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山腹工 - 荒廃地における植生回復のためのガイドライン -

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Hillside Works - Guidelines on the Restoration of Vegetation on Wasteland -

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山腹工 一荒廃地における植生回復のためのガイドライン一

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概要

山腹工を計画する際に必要となる、整備目標の設定、整備手法、整備目標に対する評価について論じる。
また、わが国における最近の山腹工実施事例を収集・整理し、各現場で行われている山腹工の実例を紹介し、山腹工を導入する際の手引きとして導入することを目的としてとりまとめたものである。

キーワード：山腹工、植生回復

Synopsis

The methods for setting goals, installing and assessing hillside works were discussed in this report. Some recent hillside works and the procedures of installations were also collected and introduced as a guideline for installing them.

Key Words: hillside works, restoration of vegetation

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Hillside Works

Guidelines to the Restoration of Vegetation on Wasteland
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1. Before execution hillside works

1.1 What are hillside works?

(1) Restoring vegetation to control constant sediment runoff.

- *Sabo* projects have long been carried out as hillside works and torrent works executed as part of flood control projects to prevent sediment disasters along downstream rivers. Hillside works that are positioned as hillside projects are a type of work that can be defined as the foundation of *sabo* that controls the constant sediment runoff by restoring vegetation on collapsed land in water resource areas and deforested land where sediment is produced.

- Hillside works are categorized as 1) hillside foundation work that stabilizes slopes on hillsides and prevents erosion of the slopes, 2) Hillside revegetation works to restore greenery by transplanting trees to prevent or mitigate the occurrence or expansion of ground surface erosion or the collapse of surface layers on collapsed land and deforested land, and 3) Hillside slope reinforcement to increase the resistance to collapsing of collapsed ground or a collapse itself. Executing these individually or in appropriate combinations controls the production of sediment.

(2) First restricting the motion of sediment on the hillside slope by hillside foundation work or hillside slope reinforcement work is counted on to encourage the natural invasion of vegetation.

- First, the movement of sediment is controlled by hillside foundation works to stabilize the hillside slope, guaranteeing the foundations of a habitat for vegetation. After the hillside foundation work has been executed, the hillside is monitored in expectation of the natural invasion of vegetation.

(3) When it is not possible to count on the natural invasion of vegetation, further hillside revegetation work is performed.

- When rapid revegetation is necessary to control sediment, or when the natural formation of vegetation cannot be counted on because of local conditions (there are no nearby stock trees for example) further hillside revegetation work is done to help establish vegetation.
1.2 To avoid failure

(4) Clarifying the improvement targets.

(5) Selecting effective “methods”

(6) Evaluating the degree of achievement of the goals over years

(7) Performing management appropriate to conditions

- Hillside works unavoidably have unexpected results, because the improvement is done taking advantage of the effectiveness of vegetation (living organisms) according to the characteristics of the work method. Measures necessary to avoid failure are clarifying the improvement targets of the sabo project, initially selecting effective methods to achieve these targets, evaluating the degree of achievement by observing the state of the vegetation over years, and to support the achievement of the targets according to circumstances, introducing appropriate management such as tending the vegetation or forest physiognomy conversion.
Pioneer forest: a forest of early maturing deciduous broad-leaved trees such as Japanese alder (Alnus japonica (thunb.) steud) or oleaster (Elaeagnus) that are resistant to drying and oligotrophic conditions and have nitrogen fixing capacity.

Target forest: a forest that has moved from the pioneer forest stage to a stage where it consists mainly of deciduous broad leaf trees such as konara oak (Quercus serrata Thunb. ex. Murray) and sawtooth oak (Quercus acutissima Carruthers).

Climax forest: Forest that has stabilized in dynamic equilibrium so that its structure and species configuration (species configuration varies according to environmental conditions) remain unchanged.
2. Improvement targets

2.1 What degree of improvement is considered as a sabo project

(8) First, considering early revegetation as a transitional point in the improvement.

(9) Simultaneously improving with the formation of the target forest as the first target.

- It is assumed that control of the constant sediment runoff can be almost achieved when, following the execution of the hillside foundation work, the pioneer vegetation has been established either by natural invasion or by hillside revegetation work, or by covering the slope surface. In the past, improvement was done from this perspective by considering early revegetation to be the first step.
- On the other hand, because trees that are primarily pioneer vegetation lack diversity and are unstable, according to circumstances, it is possible for this vegetation to deteriorate, allowing the restoration of wasteland conditions. There is also a demand for efforts to conduct projects to achieve genuine natural restoration as a consequence of the recent growing concern with the natural environment. Consequently, as a sabo project, its object must be the creation of a sound forest consisting of stabilized vegetation, and the improvement must be undertaken with the creation of the target forest that is the bridge to formation of the climax forest as the goal.

Target forest and secondary forest

The working group previously used the term “secondary forest” as the forest that is the target of hillside work, in the sense that the goal is a vegetation colony of the constituent species that are identical to those in a secondary forest.

Because the original meaning of “secondary forest” is a forest that naturally recovered after the virgin vegetation had been destroyed by a forest fire, intensive rainfall, or insect pests etc., in this case, it means a forest growing on preexisting forest soil. Because the term “secondary forest” may cause misunderstandings, “secondary forest” has been replaced by “target forest” as the word to define the target of hillside works.

2.2 To the formation of the target forest

(10) The constituent species of the target forest differ according to whether it is a warm or cool area, even under an identical temperate climate.

- Japan is classified as a temperate climate zone, but depending on whether it is a warm area or a cool area, the colonies established later vary. The transition of the large trees is generally the creation of the climax forest by the process—pioneer vegetation → deciduous broad leaf trees → coniferous
broad leaf trees in a warm zone. But in a cool zone this process is the transition: pioneer vegetation \(\rightarrow\) deciduous broad leaf trees followed by the replacement of these species to create the climax forest. As pioneer vegetation, the coniferous broad leaf medium and low trees (*Eurya japonica* Thunberg, longstock holly (*Ilex pedunculosa*) the large trees (camphor tree (*Cinnamomum camphora*), *arakashi* (*Quercus glauca* Thunb), *shirakashi* (*Quercus myrsinaefolia*)) are established but these represent a transitional phase in the process.

