

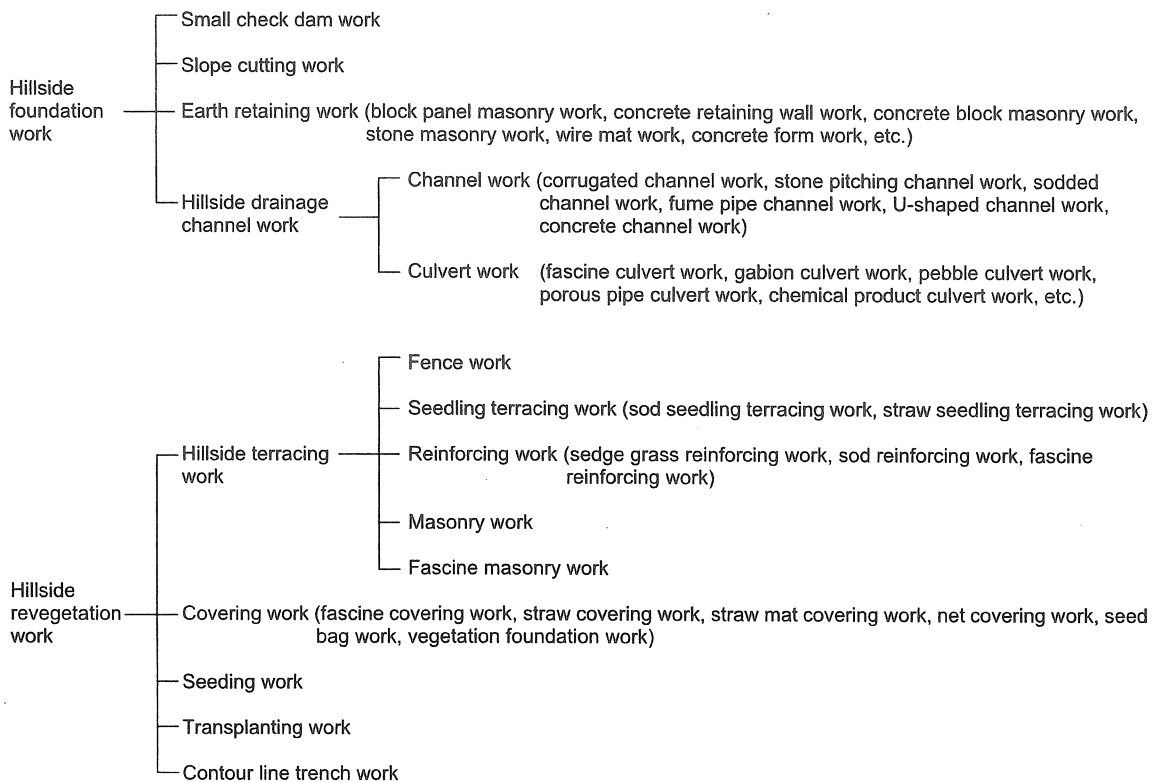
7.1 Design of hillside works

Hillside works shall be designed so that they can fully display their target functions and by accounting for safety and maintenance.

Commentary

Hillside works introduce vegetation to deforested ground and collapsed ground to control the production of sediment by preventing the expansion of weathering, erosion, and collapse of the surface soil, and are designed with reference to Chapter 13 Part 7 of the Planning Volume.

Types of hillside works are broadly categorized as hillside foundation work and hillside revegetation work depending on their purpose. Hillside foundation work creates a foundation on the execution site for a future forest by stabilizing soil deposited after slope grading and preventing the formation of slope drainage channels and erosion by rainwater. Hillside revegetation works revegetate the execution site by directly introducing vegetation. The following are typical work methods included in both of these categories.



Hillside work methods are generally selected based on the following standards

1. Work method by the geological, climatic etc. environment
2. Work method by the form of devastation

If the work method is selected according to the design procedure, it is done as follows.

- (1) Deforested ground
- (2) Collapsed ground

At locations where the surface has been eroded following the discharge of the soil and disappearance of vegetation caused by excessive cutting (deforested ground), the design prioritizes hillside revegetation work focused on trees and plants.

And at a location where part of a hillside has collapsed (collapsed ground), the design prioritizes hillside foundation work that is focused on structures that stabilize the soil.

Table 3. Design of Sabo Structures

Geological category Climate	Mesozoic – metazoan strata zone	Tertiary - Quarternary strata zone	Granite zone	Volcanic sedimentary deposit zone
Normal zone	With priority on torrent works, hillside work minimizes earth retaining work	The soil on the collapsed surface is relatively good and vegetation is aggressively introduced.	Hillside revegetation work with soil dressing type elements is fully performed. Because the slope is easily eroded, it is completely covered.	Because the topography is steep, foundation work corrects the topography. There are places where complete covering is necessary.
Heavy rainfall zone (annual rainfall of 2,000mm or more)	Priority is on hillside work, but hillside foundation work is small and hillside revegetation work is stressed	It is necessary to perform complete hillside foundation work.	Same as in a normal zone.	This corresponds to a <i>shirasu</i> (light gray volcanic ash) zone (Southern Kyushu). The slope is cut vertically and revegetation work with soil dressing effects is performed.
Low rainfall zone (annual rainfall of 1,500mm or less)	Generally the devastation is light and simple reinforcement work is adequate.	The work is done at once as hillside revegetation work. Hillside foundation work can be relatively simple.	Hillside foundation work is minimized and priority is on revegetation of the hillside surface (particularly, soil dressing type revegetation)	
Heavy snow region	Hillside work must be designed considering snow avalanches.	Hillside drainage channels are executed at high density to achieve total drainage.	Hillside revegetation work considering snow avalanches is done.	
Freezing zone	The ground is covered by various kinds of covering works and by vegetation to prevent its temperature from falling. Because terracing work collapses easily, it is done as rarely as possible.			

