, thus endangering persons or property;
- an existing tip, although appearing stable, by its size or situation constitutes a significant threat to the safety of persons or property;
- works are to be carried out on or in close proximity to an existing tip which may have an adverse effect on the stability;
- there is serious public concern that a tip may constitute a threat to persons or property.

The extent of the investigations carried out should also take into account the possible secondary consequences of a failure, such as:

- possible blockage of an adjacent watercourse leading to a sudden failure and release of water;
- possible displacement of lagoon deposits leading to overtopping (*i.e.* overflowing) and erosion of the lagoon bank with consequent failure;
- possible disruption of nearby water mains leading to a release of water which could accentuate the failure;
- possible impact of material from a rotational slip in the upper parts of a tip slope leading to liquefaction and flowslide failure in the lower part of the tip.

6.5.2 Initial assessment

An initial assessment should be carried out based on a walk-over survey and desk study (see Section 2.3) to establish the geological structure, geomorphology and any historical events influencing stability. The following information should be sought:

- the nature of the site before the tip was built, particularly with regard to original watercourses, drains, culverts and any history of previous tipping or opencast workings;
- the nature of the materials tipped and their location within the tip, particularly fine-grained materials such as tailings. Fine-grained residues present in buried lagoons or as areas of dumped materials could lead to the formation of a zone of weakness;
- the stages of construction of the tip and its varying shape and size in order to allow the identification of weathered surfaces, surfaces of low permeability, boundaries between different tip materials and areas where segregation may have occurred;
- the methods of deposition of material within the tip which may provide guidance as to the density, relative permeability and homogeneity of the tip materials;
- the presence of any zones or surfaces of weakness within the tip or its foundations deduced from knowledge or records of past problems or failures on the tip;
- the positions of all water mains and their control valves.

6.5.3 Other relevant information

Other important information to be established and taken into consideration in assessing tip stability is outlined in the following sub-sections.

Topographical details

Survey plans and sections of the tip will be required to show the site and its surroundings: before tipping was started, during the development of the tip, and at the time of the site investigation. These plans and sections will be used to complement studies of the geology, hydrogeology, rainfall and hydrology, and in compiling a history of tipping. The plans and sections will also provide information to be used in the stability analysis.

Subsidence plans

Plans of all past and proposed mining which might adversely affect tip stability should be prepared to show the cumulative effects of past and future extraction.

Geology

A study should be made of the geology and geomorphology of the tipping site. This should include details of the nature and distribution of all superficial deposits as well as details of dip and characteristics of the solid strata below the site.

Hydrogeology

An assessment should be made of the hydrogeological conditions, particularly with regard to the possible formation of springs or artesian pressures which might influence tip stability. The effects of mining subsidence on the hydrogeology should also be considered.

Ground movements

Consideration should be given to evidence of any ground movements in the natural ground beneath the tip due to rotational slips, creep, rock slides, cracks and fissures, or erosion by flowing water.

Rainfall and hydrology

Data on the rainfall and hydrological conditions should be collected. This will be necessary for the design of drainage systems. Information may also be required for the stability analysis with regard to fluctuating water levels in the tip or its foundations.

Site investigations

Subsurface exploration should be carried out using trial pits, trenches or boreholes (see Section 2.5). Boreholes should extend through all strata likely to have an influence on the stability of the tip, and will normally be carried down to bedrock. At least three boreholes, but preferably more, will be required to provide sufficient information for the stability analysis; one borehole at the toe of the slope, one mid way up, and one close to the crest of the slope. All boreholes should be sealed by grouting after sampling.

If groundwater levels and pore pressures need to be monitored over a period of time at various levels within the tip and its foundations, piezometers should be installed.

An assessment should be made of the shear strength of the tip materials based on *in situ* and laboratory testing of representative samples.

6.5.4 Stability analysis

Stability analysis must be undertaken systematically, and will involve the following activities:

- establishing the geometry of the structure to be analysed;
- collecting relevant input data for the analysis;
- assessing the likely mode or modes of failure;
- estimating security using slope stability analysis to calculate the factor of safety against failure.

Geometry

Most common methods of slope stability analysis are two dimensional and are based on the slope cross section. Critical cross sections should therefore be established from the topographical survey information.