- The large trees of the target forest are, in warm areas, mainly *konara* (*Quercus serrata* Thunb. ex. Murray) but including sawtooth oak (*Quercus acutissima* Carruthers) and abemaki (*Quercus variabilis* blume), and in warm areas, the target forest consists generally of *mizunara* (*Quercus crispula* Blume), hornbeam (*Carpinus laxiflora*), or *itayakaede* (*Acer pictum*).

(11) Supplementing the formation of soil with pioneer vegetation to support the invasion by the next generation species.

- After execution of the hillside work, the soil conditions are not completely provided, so the formation of soil is supplemented by the pioneer species to support the invasion of the next generation species. In order that this be done effectively, it is necessary to select species suited to local conditions.

(12) Forming a diverse forest physiognomy

- In order to prevent a reversion to wasteland, it is necessary to form a diverse forest physiognomy so that when the pioneer vegetation has retreated, the next generation vegetation can appear.
(13) Forming a stand with a developed stratified structure.

- In order for the sediment runoff control function, water retention function and other functions of a forest to be effective, it is necessary to form a stand with a developed stratified structure.
3. Selecting an effective method

3.1 To restore greenery on hillside slopes

(14) The study is based on a work method that can guarantee flat land on terraces with a slope gradient of 10° or less.

- To guarantee the foundation for the growth of vegetation, it is important to create the foundation in the form of terraces along the contour lines of the hillside foundation work to create flat surfaces with a slope gradient of 10° or less. This increases the certainty of the formation of a future forest. But if it is difficult to guarantee flat parts on the top of the slope for example, stabilizing it with net work etc. will be unavoidable, and work methods suited to circumstances are selected.

Tanakami hillside work: Initially slope surface treatment between seedling terracing work was not done, but because the seedling terracing work was buried by sediment, straw covering was done beginning in 1960. This stabilized of the slope and the trees grew normally.

Onagi hillside work: on the earth retaining work, scoria that is easily moved by the wind etc. was firmly solidified.

Mizutani hillside work: hillside foundation works are selected according to the slope gradient.
Gentle slope:  earth returning work + vegetation mat
Steep slope:   net work + spraying a thick layer of base material
(15) The topography is accurately assessed to perform dependable treatment of the surface water and the underground flow on the slope.

* In order to more firmly establish the greenery, it is important to accurately assess the topography to treat the surface water and the underground flow on the slope.

Tsuchiyabara hillside work: The surface flow on the slope scours the ground under the thinned material so that is above the ground, allowing the sediment to move. This delays the recovery of the vegetation.
* Countermeasures are now completed.

Nomugi Pass hillside work: As in the case of the Tsuchiyabara hillside work, thinned material is used to make the foundation work, but the surface and underground water flows are appropriately performed so that no scouring can be seen.
(16) This a soil dressing work method with extremely good vegetation growth base improvement effects.

- If the soil particle diameter on the site of the base for the vegetation is too coarse or dense, the water content falls, encouraging the fall of voids, creating a shortage of water or air needed for the growth of vegetation. Soil dressing is an improvement method that restores the appropriate particle diameter constituency, and the more soil dressing provided, the more effective it is. But it is necessary to consider the importance of the land and the cost of using the method to decide to use it.

(17) Considering the years of service until the vegetation is firmly established and the strength of the hillside foundation work materials.

- When thinned wood and bags of soil are used to execute hillside work, their service life until the vegetation is firmly established is considered.

![Nomugi Pass hillside work: example of the use of wood obtained by thinning trees](image1)

![Tsuchiyabara hillside work: Use of bags of soil Professor Ote studied the use of soil cement as material to fill soil bags in the Kyoto University Forest](image2)

(18) Basically fertilizer is not used.

- While fertilizer does speed maturation, it creates vegetation with low resistance, and other damage is caused by the stress on the vegetation when fertilization is stopped.
- If fertilizer is used, the following points should be considered.
  - It should be organic material such as straw that provides gradual and gentle effects.
  - To guarantee voids in the soil (improving the physical properties of the soil) the use of bark fertilizer (wood chips) or other material with effects other than fertilization should be considered.
Hill side revegetation work is done considering the growing period.

- Revegetation work should be done considering the period when newly introduced species grow (the two normal growing periods of vegetation are spring (March to June) and autumn (September to October)).

Planting (seeding) must be performed in three stages, collecting → storing → sowing based on a thorough knowledge of the individual properties of the seeds themselves.

- Planting (seeding) must be performed in three stages, collecting → storing → sowing based on a thorough knowledge of the individual properties of the seeds themselves. Simple collection and simple seeding can be done for all kinds of seeds, but to perform simple seed collection, the maturing period of the seeds is clarified, and to perform simple seeding, the basic steps are removing the raw humus from the ground surface, sowing the seeds, and placing enough soil to cover the surfaces of the seeds.

Basically revegetation of rock ground is not done.

- Basically this is not done, because it often creates unnatural scenery and there are few cases where it is necessary to carry out emergency measures to control sediment runoff.

Matsuki hillside work: example of rock revegetation
Rock revegetation is done as a measure to prevent surface erosion of weathered rock under harsh climatic conditions such as freezing and cold wind damage during the winter.
As a measure to prevent falling rocks during the work on the lower slope, net work is often done on exposed rock near the top of the slope, but simple revegetation is avoided whenever possible.

To encourage the transition to the target forest

Problems such as delayed transition of species by vegetation with excessive fecundity.

- The following are conditions for the early introduction species when the first priority is early
revegetation.

- From the start of its growth, it is highly adaptable to direct sunlight, drying, freezing and other climatic conditions and to the soil texture.
- There are many seeds from stock trees and they are widely available.
- It grows quickly.