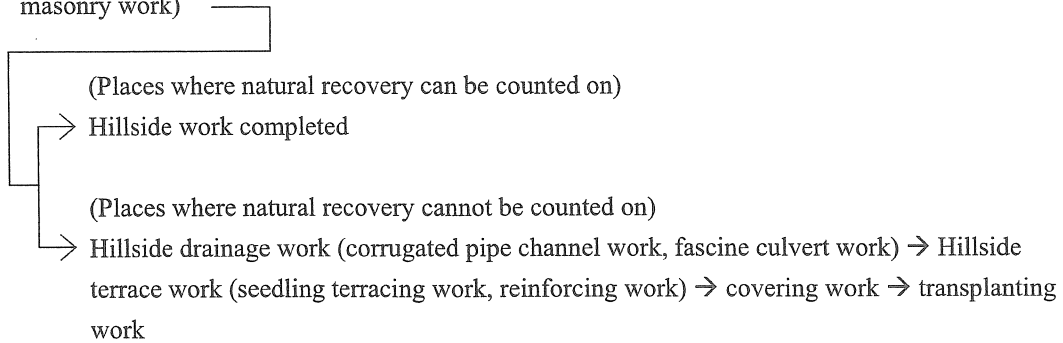
Hillside work design is done as follows. However steps in () are the work methods that are primarily used.

1. Deforested land

Small check dam work → earth retaining work (block panel masonry work) → slope grading → hillside terracing (seedling work, reinforcing work) → covering work (fascine covering work, straw covering work, seed bag covering work, vegetation foundation work) → transplanting work

2. Collapsed ground

Small check dam work → earth retaining work (concrete retaining wall work, concrete block masonry work)



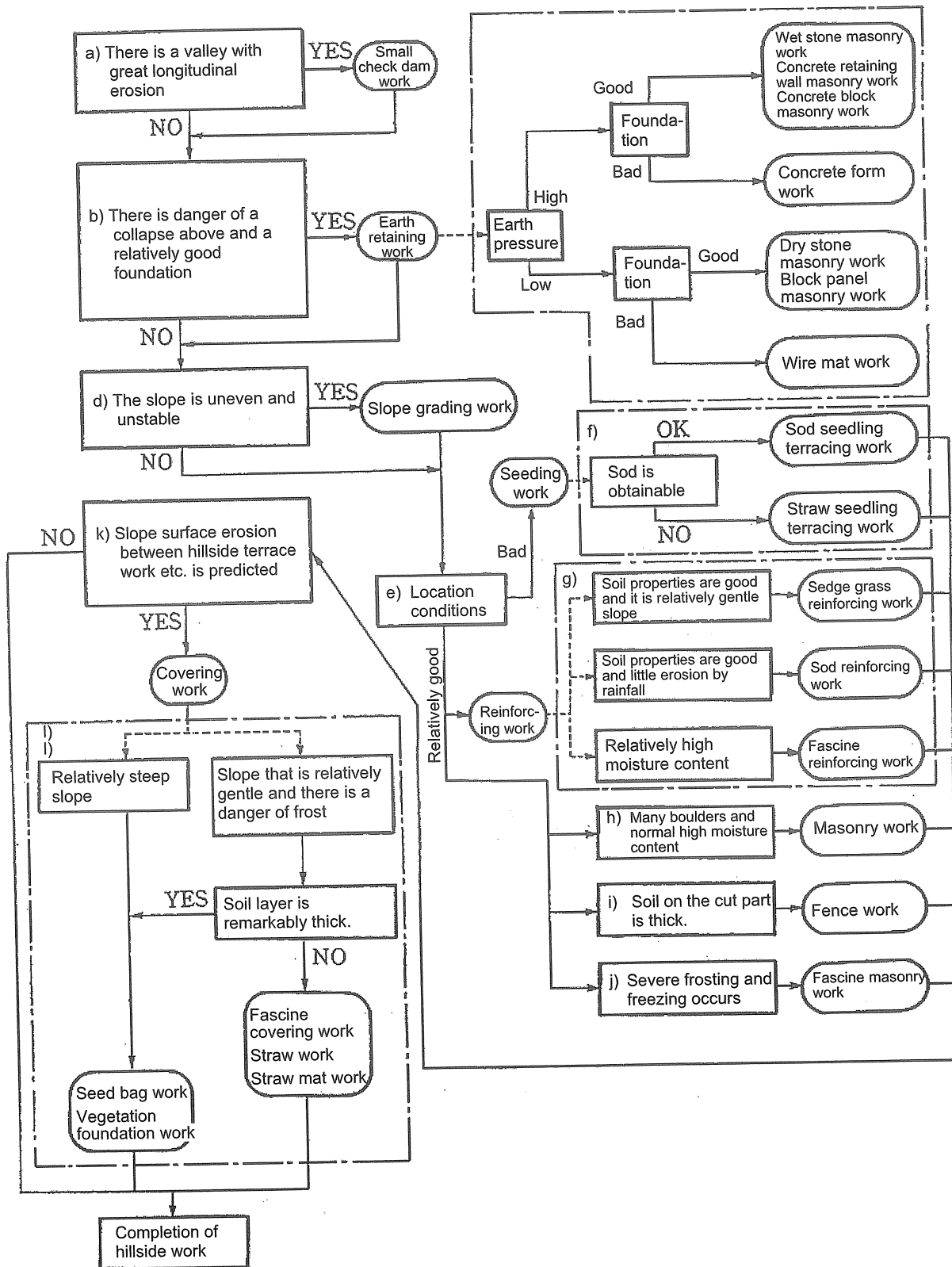
7.2. Small check dam work

Small check dam work shall be designed as stipulated in Part 2 of this chapter.