Input data

The relevant input data should be based on the information discussed in Section 6.5.3. The shear strengths of the materials in or beneath the tip should be obtained from:

- laboratory testing of representative samples;
- *in situ* testing;
- empirical strength relationships;
- experience based on previous test results and published values;
- past analyses of previous failures.

Mode of failure

The most critical modes of failure should be considered. Modes of failure are discussed in Section 6.4.

Slope stability analysis

Slope stability analysis is normally carried out by computer program on an iterative basis using one of a number of design methods which are available.[100] Factors of safety can be calculated for various situations, and the most critical factor of safety should be established by varying the following parameters as appropriate depending on the circumstances:

- mode of failure;
- range of failure surface geometries;
- geometry of the tip *i.e.* height, slope angle, foundation gradient;
- water table;
- shear strengths of the tip materials and tip foundations.

Minimum acceptable factors of safety are shown in Box 6.3.

6.6 Remedial measures on existing tips

6.6.1 Introduction

Remedial measures on existing tips can be categorised under the following headings:[169]

- precautionary work;
- remedial work;
- maintenance.

6.6.2 Precautionary work

Precautionary work is required where stability analysis indicates that a tip may become unstable, or where features observed on site suggest a failure may occur. Precautionary measures may also be required in the following circumstances:

- to counteract the adverse effect on a tip due to external influences *e.g.* regrading a slope, or constructing a berm at the toe of a tip to counteract the effect of subsidence from proposed mine workings;
- to reduce risks where it is suspected that a failure may occur *e.g.* by closing roads in the vicinity, or by evacuating nearby property;
- to reduce risks where failure is not expected but where a tip or lagoon presents a risk to persons or property *e.g.* regrading a large steeply sloping tip located near houses.

Box 6.3: Minimum factors of safety suggested for tip design (after Geoffrey Walton Practice, 1991[100])

Design criteria	**Factors of safety**	
	Case 1	**Case 2**
Design based on peak shear strength parameters	1.5	1.3
Design based on residual shear strength parameters	1.3	1.2
Tip designed to appropriate strength parameters and subject to seismic or other ground accelerations	1.2	1.15

$$\text{Factor of safety} = \frac{\text{Resisting forces}}{\text{Disturbing forces}}$$

Case 1: applies where persons or property may be at risk

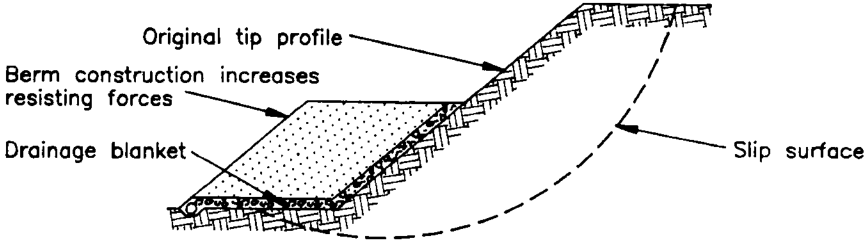
Case 2: applies where persons or property would not be endangered by failure.

Note: These factors of safety are given for guidance only. Higher or lower factors of safety may be appropriate depending on the adequacy and reliability of the input data and design assumptions.

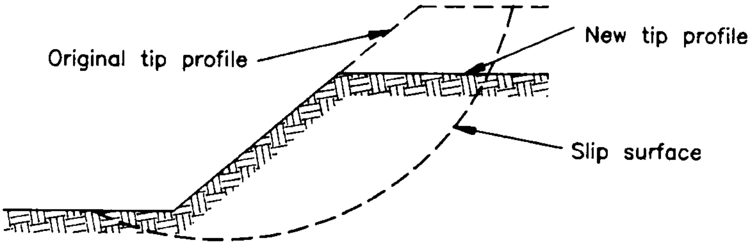
6.6.3 Remedial works

Remedial work is required where slippage has occurred or where movement of the tip indicates that it is unstable. Depending on the circumstances, the following precautionary or remedial works may be carried out to increase or restore stability:

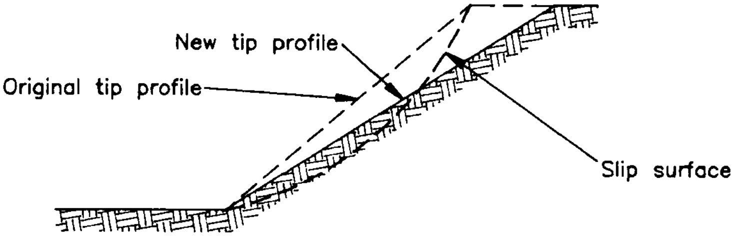
- construction of a berm one third or half way up the slope to increase the resisting forces (see Figure 6.3(a));



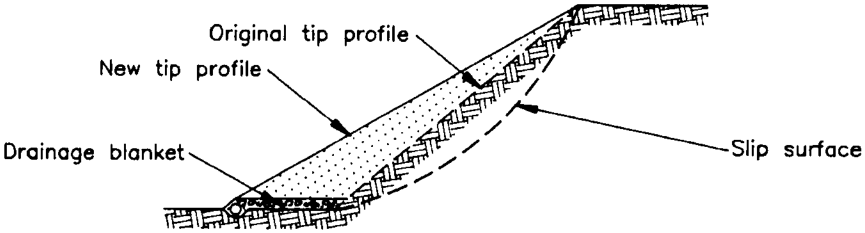
**(a) Construction of a berm
(effective for deep-seated forms of instability)**



**(b) Reducing the height
(effective for deep-seated forms of instability)**



**(c) Reducing the slope by cutting
(effective for shallow forms of instability)**



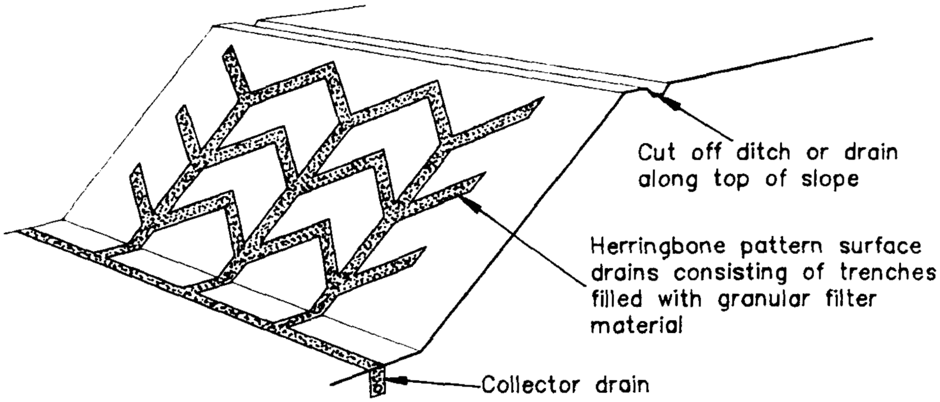
**(d) Reducing the slope by filling
(effective for shallow forms of instability)**

Figure 6.3: Methods of improving the stability of spoil heaps (after National Coal Board, 1970[169])

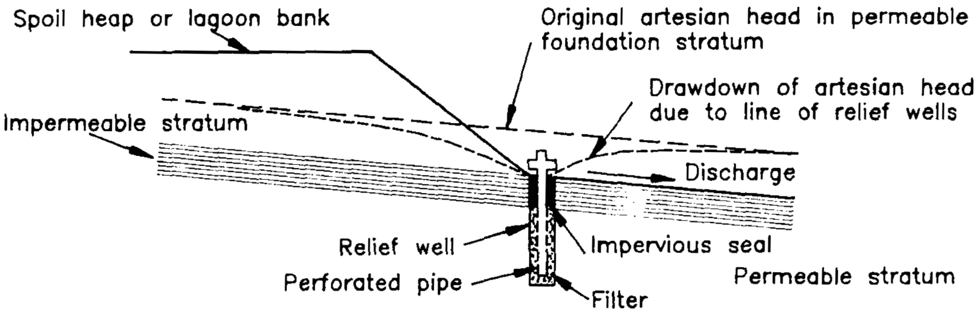
- reduction of the height of the tip (see Figure 6.3(b));
- flattening of the slope to reduce the disturbing forces (see Figure 6.3(c));
- reducing the gradient of a slope by introducing new material (see Figure 6.3(d));
- lowering the water table in the tip by improving the existing drainage system or by installing a deep drainage system using relief wells or bored filter drains (see Figure 6.4);
- construction of a retaining wall, or the installation of sheet piling at the toe of the tip. For sheet piling, consideration should be given to the possible adverse effects of pile driving on tip stability;
- preventing surface erosion through the use of vegetation (see Section 13.6.4).