But carrying out improvements looking ahead to the formation of the target forest must be done carefully, because the high fecundity (competitiveness) of the early introduction species may cause problems such as delayed transition.

- Coniferous trees such as pine and Japanese red cedar are often used because of their high fecundity, but their needles do not decompose easily so that soil does not form for a long time. And the needles that are not decomposed cover the ground, preventing the invasion of other species, also delaying the transition.

Tanakamiyama hillside work: A clear cutting experiment was done to simulate a case where all pines dried up leaving the land almost bare, but because there were no stock trees, vegetation did not invade even though the light conditions were good. Later broad-leaved trees were planted at the same location, but they did not grow. It is hypothesized that this failure occurred because the pine needles were deposited in a lower layer without decomposing, so that soil is not formed.

Otomikawa hillside work: Example of the impact of early introduction planting work over a long period
A long period of time passed without any transition from the transplanted trees that were introduced early. Then 50 years after the execution, the originally planted trees had declined and completely disappeared, allowing a low forest to form by natural invasion.
To introduce early introduction species, it is necessary to give careful thought to the constituent species when the transition to the target forest has been completed.

- The early introduction species should be selected by giving careful thought to the constituent species when the transition to the target forest has been completed.
- From the start of the execution, the pioneer vegetation and the next generation vegetation should be mixed.
- The initial introduction species are selected according to local conditions with reference to nearby transition processes without necessarily being limited to the normal vegetation transition process (annual grasses → perennial grasses → low trees → high trees).
- Native species (if possible, locally produced species) should be used whenever possible.

Japanese alder (*Alnus japonica* (thunb.) steud) or firma alder (*alnus firma*) that have nitrogen fixing bacteria that help the growth of vegetation are selected as early introduction species.

- Selecting species with nitrogen fixing bacteria effectively establishes vegetation. Until now, legume vegetation that includes black locust (*Robinia pseudo-acacia*) and false indigo (*Amorpha fruticosa*) has been widely used. However, considering later vegetation transition, these should be avoided as much as possible, and at the same time Japanese alder (*Alnus japonica* (thunb.) steud) or firma alder (*alnus firma*) that have nitrogen fixing bacterial may be selected.

Species that must be handled carefully are legume vegetation that include false indigo (*Amorpha fruticosa*) and black locust (*Robinia pseudo-acacia*), and exotic gramineous vegetation typified by Kentucky 31 fescue.

- The following are species that must be handled carefully when they are introduced.
  - If too many seeds of *Lespedeza* vegetation such as false indigo (*Amorpha fruticosa*) are sowed, their roots are thickly concentrated near the surface, delaying the transition by preventing the invasion of other vegetation.
  - Because *Lespedeza* vegetation such as false indigo (*Amorpha fruticosa*) have nitrogen fixing bacteria, if too much is spread, the soil acquires excessive nitrogen. This results in the ground being dominated by gramineous vegetation or bamboo grass that thrive on nitrogen, delaying the transition by preventing the invasion of other vegetation.
  - The fecundity of black locust (*Robinia pseudo-acacia*) is extremely high, delaying transition by preventing the invasion of other vegetation. And because its roots are shallow so that it is easily toppled, it should not be selected because it is not suitable for slope stabilization.
  - Exotic grass vegetation typified by Kentucky 31 fescue requires a large quantity of fertilizer, and when the fertilizer is exhausted, it dries up. Another reason it should not be selected is that
because its color is unnaturally blue when it is flourishing, it often seems in disharmony with the surrounding scenery.

Upper slope of the Mizutani hillside work: overall luxuriant growths of Chinese lespedeza (Lespedeza juncea), bush clover (Lespedeza bicolor), and false indigo (Amorpha fruticosa) introduced as early introduction species have appeared more than 10 years after execution, but no conspicuous transition can be seen.

Ushibushi hillside work: Case of problems caused by black locust (Robinia pseudo-acacia) Initially, red pine, himeyashabushi alder (Alnus pendula matsumura), and black locust (Robinia pseudo-acacia) were planted, but later the ground was almost completely taken over by black locust (Robinia pseudo-acacia). Consequently, the forest physiognomy was transformed in order to prevent disasters caused by an exclusively black locust (Robinia pseudo-acacia) forest and resolve ecological problems, then measures were taken to encourage a native species forest consisting mainly of the exotic species, konara (Quercus serrata Thunb. ex. Murray), oak (Quercus crispula Blume), Japanese chestnut (Castanea crenata), Japanese linden (Tilia japonica), sawagurumi (Pterocarya rhoifolia), and Japanese katsura tree (Cercidiphyllum japonicum).
4. Evaluation and appropriate management of the degree of achievement of the improvement target

4.1 Why is an evaluation necessary?

(26) In order to prevent unwanted results such as restoration of the wasteland, it is necessary to clarify the process of the growth in order to evaluate the degree of achievement of the improvement target.

• Several decades are necessary to complete transition to the target forest, and in order to prevent unwanted results such as the restoration of wasteland, it is important to clarify the process of growth. This means that various monitoring surveys must be performed every 3 to 5 years to evaluate the degree of achievement of the improvement target at the time of each survey. The results also provide basic information to determine the need for management and management methods.

4.2 What is the object of the evaluation?

(27) The evaluation is done by performing monitoring to determine how firmly the vegetation has been established and the state of transition of the vegetation, formation of soil, control of the runoff of sediment and so on to find out how much progress is being made to reach the target.

• The principal items evaluated are:
  • State of establishment (growth) of species
  • Transition (invasion) of vegetation
  • State of development of the soil ➔ soil hardness survey, ph test
  • State of control of sediment runoff ➔ sediment runoff survey

And as necessary, surveys of the change over time of species of biological communities and number of each species are performed to evaluate the degree of the restoration of the natural environment by the hillside work based on indices of similarity.