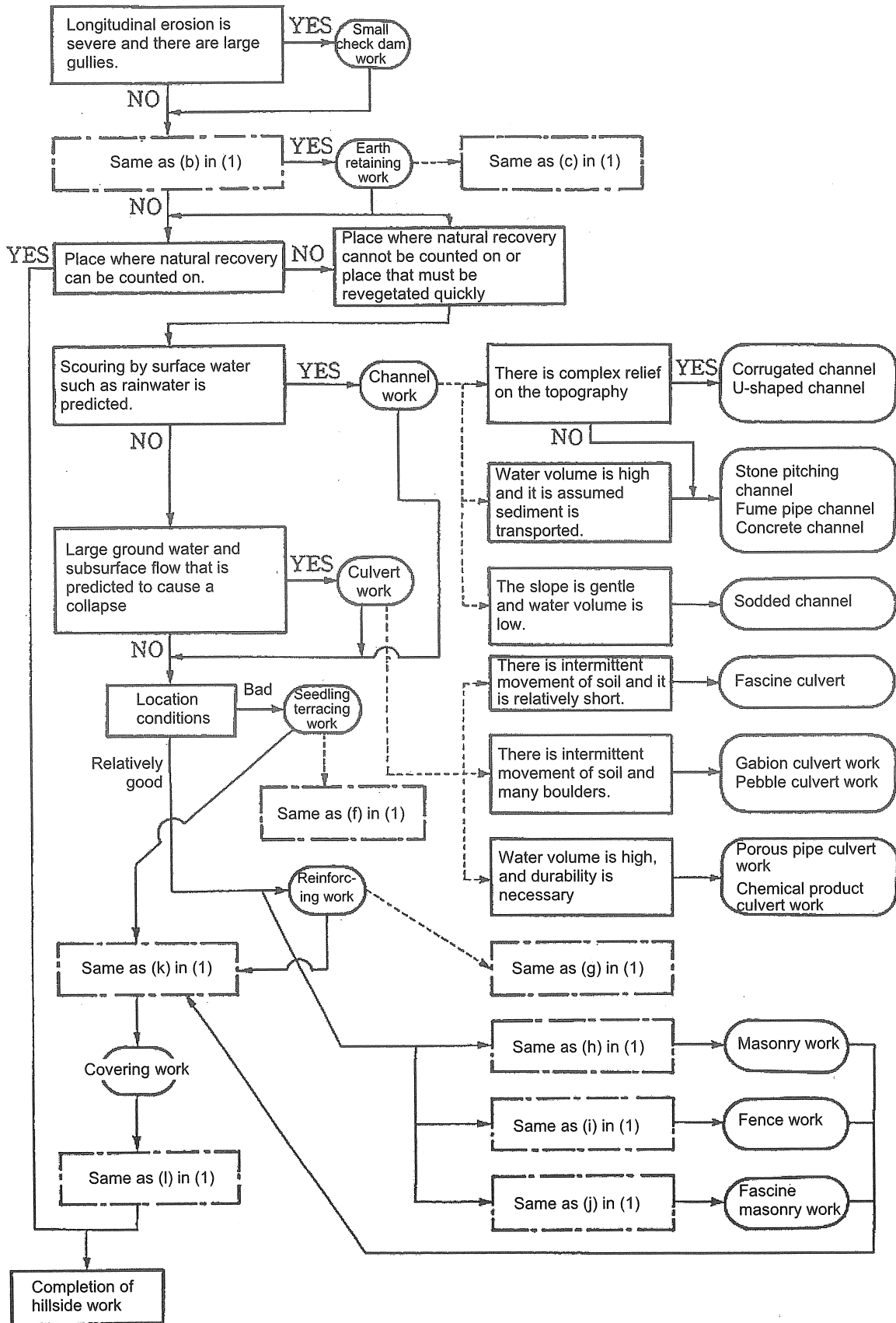
Commentary

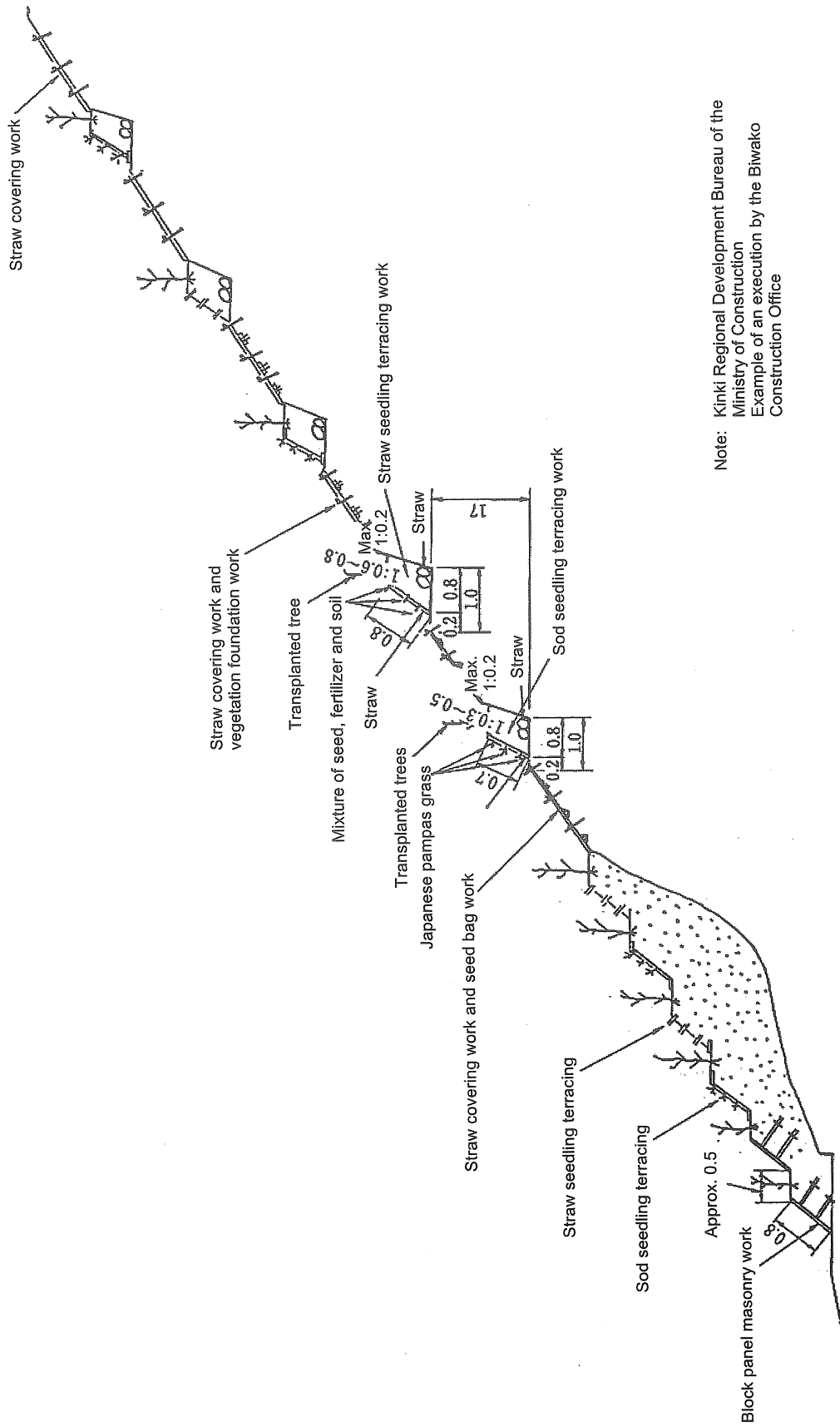
Small check dam work is a work method that prevents erosion and forms the foundation for other structures on deforested ground and collapsed ground where large scale erosion occurs.