The remedial work should be designed so that during construction there is a progressive increase in stability. Any work involving changes to existing conditions should be carefully designed to avoid adverse secondary effects occurring. The following aspects should be considered:

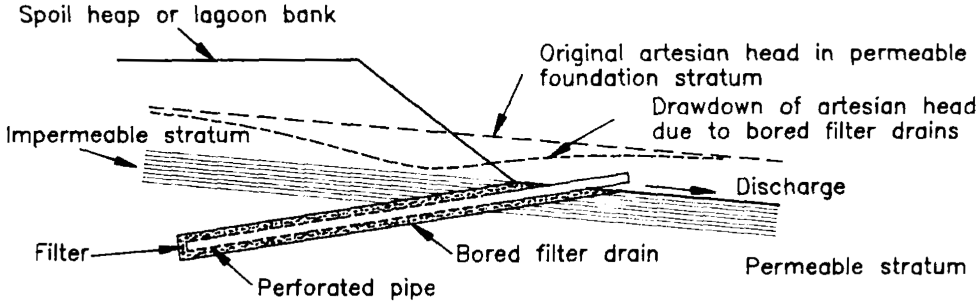
- erosion which might follow the disturbance of existing vegetation or a mature weathered surface;
- instability which might arise from the exposure of buried lagoons or other weak zones during regrading;
- reduction in stability which might arise from an inappropriate sequence of earthmoving operations, from incorrect siting of drainage works, or from an incorrect choice of earthmoving plant or procedures;
- the starting of a fire or the encouragement of burning;
- the proper collection of running or standing water and its continuous removal prior to earthmoving operations;
- the long-term effectiveness of any previous remedial work such as emergency drainage works;
- further instability caused by the deterioration and collapse of steep scarps remaining after a slip.



(a) Surface drainage system



(b) Deep drainage using relief wells



(c) Deep drainage using bored filter drains

Figure 6.4: Improving slope stability by shallow and deep drainage (after National Coal Board, 1970[169])

6.6.4 Maintenance

The need for maintenance

Maintenance work is required on all tips whether they are active or disused. Any features of concern noted during inspection or maintenance should be reported in writing to the responsible authority so that a re-appraisal can be made of the stability of the tip. The following subsections discuss items which require maintenance.

Drainage system

Maintenance of the drainage systems should be carried out at periodic intervals, and particularly after heavy rain, to prevent the unnecessary entry of water into the tip. Such work will include:

- the clearance of vegetation, spoil and refuse from screens, settlement ponds and ditches;
- rodding pipes to remove sediment;
- cleaning silt traps;
- cleaning of drainage inlets and outlets;
- diverting any flow or accumulation of water into the permanent drainage system;
- maintenance of filters and settlement ponds particularly where river pollution may be a problem.

Lagoons

Maintaining lagoons can involve the adjustment of inlet and draw-off or overflow arrangements, the clearance of any blockages, and the rectification of any undercutting due to wave action. Where lagoons have become redundant but have not been filled, the draw-off or overflow arrangements should be maintained so as to control accumulation of water which may occur in the future. A specific programme should be prepared for the infilling/abandonment of any disused lagoons and other features.

Haul roads

Haul roads remaining in use may require periodic regrading and repair. Drains and culverts should also be inspected and maintained in good order to avoid flooding.

Vegetation

Existing vegetation should be maintained in a healthy condition. Grass should be controlled by cutting or grazing, which also acts as a useful precaution against damage caused by burning.

6.7 Construction methods for new tips and the reshaping of existing tips

6.7.1 Design requirements

Design requirements for reshaping existing tips are similar to those for new spoil heaps and lagoon banks and are likely to include consideration of the following items:[100]

- site investigation (including a desk study of available data);
- stability analysis;
- calculation of volumes;
- design of surface and subsurface drainage measures;
- selection of earthworks equipment;
- specification of tipping rules and details of construction.