○ Confirming the vegetation foundation stability (degree of rot survey)
  • Clarification of the degree of rot using a Yamanaka type soil hardness meter
  • Observing and recording the degree of rot by visual examination

○ Confirming the establishment of the vegetation
  • Hillside work introduction effects (observing and recording the establishment of the vegetation)
  • Relationship with the characteristics of collapsed ground (measuring the soil layer thickness and the slope gradient)

Tsuchiyabara hillside work: Various surveys shown on the left are performed after execution to verify the effectiveness of introduction and to study the effective application of the method according to local characteristics.
4.3 What is appropriate management?

(28) When the transition to the target forest has been obstructed, its cause must be discovered to perform suitable management to resolve the problem.

- When the results of an evaluation of the degree of achievement of the improvement target reveals any of the following signs of the obstruction of the transition to the target forest, it is necessary to perform appropriate management to encourage the transition to the target forest.
  - The vegetation is not established.
  - The vegetation has deteriorated (return of wasteland conditions)
  - Clear delay in the vegetation transition considering the elapsed time is revealed.
  - Sediment runoff control effects have not improved.
  - The following appropriate management is performed according to the cause and urgency.
    - The situation is not serious and its cause is not specified → continued observation of the process
    - Light conditions are poor so that grasses and next generation vegetation do not grow (or do not invade) → thinning trees, forest physiognomy conversion etc.*
    - Confinement by grasses → mowing grass, mulching
    - Poor growth caused by soil conditions (soil particle diameter, dryness) → soil improvement by wood chips, mulching
    - Pest (insects/vermin etc.) → nets, installation of vegetation protection pipes

Forest physiognomy transformation* — In order to qualitatively improve the existing forest, new vegetation is introduced and aggressively managed on land where existing trees have been removed by thinning or clear cutting to encourage the growth of a more stable forests.
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Matsuki Hillside Work

The Ministry of Land, Infrastructure and Transport (Wateraze River Office) formed a committee of scholars and representatives of concerned organizations to compile the Guidelines for Matsuki Hillside Work Revegetation (Draft). It is working to restore greenery through links with the local residents according to the Guidelines. The following are the major features of the Guidelines:

- Its major goal is to revegetate the hillside slopes to control the runoff in order to guarantee the safety of the region and its aim is to restore nature by forming zones of terraced land suited to the Matsuki District.
- It calls for regular monitoring surveys to increase the effectiveness of the revegetation methods under harsh revegetation conditions. It also offers guidelines to carry out revegetation project while revising them based on the results of the monitoring.
- In the future, links with volunteers will be strengthened to perform revegetation while maintaining a cooperative organization.
- The successful results of revegetation projects will be used as opportunities for sales and environmental education and as a tourist attraction in order to contribute to the region.

Advice from Professor Ota

Concerning the soil
There was fear that heavy metals in the soil at this location would obstruct the growth of vegetation. It is assumed that soil dressing is effective in such cases, but the deep layer base material spraying method that is now used can only guarantee soil to a depth of 10cm, so that it is difficult for tall trees to take. To be sure that tall trees will take, from 30 to 50cm of soil is necessary, and considering the slope gradient, it is difficult unless terraces are cut into the slope.

Concerning rock revegetation
Revegetation of rock often creates unnatural scenery; so its use must be studied carefully. A method often used to prevent rocks from falling when performing work at the bottom of a slope is to spread net work over the exposed rock at the top of the slope, but simple revegetation to prevent this should be avoided.
Oya Hillside Work

Outline

Mt. Oya, one of the sources of the Abe River, is the site of the Oya Slide, one of Japan's three most massive slides. The Oya Slide, which covers an area of 1.86 km² with a width of 1.2 km and an elevation difference of 500 m, is estimated to have discharged 120 million m³ of collapsed soil. The geology in this zone is characterized by layers of shale and sandstone from the Paleocene period, with remarkable changes caused by faults and folds produced by structural movement, which have resulted in severe cracking and block sliding. The Oya Slide was triggered by a large earthquake in 1707 and the sediment it produced triggered a severe earthquake in 1708. Therefore, hillside revegetation was done to stabilize the area and prevent further damage. The Hillside work on the Oya Slide was undertaken to (1) form a stabilized area by revegetation, (2) control sediment production from slides, and (3) supply the unstable sediment to the river. The characteristics of the work methods were confirmed by monitoring, and the results show significant improvements.

Table:

<table>
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<th>Purpose of improvement</th>
<th>Prevent erosion of the collapsed ground</th>
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<td>Tertiary zone</td>
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<td>Soil</td>
<td>Conglomeratic soil</td>
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<tr>
<td>Execution location</td>
<td>Shizuoka City, Shizuoka Prefecture</td>
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<td>Work method, form</td>
<td>Hillside terracing work, steel fence work, transplanting, spraying special mortar</td>
</tr>
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<td>Slope</td>
<td>30°</td>
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<tr>
<td>Gradient</td>
<td>SE</td>
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<td>Jurisdiction</td>
<td>MLIT Chubu Regional Development Bureau, Shizuoka River Office</td>
</tr>
<tr>
<td>Execution years</td>
<td>1966 to present day</td>
</tr>
</tbody>
</table>

Diagram:

- Location Map
- Section Diagram
- Rockfall prevention work
- Rockfall spraying work

Legend:
- Work scheduled to begin in 2003
- Range of work completed before 1999
- Range of work completed between 1999 and 2002

Note:

- The image includes various diagrams and tables related to the Oya Hillside Work, showing the area's topography, geology, and the work performed.

- The work focused on preventing erosion, stabilizing the area, and controlling sediment from the slide.

- The results show significant improvements in the area's stability and sediment control.