(1) Deforested land



(2) Collapsed ground





Note: Kinki Regional Development Bureau of the
 Ministry of Construction
 Example of an execution by the Biwako
 Construction Office

Figure 3-12. Section Drawing of Deforested Ground (Sample Execution) (unit: m)

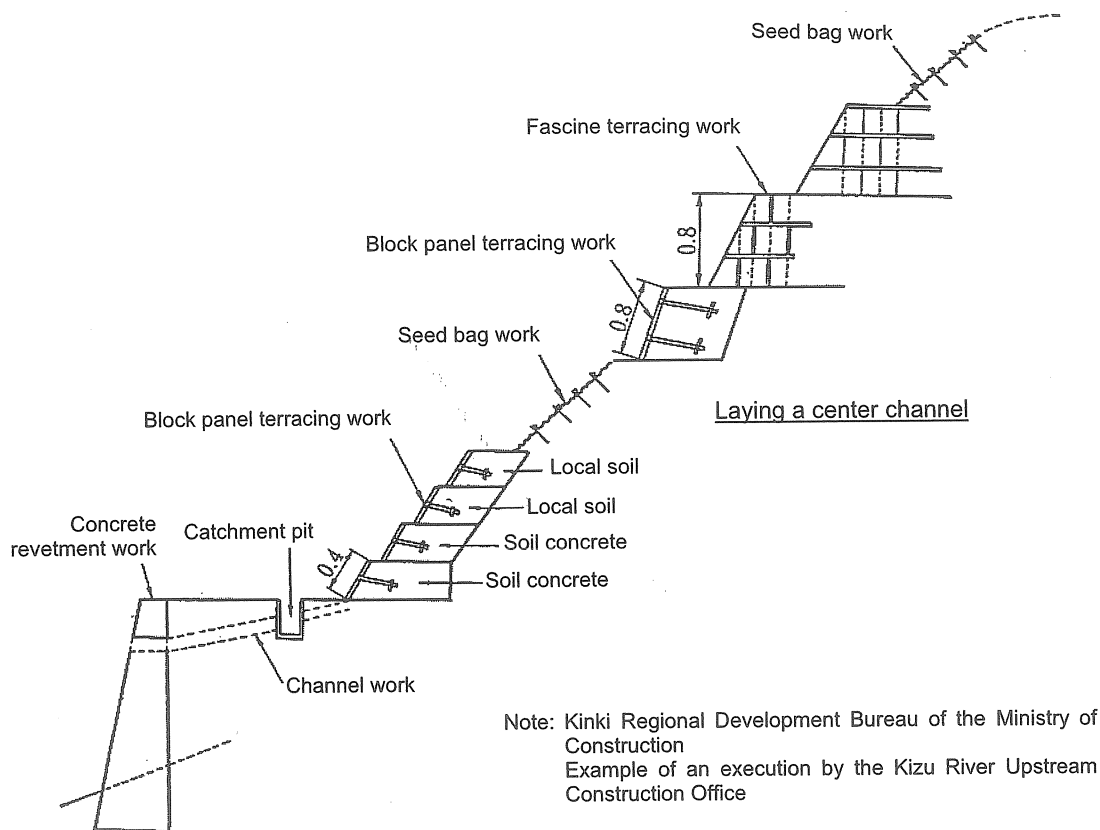


Figure 3-13. Sectional Diagram of Collapsed Ground (Sample Execution) (unit: m)

The design of small check dams is based on Part 2 of this chapter, but the crown width can be lower than the value in the commentary in 2.5.1 of this Chapter if it is considered suitable in light of conditions such as the flow volume and form of sediment transport.

7.3 Slope grading work

Slope grading work shall be designed as a structure that can stabilize the hillside slope.

Commentary

In the case of a steep hillside slope with irregular relief that is predicted to be unstable in the future if left as it is, slope grading work is done to smooth its relief and reduce its steepness. If the vertical height of the graded slope surface is high, in principle the top is finished with a steep grade and the bottom with a gentle grade, but the standard graded gradient is 15%.

In the case of large-scale grading that produces a large volume of excavated soil, counterweight fill may be executed to stabilize the slope. Counterweight fill is a method of creating a terraced slope by embanking using soil with stone masonry or wicker work as the foundation in order to stabilize a steep slope or a slope with irregular relief, and basically, if there are many rocks near the execution site, it is stone masonry work, and if there are few rocks it is wicker work.

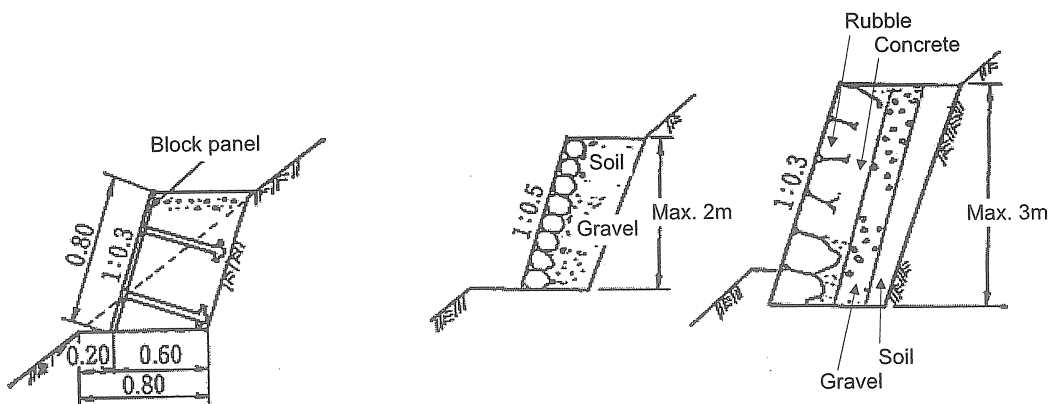
7.4 Earth retaining work

Earth retaining work is designed considering topographical, geological, and climatic conditions and safety.

Commentary

When grading has produced a steep slope of sedimentary soil, the earth retaining work stabilizes the sedimentary soil and supports the hillside work executed at the top. And in the case of a steeply graded slope on deforested ground or collapsed ground, or in the case of a steep forested slope at the top, planning earth retaining work can minimize the area of the slope grading and reduce the slope gradient.

According to the materials used, it is categorized as block panel terracing work, concrete retaining wall work, concrete block masonry work, stone masonry work, wire mat work, and concrete form work.