Additional requirements for lagoons and attenuation ponds should include:

- determination of required lagoon area and capacity;
- design of an efficient surface drainage network for the site;
- specification of inflow, outflow and emergency outflow arrangements.

6.7.2 Method of placing spoil

Spoil should be placed in heaps on lagoon banks in a controlled manner in accordance with good earthworks practice such as that set out in Box 6.4.

6.7.3 Tip geometry

Safe slope gradients for spoil materials and for terracing of slopes should be determined following stability analysis (see Section 6.5.4)

6.7.4 Lagoon banks

Special care is required in the design and siting of lagoon banks, particularly where these are to be built on or adjacent to existing tips or lagoon deposits. Generally, lagoon banks are designed either as a drainage bank to allow maximum drainage from the lagoon deposits, or as an impermeable bank which restricts drainage from the deposits.

6.7.5 Drainage measures

Drainage provisions should be made to reduce pore pressures within the tip and to collect and discharge surface water and groundwater and prevent saturation or ponding. Drainage measures may include the provisions in the following paragraphs.[169]

Tip underdrainage

This may take the form of a drainage blanket, radial or herringbone drains, or relief wells depending on the site conditions (see Figures 6.4(b) and 6.5). Filter materials for drainage purposes should be selected to avoid long-term deterioration. Where suitable filter granular materials are available only in limited quantities the use of geotextiles may be appropriate.

Internal drainage

Additional drainage blankets may be required within the body of the tip to reduce pore pressures and prevent the development of perched water tables.

Box 6.4: Methods of placing spoil[169]

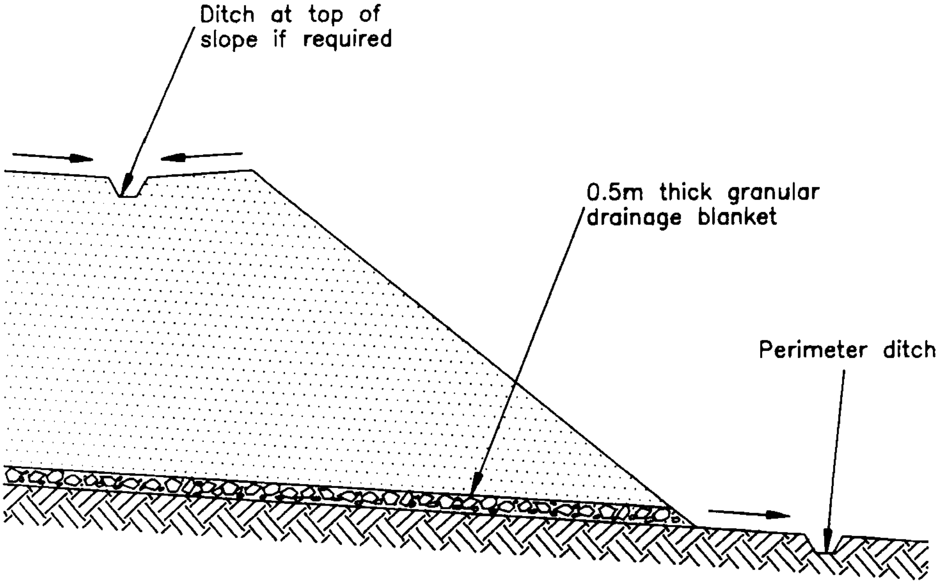
Method A - in layers not greater than 300mm thick (uncompacted or tracked in with a bulldozer);

Method B - in layers not greater than 300mm thick and compacted with a minimum of four passes of a towed smooth-wheeled roller having a weight not less than 5 tonnes per metre width, or equivalent roller;