- The work methods were confirmed by monitoring, and the results were positive.
Case 3
Tanakami Hillside Work

Outline

More than one thousand years ago, the Tanakami Mountain area was a vast beautiful of luxuriant Japanese cypress, Japanese cedar, and evergreen oaks. Later during the Asuka and Nara Periods (seventh century), the arrival of Buddhism and the continental culture spurred the establishment of palaces, shrines, and temples, requiring that vast numbers of Japanese cedar and other trees be cut and transported by water to locations where they were used as lumber. In this way, a primary beautiful forest of Japanese cedar and evergreen oaks was replaced by secondary forest (pine). Later as the arts and crafts advanced, pine was cut excessively to provide fuel to make ceramics. And as a key point on transportation routes, the province of Omi was at the center of frequent wars accompanied by attackers burning their enemies' towns and setting continuous forest fires. Because the geology of the Mt. Tanakami region consists of deep layers of weathered granite, once its trees were removed by the above actions, every rainfall ran off its surface soil, increasing the destruction of its land. By the seventeenth century, the sides of the mountain were so completely devastated that not one tree remained, inflicting the downstream residents with constant sediment disasters. Mt. Tanakami has been revegetated and hillside works done to stop surface erosion from running off sediment. Tanakami hillside work projects have been underway for more than 120 years beginning in the late nineteenth century. Sediment production source measures have been extremely effective, and the methods used have matured. The methods used have been earth retaining work as hillside terrace, hillside terracing work as hillside terrace, and hillside terracing work as hillside terrace. Covering work (slope revegetation), transplanting work (black pine, hinoki cypress, and so on). And as a way of encouraging the growth of needled after transplanting, hillside tending method A and B have been established. And to guarantee the sediment production reduction measures continue to be effective far into the future, it is essential to transform it from a forest consisting of only pine trees to a forest phylogeny that will not cause it to return to its devastated condition.
Tsuchiyabara Hillside Work (Shorenji River Hillside Work)

Outline

The mountains in the Kizu River Basin were once covered with huge luxuriant forests, but the advance of civilization destroyed them as, during the Nara Period in particular, unrestricted cutting to obtain lumber to build temples and shrines deforested the land. As the deforested area expanded to 4,500 hectares, the sediment runoff from its surface caused frequent disasters in the downstream river basin. To resolve this problem, beginning in the late nineteenth century, the government undertook sabo projects consisting mainly of hillside work to reorientate the deforested land. By 1969, hillside work had been completed on 2,600ha in the Kizu River Basin. But in the upstream Kizu River Basin, torrential rainfall including that brought by the Isae Bay Typhoon of 1959 collapsed slopes at many places (2,498) because of the granite topography in the region. Many of these were extremely small with surface areas less than 0.1ha on steep mountain slopes with gradients between 30° and 40° where work conditions are poor. The Upstream Kizu River Office has executed hillside works (slope-retaining work) to stop hillsides by using gravity concrete retaining walls and concrete secondary products etc., but it has faced cost problems and difficult executions. It has developed hillside work reduction methods based on the concept to stop the movement of sediment on the surface and then perform gramin sabo that does not require the use of concrete. It is an economical easily executed method that prevents the movement of sediment by combining thinned Japanese cedar and Japanese cypress logs and anchoring them to the slope with wooden stakes.

<table>
<thead>
<tr>
<th>Purpose of improvement</th>
<th>Prevention of the expansion of collapsed ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>Granite zone</td>
</tr>
<tr>
<td>Soil</td>
<td>Rock pebbles</td>
</tr>
<tr>
<td>Execution location</td>
<td>Ushijima, Nara Prefecture</td>
</tr>
<tr>
<td>Work methods, form</td>
<td>Slope cutting, earth retaining work,</td>
</tr>
<tr>
<td></td>
<td>hillside drainage, concrete secondary work,</td>
</tr>
<tr>
<td></td>
<td>wooden form work, transplants work (cuttings)</td>
</tr>
<tr>
<td>Slope</td>
<td>-</td>
</tr>
<tr>
<td>Gradient</td>
<td>-</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>MLIT, Kinki Regional Development Bureau, Kizu</td>
</tr>
<tr>
<td></td>
<td>River Office</td>
</tr>
<tr>
<td>Execution years</td>
<td>1969 to 1991</td>
</tr>
</tbody>
</table>

Cuttings (Willow, eulalia, sakura, and other trees) brushwood were placed at lateral intervals of 30cm and longitudinal intervals of 90cm.

Fascines were inserted at lateral intervals of 30cm and longitudinal intervals of 0.66 cm.

Immediately after completion (1991)
Six months after completion (1991)
One year after completion (1992)

Immediately after completion (1989)
One year after completion (1990)
Three years after completion (1993)
Twelve years after completion (2003)

2002
Rokkozan Chain Green Belt

Outline

In the late decades of the nineteenth century, the forests on the Rokkozan chain were devastated by unrestricted cutting of trees to obtain firewood. The slopes of the Rokkozan chain were naturally prone to collapse, because they consist mainly of granite and many of their slopes are extremely steep. Exposed to wind and rain, their devastation continued with every intensive rainfall causing disasters. Sabo projects that were started in 1983 to protect the city from sediment disasters have now restored their vegetation. But the trees on the Rokkozan chain include red pine and black locust (Robinia pseudo-acacia) that die very easily; a situation detrimental to sediment disaster prevention. But because the Rokkozan chain is located directly beside the city and is closely related to the lives of its residents, it is essential to not only provide protection from sediment disaster originating on its slopes, but to guarantee other functions including permitting its recreational use. The Rokkozan Chain Green Belt Project positions the slopes facing the city in urban plans as districts where particularly aggressive measures are necessary, and at the same time, provides groves on the Rokkozan chain to create forests that fill four functions: (1) preventing sediment disasters, (2) preventing urban sprawl, (3) conserving and nurturing a good quality urban environment, elegant scenery, ecosystem, and biodiversity, and (4) providing suitable places for recreation. To carry out a green belt development, the first step is to undertake aggressive measures utilizing civil engineering structures with top priority on preventing sediment disasters caused by the collapse of slopes. A forest consisting of only a single species of tree, such as kuroki, etc. is transformed to a forest with a developed stratified structure and a mixture of various species of trees of diverse age, by providing and managing its trees. Where good quality trees are now growing, they are conserved and further improved by carrying out regular inspections of these locations and cutting weeds or thinning trees as necessary.