(a) Dry stone masonry work (b) Wet masonry work

Figure 3-14. Block Panel Terracing Work (unit: m)

Figure 3-15. Stone Masonry Work

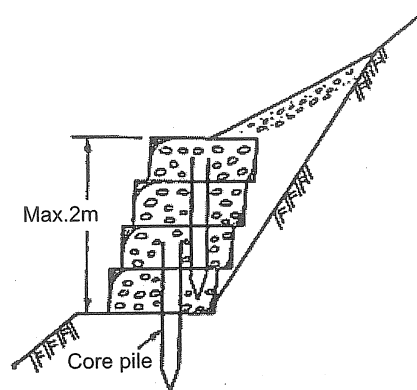


Figure 3-16. Wire mat Work

Block panel terracing work is unsuitable for places with high earth pressure, although the material is light and easy to transport and the work is easily executed (see Fig. 3-14).

Concrete retaining wall work and concrete block masonry work are used as they are in ordinary public works, but they can be used a locations with relatively high earth pressure (see fig. 3-9).

Stone masonry work includes dry and wet stone masonry work. Dry stone masonry work is limited to

height of 2m and it is not done on a slope steeper than 5% (see Fig. 3-15(a)). Wet stone masonry is limited to a height of 3m and it is not done on a slope steeper than 3% (see Fig. 3-15(b)).

Wire mat work is not permanent work, and in principle, its maximum height is 2m. Its anchor piles are made of rot resistant wood, that are generally installed at intervals of 2m (see Fig. 3-16).

Concrete pile work is used at locations where the foundation ground is unstable (see Chapter 4 of this manual).

7.5 Channel works

Channel works are designed as structures that can quickly and safely drain flowing water outside the planning area.

Commentary

Channel works are installed to prevent erosion of slopes by flowing water. They are designed with a gentle gradient that does not abruptly change, they are fully embedded in ground with collapsed zone relief, and they easily gather the surrounding flowing water. The channel section must provide enough leeway to safely carry the flow volume. And in addition to the channel work, earth retaining work or band works are done at the bottom end. If the channel is long, band works are done every 20 to 30mm of the channel to stabilize it.

Types of channel works are categorized as corrugated, stone pitching work, sodding, fume pipe, concrete channel work according to the materials used.

See Figure 3-17 for an example of a corrugated channel.

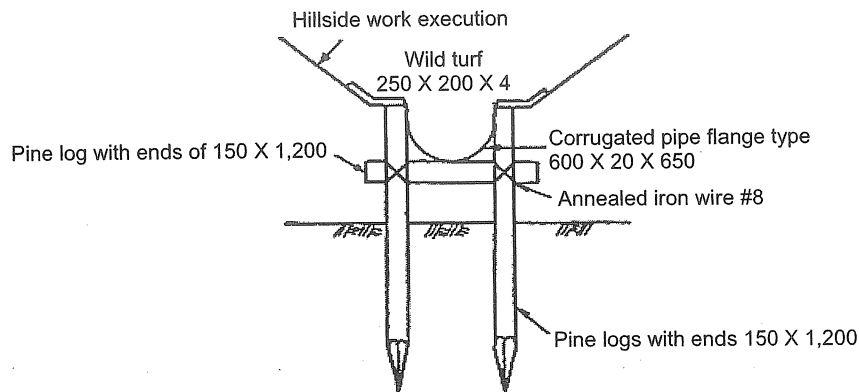


Figure 3-17. Example of corrugated channel work (unit: mm)

7.6 Culvert work

Culvert work shall in principle, be constructed above an impermeable layer and be designed with a structure that can quickly guide groundwater to the ground surface and drain it.

Commentary

Culvert work is done in order to drain ground water that might reduce the stability of the slope, is constructed above an impermeable layer in natural ground mass so that it can most easily drain groundwater from wet locations and at places where springs occur.

Culvert work is categorized as fascine, gabion, pebble, porous pipe, and chemical product culvert work according to the materials used. A fascine culvert is used as a small scale culvert. A gabion culvert is used so that it can work effectively even if the ground is unstable and moves, and generally cylindrical gabions are used. A pebble culvert is used where there ground water content is high and the pebble diameter ranges from 0.05 to 0.15m. Recently the porous pipe and chemical products etc. have been used.

As reference, Figure 3-18 shows a gabion culvert.

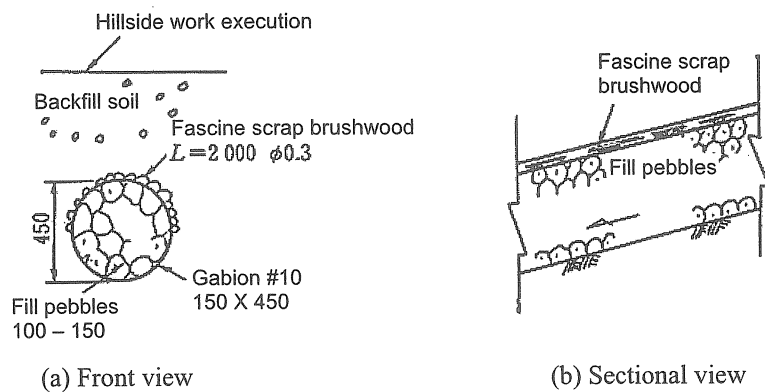


Figure 3-18. Example of a Gabion Culvert (unit: mm)

7.7 Fence work

Fence work shall be designed as a structure that can prevent the runoff of surface soil from the slope.

And fence work shall in principle be used at cuttings while its use on embankments shall be avoided.

Commentary

Fence work is used at locations where there is a shortage of natural sod or stones near the execution site, the soil on the hillside slope is relatively thick, and it is easy to introduce vegetation.

Fence work is categorized as wicker fence work and concrete slab work according to the materials used.

As reference, Figure 3-19 shows wickerwork fence work.

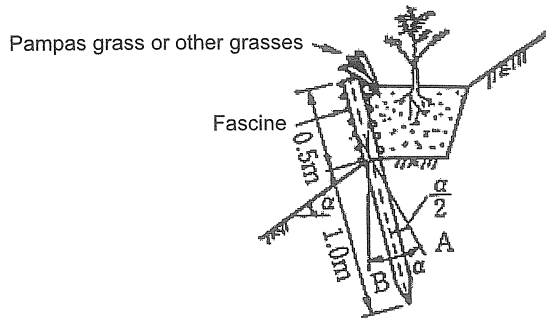


Figure 3-19. Example of Wicker Fence work

7.8 Seedling terracing work

Seedling terracing work shall be designed as a structure that can stabilize a slope where the ground mass is exposed. This method shall be selected according to topographical, geological, climatic and other conditions.