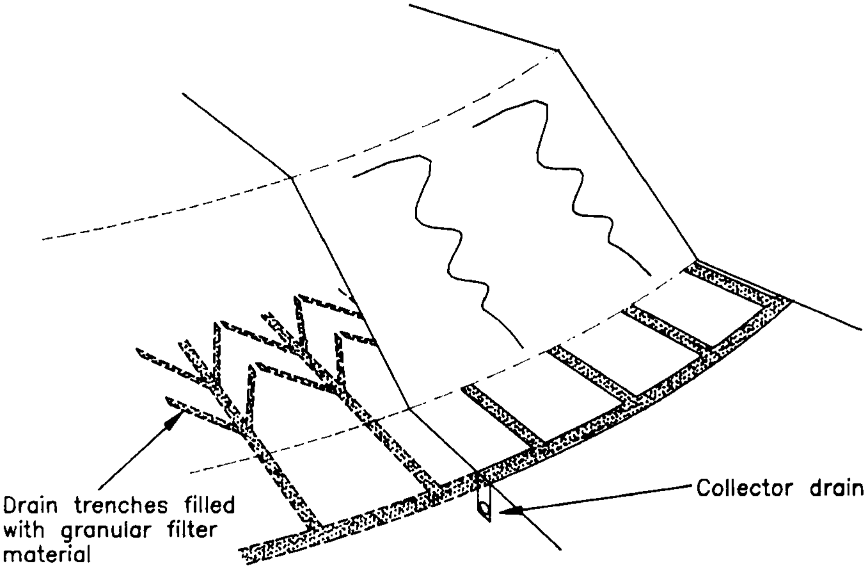
Method C - in layers not greater than 5m thick; within the range 300mm to 5m the thickness of layers must be the minimum commensurate with stability requirements and practical considerations. If placed in a lagoon bank the maximum thickness should be 1.5m.

Notes:

- where shear strength (*i.e.* stability) is the main requirement the spoil should be placed in thin layers by Method A or B;
- where permeability for drainage purposes is the main requirement the spoil should be placed in uncompacted layers by method A or C;
- lagoon banks and spoil liable to combustion should be placed in thin layers in accordance with Method A or B.



(a) Provision of drainage blanket



(b) Provision of herringbone drainage system

Figure 6.5: Provision of drainage beneath new tips

Surface drainage

A main drainage ditch should be provided around the bottom edge of the tip to collect surface water and water from internal drainage. The ditch should be located at least 3m from the toe of the heap, and may need to be lined depending on the ground conditions. A ditch may also be required along the top edge of the tip in order to intercept surface water reaching the tip from higher up the slope (see Figure 6.5(a)).

6.8 Inspections

At periodic intervals inspections should be carried out by a suitably qualified engineer to check the stability of active or disused tips in accordance with relevant legal requirements. Items likely to be included in the inspection are shown in Box 6.5.

Box 6.5: Periodic inspection of tips

Defects highlighted by poor performance must be attended to, and a system of inspection, reporting and implementation of recommendations should be established within the responsible organisation.

The items to be included in the inspection are as follows:[170]

Changes in situation and shape
Any changes with regard to development on adjacent land, clear space at the toe of the tip, dimensions and volumes of the tip, and widths at the bottom and top of slopes will require inspection. Assessment of the probable consequences of a failure of each section of the tip and of overtopping of each lagoon should be made.

Drainage
Inspection of surface drainage with regard to the condition, adequacy and freedom from obstruction of watercourses. Inspection of the efficacy of internal drainage of spoil heaps, lagoons and foundations is also necessary as is the inspection of surface drainage arrangements of lagoons and any erosion at inlets or outlets.

Tipping operations
For active tips, inspection should be made with regard to: the characteristics of the spoil, adherence to specification and tipping rules, method of placing and compaction, location and condition of lagoons, any excavation works or emptying of lagoons, any precautionary, remedial or improvement works, and any other work.

Cracks or movement of the tip and foundation
Inspection of the following is necessary: the positions and sizes of any cracks or movement and comments on causes, any land slips, and records of movements. Special attention should be given to the locations of buried lagoons and areas which may be affected by mining subsidence.

Fire
Inspection of the position and extent of any fire, fumes given off, and any control measures carried out.

Safety
Inspections (where appropriate) of personnel, public, trespassers, notices, lighting, fences, dangerous practices, adequacy of manhole covers and screens, walkways to lagoon controls and communications are useful and necessary.

Vegetation
Inspection of the extent and type of vegetation is useful as a guide to the successful management of the tip, its integrity and moisture characteristics, and its ecological value and balance.