Purpose of improvement
Replace trees that obstruct disaster prevention with trees that effectively prevent disasters.

Geology
Granite zone

Soil
Weathered rock

Execution location
Kobe City, Hyogo Prefecture

Slope Direction
SE – SW

Gradient
-

Jurisdiction
MLIT, Kinki Regional Development Bureau, Rokko Sabo Office

Execution years

Need for and purpose of forest physiognomy transformation and tree introduction
Replace trees that now hamper sediment disaster prevention (communities of Japanese cedar, Japanese cypress, communities of eucalyptus and mellita, Phoebeudus chinus var. vindis), communities of black locust (Robinia pseudo-acacia, etc.) by introducing and managing trees that effectively prevent sediment disasters.

Target forest
Forest with a developed stratified structure and a mixture of various species of trees of diverse age

Forest physiognomy transformation and tree introduction methods
- Planting Japanese cedar and Japanese cypress groves, Thinning 20 to 30% (Phoebeudus chinus var. vindis) and black locust (Robinia pseudo-acacia) groves
- Completely cutting the nezasa (Phoebeudus chinus var. vindis) and black locust (Robinia pseudo-acacia) in belts

Cutting
(Planted Japanese cedars and Japanese cypress groves)

Transplanting
(Transplanted tree species)
Korese oak (Quercus serrata Thumb. ex Murray), hornbeam, Korean hornbeam, fagus racemosa, Yamazakura (Prunus jatamakura Sieb. ex Koiz), Japanese oak, Japanese zelkova (Ulmus zelkova Zelkova serrata), (Thunb.), Mukusushi (Aphananthus aspera), etc.

Transplanted density (8,500 trees/ha)

Weeding and brushing
Once or twice a year, cutting bamboo grass, cutting black locust (Robinia pseudo-acacia) sprouts

Thinning
Done as necessary
Scheduled to be done as necessary with reference to the staged target (10 years in the future for example)

Fertilizing
Not done
Scheduled to be done as necessary with reference to the staged target (10 years in the future for example)

Follow-up survey
Done starting in 2001
- Height, branch spread, tree vigor of transplanted trees
- Starting in 2002, measurement of surface erosion of soil by tree type based on whether the forest is or not managed

- It is important to process the sprouts of black locust (Robinia pseudo-acacia) and to cut the nezasa (Phoebeudus chinus var. vindis)
- Because locations where forest physiognomy transformation is done are temporarily conspicuously almost completely bare of vegetation, it is necessary to explain the need and effectiveness of the project to residents to gain their understanding.
- It is necessary to establish a stable seedling supply system in the region.

Planning forest physiognomy transformation and tree introduction (manual, guideline, etc.)
Rokko Green Belt Forest Improvement Manual (Rokko Sabo Works Office, 2001)
Case 6
Dashidaira Revegetation Work

Outline

Work on the Ozosawa Hydroelectric Power Station was started in September, 1982 by the Kansai Electric Power Company and started full operation 3 years later on September 27, 1985 as a result of the Ozo-water flood prevention project. Developed based on the concept of integrated river system development, it is located at the Kurosawa Gorge, its total height of 79.7m constructed at the Dashidaira on the main course of the Kurobe River, to produce power by an effective drop of 103.7m. The construction of the Ozosawa Hydroelectric Power Station created the need for revegetation work on the right bank slope at the Dashidaira Dam. Because it is in a heavy snowfall area, transplanted trees were damaged by snow avalanches and by deer and Japanese serow that ate their foliage in the winter, hampering the revegetation. The Dashidaira's revegetation work was executed on the right bank slope at the Dashidaira Dam, and because it is in a national forest and national park, it was necessary to quickly form communities as similar as possible to natural forest. Therefore, the plan stipulated that first pioneering species would be introduced to form communities followed by a later transition to natural communities. In order to transplant pioneering species of vegetation and selected species that are suited to the Dashidaira District, the pioneering species selected were Abies (Abies sieboldiana matsumurae) and Manchurian oak (Ailanthus alternata). The selected species were Acer kawakamii, Japanese maple, Metasequoia glyptostroboides, Magnolia obovata, Plantago major, and Erigeron annuus. The work was completed in 1987.

Map of the surveyed district

Transplantation method by revegetation category

Revegetation category A (flat)

Revegetation category B (flat)

Revegetation category C (Longitudinal slope)

Legend

- Presence of tree
- Presence of sapling
- Presence of grass

Key

- Presence of tree
- Presence of sapling
- Presence of grass

Species

- Acer kawakamii
- Japanese maple
- Metasequoia glyptostroboides
- Magnolia obovata
- Plantago major
- Erigeron annuus
- Abies sieboldiana matsumurae
- Manchurian oak

Note

- Species selection based on the same as previous work.
Ushibuse River Forest Physiognomy Transformation

Outline

The Ushibuse River is a first class river that originates in the Hashibuse Mountain Yokomin to the east of Matsumoto City, converges with the Togawa River inside the city, then flows into the Japan Sea as its name changes to the Haruka River. Kuzu River, and finally to the Shinano River. The geology in the river basin is composed of sandstone, shale, conglomerate etc. above an elevation of 1,300m, while below that elevation, it consists of volcanic rock such as trapole and granite which are easily weathered and eroded. And because of its steep topography, the area has a long history of frequent sediment disasters. In particular, by the late nineteenth century most slopes in the water resource zone of the main course of the Ushibuse River, mainly those in around the Hikage Marsh and the Jokoji Gorge, were deforested and devastated. In response, the Sabo Division of the Home Ministry carried out Sabo works along the Ushibuse River for a five year period beginning in 1885. Then beginning in 1998, Niigata Prefecture took over Sabo works on the Ushibuse River with financial assistance from the national government, finally completing a series of projects in 1998. To restore the trees on the devastated slopes along the Ushibuse River, red pine, black locust (Robinia pseudo-acacia) etc. were planted. Of these, the black locust, being a dominant species, are now distributed widely, but the black locust are near the end of their lifetime, and toppled trees have caused disaster prevention problems. And because they mature quickly, obstructing the germination and growth of other native species, they have been completely cut in order to transform the forest physiognomy to a forest of deciduous broad-leaved trees native to the region. Since 1997, forest physiognomy transformation work has been completed on about 32ha of the upstream region.