Commentary

Seedling terracing work is executed by first forming a terrace with vertical height of about 1.5m and width of about 1m on the ground mass, then covering it with sod or straw and backfilling to create a transplanting bed.

Seedling terracing work is categorized as sod seedling terracing work and as straw seedling terracing work according to the materials used. Sod seedling terracing work is a typical seedling terracing work for devastated land in dry areas where there is little rain, and it is suitable for locations where sod is available (see Figure 3-20(a)). Straw seedling terracing work is constructed where there is a shortage of straw that is the major material used for sod seedling terracing work (see fig. 3-20(b)).

Stepped seedling terracing work is a method of executing seedling terracing work continuously in steps on a slope, and is mainly done above sedimentary soil.

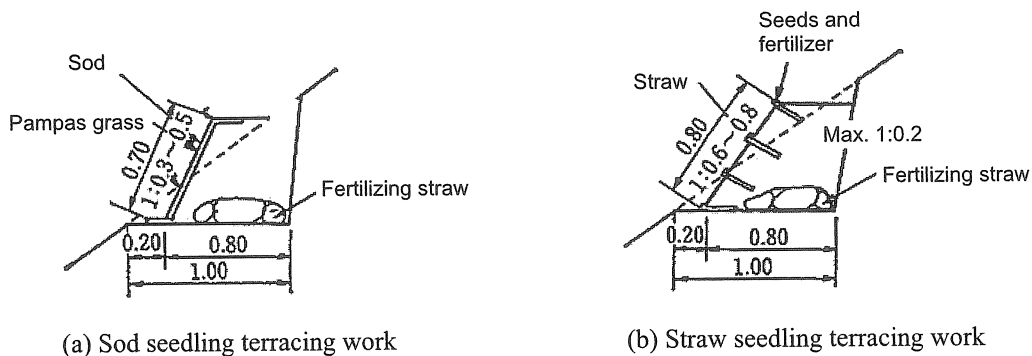


Figure 3-20. Examples of Seedling Terracing Work (unit: m)

7.9 Reinforcing work

Reinforcing work shall be designed as a structure that can stabilize a slope, and this method shall be selected according to topographical, geological, climatic, and other conditions.

Commentary

Reinforcing works are categorized as sedge grass reinforcing work, sod reinforcing work and fascine reinforcing work according to the materials used.

Sedge grass reinforcing work is generally executed on terraces with vertical height of 1.0 to 1.5m and width of 0.4 to 0.6m and using 0.2 or 0.3 bundles of sedge grass per 1m. At locations where sedge grass can be counted on to grow in a good quality sedimentary soil zone with a relatively gentle gradient, terraces need not be formed (see Fig. 3-21).

Sod reinforcing work is substituted for sedge grass reinforcing work at locations on deforested ground where rainfall causes little erosion (see Fig. 3-22).

Fascine reinforcing work is executed at locations with relatively large water content and where fascine is easily obtained. Generally, fascine reinforcing work forms terraces with vertical height from 1.0 to 1.5m and width of 0.6 to 0.8m, the fascine is placed to a height of about 0.4m, it is about 0.4 long, the diameter of the fascine bundles is about 1m, and sedge grass stalks or perennial grasses are placed between these bundles to prepare for the rotting of the fascine (see Fig. 3-23).

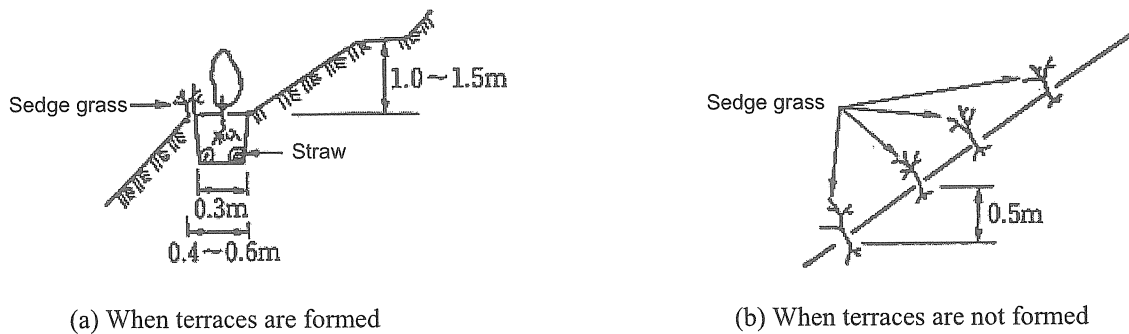


Figure 3-21. Sedge Grass Reinforcing

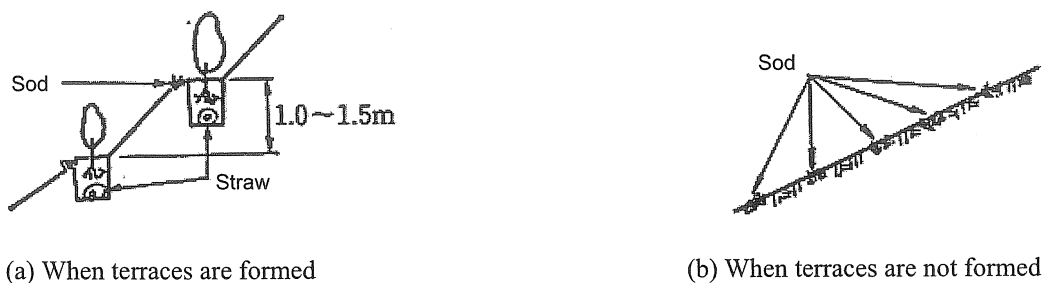


Figure 3-22. Sod Reinforcing

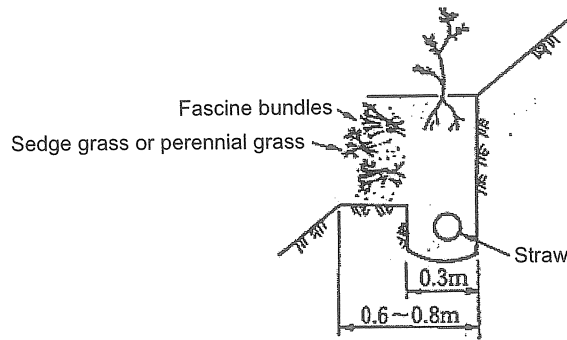


Figure 3-23. Fascine Reinforcing Work

7.10 Covering work

Covering work shall be designed as a structure that can prevent surface erosion on a slope between seedling terracing work and reinforcing work etc. and this method shall be selected according to topographical, geological, climatic and other conditions.

Commentary

Covering work includes fascine covering work, straw mat work, and net covering work.

Covering work is a method of preventing surface erosion of slopes on collapsed ground and on deforested ground, and because it stabilizes the slope until the materials used have rotted, it should be seeded with grass seeds. In this case, the methods mainly used are fascine and net reinforcing works.

To prevent the grass seeds that are directly sown from being washed away, at locations on the execution site with relatively good conditions, straw covering work and straw mat covering works are also used.

Fascine covering work is generally executed on relatively narrow deforested ground or on slopes where seedling terracing work or reinforcing work is done, and is used at locations where fascine is easily obtained and anchor piles can be firmly placed. Generally fascine covering work is done by placing the fascine in rows, installing vertical wood strips on them to hold them in place, then fixing these with anchor piles.

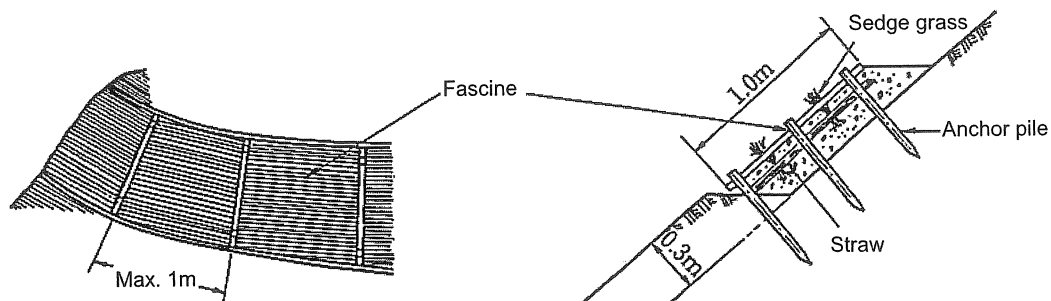


Figure 3-24. Fascine Covering Work

Net covering work is applied to soft hillside slopes with gentle gradient. The meshes are usually longitudinally 2m and laterally 4m rhombic shapes, and they are anchored either with bamboo skewers

inserted at the joints and between the fascine or by piles (see Fig. 3-25). Inside the meshes, seedlings with luxuriant roots suited to the execution site are transplanted. Recently synthetic resin products have been used with seed bag work filled with grass seeds or vegetation foundation work executed inside them (see Fig. 3-26).

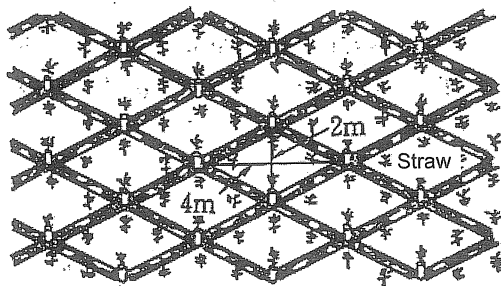


Figure 3-25. Seeding Work

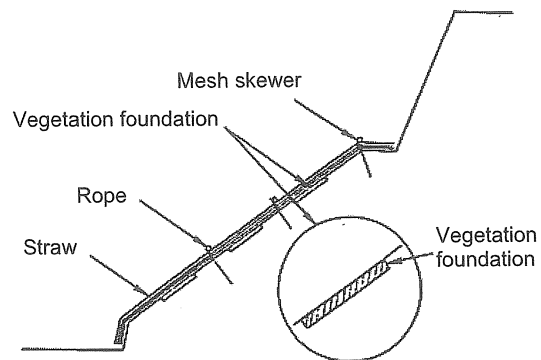


Figure 3-26. Straw Work and Vegetation Bed Work

7.11 Seeding work

Seeding work shall be selected in order to speed up revegetation by directly seeding with grass seed.

Commentary

Seeding work is used at locations where the hillside slope is gently graded and has good soil conditions in order to speed up revegetation by directly seeding the site with grass seeds. The types of grass used for seeding work are, in principle, selected with a variety of growing periods so they will not be unbalanced, and considering the state of surrounding vegetation, are types that can withstand dry ground and infertile ground, have rich root systems and above-ground stems, are perennials with good recovery capability, are low and spread widely, and grow from autumn to spring.

If seeding is done on a steep slope, it is generally necessary to be careful to do covering work to prevent the seeds and fertilizer from being washed away.

Standard grasses used for seeding work are shown in Table 3-9.

Table 3-9. Major Grasses Used for Hillside Sabo work

Species name	Growth period	Characteristics	Cold tolerance	Heat tolerance	Drought tolerance	Acid tolerance	Fertilizer requirement
Chinese fountaingrass	Perennial		Medium	Medium	Medium		Small
Chinese lespedeza	“		Strong	Strong	Strong		Small
Reynoutria japonica Houtt.	“	Suited to land damaged by smoke	Strong	Strong	Strong	Strong	Small
Wormwood	“		Strong	Strong	Strong		Small
Broomsedge bluestem	“		Strong	Strong	Strong		Small
Kentucky 31 fescue	“	Suited to many ground properties, evergreen	Strong	Medium	Medium	Strong	Large
Red fescue	“	Suited to cold areas	Strong	Strong	Strong	Strong	Medium
Red top	“	Large covering ability	Strong	Strong	Strong	Strong	Small
Timothy grass	“	Resistant to cold and dampness	Extremely strong	Weak	Weak	Strong	Large
Weeping love grass	“	Overwhelms other grasses	Weak	Strong	Strong	Strong	Small
Italian rye grass	Annual – biannual	Mixed as a supporting type in winter executions	Strong	Weak	Weak	Strong	Large
Bermuda grass	Perennial	Does not bud without high temperatures	Weak	Strong	Strong	Strong	Small
White clover	“	Sown mixed with gramineous grasses	Strong	Weak	Weak	Medium	Small
Orchard grass	“	Particularly strong shade tolerance	Strong	Medium	Medium	Strong	Large

7.12 Transplanting work

Transplanting work shall be selected to stabilize slopes through early revegetation. This work method shall be selected according to topographical, geological, soil, climatic, and other conditions.

Commentary

Trees used for transplanting work are those that can tolerate dry ground and infertile ground, those with flourishing root development that anchors them quickly to the ground, those with powerful sprouting capacity, and those with great resistance to various kinds of damage (pest, cold, frost damage, temperature change tolerance).