Need for and purpose of forest physiognomy transformation and tree introduction

The locust (Robinia pseudo-acacia) that have become most of the tall trees in the area are aging and as they fall over, they increase the risk of disasters caused by collapsed soil and flooding logs. And their high fecundity prevents the invasion of natural vegetation. The forest physiognomy transformation project was undertaken to reduce disaster problems and to protect the region's ecosystem.

Target forest

Forest of a large variety of deciduous broad-leaved trees native to the region (kame and kane) (Quercus serrata 'Thunb. ex Murray'), mitsubusa (Quercus crispula Blume), sawgurumi (Perecoryx rotipes), katsura tree (Cercidiphyllum japonicum), etc. (secondary deciduous broad-leaved forest).

Cutting

Culling all black locust (Robinia pseudo-acacia) in bands 15m in width.

Forest physiognomy transformation and tree introduction methods

1. Tran-planting (Transplanted tree species) forest banks: sawgurumi (Perecoryx rotipes), katsura tree (Cercidiphyllum japonicum), tohime (Acer pectinatum), ohno (Ulmus lactea), shiga (Ulmus pumila), and Japanese chestnut (Castanea sieboldii Castanea), Japanese hiba (Tilia japonica), mitsubusa (Bataula grossa Sieb. et Zucc.), Japanese hornbeam (Carpinus japonica), yomatsukura (Phorono phantasma Sieb. et Zucc.) etc.

2. Weeding and brushing

Culling black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

3. Thinning

In principle, it is not done. It is expected that natural thinning will maintain the correct density.

4. Fertilizing

Not done.

Follow-up survey

Are performed annually beginning in 1997.

- Cutting rate and growth of trees
- Pest damage survey
- Toppled trees and transition in areas where execution has not been done

Challenges

- It is important to process sprouts of black locust (Robinia pseudo-acacia)
- Damage by foraging Japanese serow was a serious problem when the project began, but it has been almost completely resolved by installing protective nets.
- Because the mortality of saplings is high, it is necessary to find the causes and study countermeasures.
- It is necessary to establish a stable local sapling supply system.


Figure 2. Project Plan Diagram

Legend

Area transplanted in 2000
Area transplanted in 1999
Area transplanted in 1998
Area transplanted in 1997
Area transplanted in 1996

Project Plan Area: 32ha
First project section: 7.6ha

- In principle, it is not done. It is expected that natural thinning will maintain the correct density.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- In principle, it is not done. It is expected that natural thinning will maintain the correct density.

- Not done.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- Not done.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- In principle, it is not done. It is expected that natural thinning will maintain the correct density.

- Not done.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- Not done.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- Not done.

- Cutting black locust (Robinia pseudo-acacia) sprouts once a year (summer) and cutting grasses

- Not done.
Appendix

Chapter 7  Hillside Works

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 re-vegetate the execution site by directly introducing vegetation. The following are typical work methods included in both of these categories.

Hillside foundation work
- Small check dam work
- Slope cutting work
- Earth retaining work (block panel masonry work, concrete retaining wall work, concrete block masonry work, stone masonry work, wire mat work, concrete form work, etc.)
- Hillside drainage channel work
  - Channel work (corrugated channel work, stone pitching channel work, sodded channel work, fume pipe channel work, U-shaped channel work, concrete channel work)
  - Culvert work (fascine culvert work, gabion culvert work, pebble culvert work, porous pipe culvert work, chemical product culvert work, etc.)

Hillside revegetation work
- Fence work
  - Seedling terracing work (sod seedling terracing work, straw seedling terracing work)
- Hillside terracing work
  - Reinforcing work (sedge grass reinforcing work, sod reinforcing work, fascine reinforcing work)
  - Masonry work
  - Fascine masonry work
- Covering work (fascine covering work, straw covering work, straw mat covering work, net covering work, seed bag work, vegetation foundation work)
- Seeding work
- Transplanting work
- Contour line trench work

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

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

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 $\rightarrow$ earth retaining work (concrete retaining wall work, concrete block masonry work)

   (Places where natural recovery can be counted on)

   $\rightarrow$ Hillside work completed

   (Places where natural recovery cannot be counted on)

   $\rightarrow$ Hillside drainage work (corrugated pipe channel work, fascine culvert work) $\rightarrow$ Hillside terrace work (seedling terracing work, reinforcing work) $\rightarrow$ covering work $\rightarrow$ transplanting 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

- a) There is a valley with great longitudinal erosion
  - YES: Small check dam work
  - NO

- b) There is danger of a collapse above and a relatively good foundation
  - YES: Earth retaining work
  - NO: Earth pressure
    - High: Foundation work
      - Good: Wet stone masonry work
        - Concrete retaining wall masonry work
        - Concrete block masonry work
      - Bad: Concrete form work
    - Low: Foundation work
      - Good: Dry stone masonry work
        - Block panel masonry work
      - Bad: Wire mat work

- d) The slope is uneven and unstable
  - YES: Slope grading work
  - NO: Seeding work
    - Bad: Sod is obtainable
      - OK: Sod seeding terracing work
    - Good: Straw seedling terracing work

- k) Slope surface erosion between hillside terrace work etc. is predicted
  - NO: Covering work
    - Relatively steep slope
      - YES: Soil layer is remarkably thick
        - YES: Seed bag work
          - Vegetation foundation work
          - Completion of hillside work
        - NO: Fascine covering work
          - Straw work
          - Straw mat work
      - NO: Reinforcing work
        - Relatively high moisture content
          - Masonry work
        - Many boulders and normal high moisture content
          - Sod reinforcing work
        - Soil properties are good and little erosion by rainfall
          - Sod reinforcing work
        - Soil properties are good and it is relatively gentle slope
          - Sedge grass reinforcing work
        - Relatively high moisture content
          - Fascine reinforcing work
        - Masonry work
        - Sod reinforcing work
  - YES: Reinforcing work
    - NO: Sod reinforcing work
      - NO: Fascine masonry work
(2) Collapsed ground