Standard trees used for transplanting work are shown in Table 3-10.

(Reference 3.1) Stone masonry terracing work

Stone masonry terracing work is a method suited to locations with constant high water content or places where strength is required because soil on the graded surface is easily washed away by intensive rainfall. It is substituted for seedling terracing work at locations where there are many loose boulders after grading or

a place where the hillside has large relief and the soil is hard. The standard spare length of the stone is normally about 0.3m, the gradient of the slope between 3% and 4%, the height of the masonry work between 0.5 and 1.0m, and the berm is 0.15 to 0.2m.

Stone masonry work is designed with reference to figure 3-27.

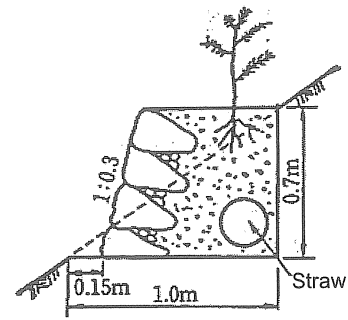


Figure 3-27. Example of Stone Masonry Work

(Reference 3.2) Fascine terracing work

Fascine terracing work is a method that is generally done to increase the quantity of water retained by a hillside slope in zones where freezing is severe, and its standard height is 1.0m.

Fascine terracing work is designed with reference to Figure 3-28.

Table 3-10. Major Trees Used for Hillside Sabo Work

Tree name	Applicability	Reforestation method	Characteristics							
			Rooting ability	Root system development	Infertile ground tolerance	Dryness tolerance	Moisture tolerance	Cold tolerance	Shade tolerance	Acid tolerance
Red pine	Used inland because of its poor resistance to sea breezes.	Transplanting and seeding	Good	Good	Strong	Strong	Weak	Strong	Weak	
Black pine	It is the most commonly used.	"	Good	Good	Strong	Strong	Medium	Strong	Weak	
Black locust	Collapsed ground, deforested hills that are a little fertile	"	Good	Good	Strong	Strong	Weak	Strong	Medium	Weak
Screw pine	Suitable for most devastated ground, but unsuited to cold locations and those with strong winds.	Transplanting, cuttings	Good	Good	Strong	Strong	Weak	Medium	Weak	Weak
Black locust		Cutting, branch spreading, seeding	Good	Good	Strong	Strong	Weak	Strong	Weak	Medium
False indigo	The most applicable species									
Shrubby bush clover	Same as false indigo	"	Good	Bad	Strong	Strong	Weak	Strong	Weak	Medium
Japanese alder	Dryness tolerant	Transplanting	Good	Medium	Strong	Strong	Strong	Strong	Weak	Strong
Manchurian alder	Suited to very cold locations	"	Good	Good	Strong	Strong	Strong	Strong	Medium	Strong
Alder (<i>Alnus pendula matsumura</i>)	Suited to locations other than cold locations	"	Good	Good	Strong	Strong	Weak	Strong	Weak	Strong
Alder (<i>Alnus sieboldiana matsumura</i>)	Suited to most devastated ground	"	Good	Good	Strong	Strong	Weak	Strong	Medium	Strong
Yamamoto (<i>Myrica rubra</i>)	Suited to warm locations	"	Bad	Good	Strong	Strong	Weak	Medium	Strong	Strong

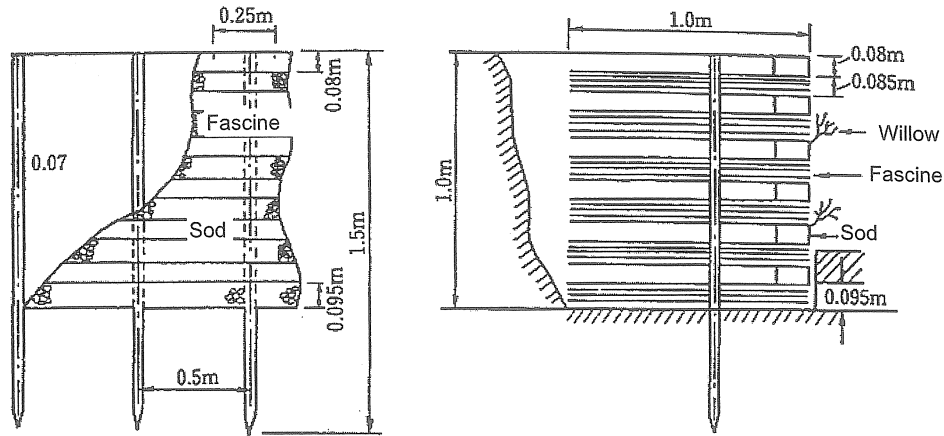


Figure 3-28. Example of Fascine Terracing Work

(Reference 3.3) Contour line trench work

Contour line trench work is a method of preventing the runoff of sediment by installing trenches along the contour lines of deforested ground and other devastated ground to retain and absorb snow and rainwater that have fallen on the slope in order to retain them on the hillside to permit the growth of grass.

The trenches are excavated horizontally along contour lines at a standard interval of 6 to 12m. The trenches are divided by banks at intervals between 6 and 12m, and their height is about 0.1m lower than the height of a bank in a trench on a torrent. The section of the trenches is adequate to prevent the retained water from overflowing the trenches considering the hillside gradient and the state of the surface soil.

If the trenches cross a relatively large gully (more than 0.6 X 0.6m), banks about the same height as those on the gully side are constructed on opposite sides of the gully.

Contour line trench work is designed with reference to Figure 3-29.

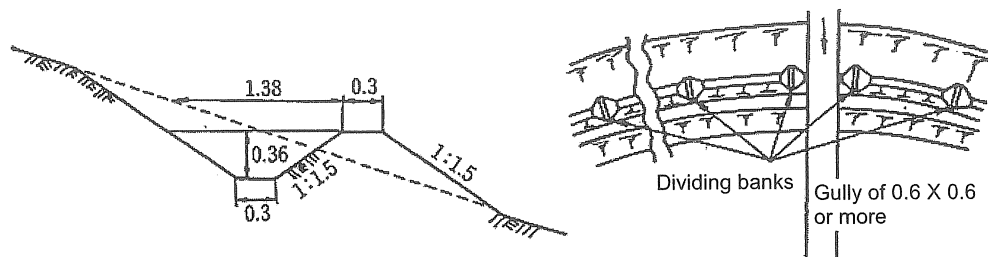


Figure 3-29. Example of Contour Line Trench Work (unit: m)