- Longitudinal erosion is severe and there are large gullies.
  - Yes: Small check dam work
  - No: Same as (b) in (1)

- Earth retaining work
  - Yes: Same as (c) in (1)
  - No:
    - Place where natural recovery can be counted on:
      - Yes:
        - Scouring by surface water such as rainwater is predicted:
          - Yes: Channel work
          - No:
            - Large ground water and subsurface flow that is predicted to cause a collapse:
              - Yes: Culvert work
              - No:
                - Location conditions:
                  - Relatively good:
                    - Same as (f) in (1)
                  - Bad:
                    - Seeding terracing work
                  - Reinforcing work
                    - Same as (k) in (1)

- Covering work
  - Same as (l) in (1)

Completion of hillside work

- Place where natural recovery cannot be counted on or place that must be revegetated quickly:
  - Yes:
    - There is complex relief on the topography:
      - Yes: Corrugated channel U-shaped channel
      - No:
        - Water volume is high and it is assumed sediment is transported:
          - Yes:
            - The slope is gentle and water volume is low:
              - Yes:
                - There is intermittent movement of soil and it is relatively short:
                  - Yes:
                    - Fascine culvert
                    - No:
                      - Gabion culvert work Pebble culvert work
                      - Porous pipe culvert work Chemical product culvert work
          - No:
            - There is intermittent movement of soil and many boulders:
              - Yes:
                - Masonry work
                - No:
                  - Fence work
                  - Fascine masonry work
  - No:
    - Same as (g) in (1)
    - Same as (h) in (1)
    - Same as (i) in (1)
    - Same as (j) in (1)
Figure 3-12. Section Drawing of Deforested Ground (Sample Execution) (unit: m)
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 steeply 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.

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

(a) Dry stone masonry work

(b) Wet masonry work

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 at 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.

![Hillside work execution](image)

(a) Front view

![Fascine scrap brushwood](image)

(b) Sectional view

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.
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 were 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**
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.

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](image1)

![Figure 3-26. Straw Work and Vegetation Bed Work](image2)

### 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

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

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](image)

(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

<table>
<thead>
<tr>
<th>Tree name</th>
<th>Applicability</th>
<th>Reforestation method</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red pine</td>
<td>Used inland because of its poor resistance to sea breezes.</td>
<td>Transplanting and seeding</td>
<td>Good Good Strong Strong Weak Strong Weak</td>
</tr>
<tr>
<td>Black pine</td>
<td>It is the most commonly used.</td>
<td>&quot;</td>
<td>Good Good Strong Strong Medium Strong Weak</td>
</tr>
<tr>
<td>Black locust</td>
<td>Collapsed ground, deforested hills that are a little fertile</td>
<td>&quot;</td>
<td>Good Good Strong Strong Weak Strong Medium Weak</td>
</tr>
<tr>
<td>Screw pine</td>
<td>Suitable for most devastated ground, but unsuited to cold winds.</td>
<td>Transplanting, cuttings</td>
<td>Good Good Strong Strong Weak Medium Weak Weak</td>
</tr>
<tr>
<td>Black locust</td>
<td>Locations and those with strong winds.</td>
<td>Cutting, branch spreading, seeding</td>
<td>Good Good Strong Strong Weak Strong Medium</td>
</tr>
<tr>
<td>False indigo</td>
<td>The most applicable species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrubby bush clover</td>
<td>Same as false indigo</td>
<td>&quot;</td>
<td>Good Bad Strong Strong Weak Strong Weak Medium</td>
</tr>
<tr>
<td>Japanese alder</td>
<td>Dryness tolerant</td>
<td>Transplanting</td>
<td>Good Medium Strong Strong Strong Weak Strong</td>
</tr>
<tr>
<td>Manchurian alder</td>
<td>Suited to very cold locations</td>
<td>&quot;</td>
<td>Good Good Strong Strong Strong Medium Strong</td>
</tr>
<tr>
<td>Alder (<em>Alnus porosa</em> matsumura)</td>
<td>Suited to locations other than cold locations</td>
<td>&quot;</td>
<td>Good Good Strong Strong Weak Strong Strong</td>
</tr>
<tr>
<td>Alder (<em>Alnus rhombifolia</em> matsumura)</td>
<td>Suited to most devastated ground</td>
<td>&quot;</td>
<td>Good Good Strong Strong Weak Strong Medium Strong</td>
</tr>
<tr>
<td>Yamamomo (<em>Myrica rubra</em>)</td>
<td>Suited to warm locations</td>
<td>&quot;</td>
<td>Bad Good Strong Strong Weak Medium Strong Strong</td>
</tr>
</tbody>
</table>
(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.
Part 8. Other structures

8.1 Other structures

Sabo structures shall, as necessary, be management use channels, access steps, fishways, fences, and so on.

(Reference 3.4) Sand catching works

Sand catching works, that are upstream sabo works executed when it is impossible to reduce the quantity of sediment that is run off to the allowed quantity of sediment in the downstream channel, are designed to fully satisfy their purpose accounting for the topography, geology, and vegetation of the river basin, the riverbed gradient, form of sediment runoff etc., and also accounting for safety, cost, and maintenance.

Sand catching works that deposit soil, sand, and gravel by expanding part of the channel are often constructed at the top ends of areas subjected to debris flows, fans, and channel works.

The capacity of sand catching works is determined by the predicted quantity of sediment that will be deposited, but it should be at least the capacity that permits its function to be recovered by removal work done once a year, and considering the convenience of the deposited sediment removal work, a transport channel and other structures are designed.

The plane shape of sand catching works is designed considering topographical conditions, but there are cases where it is square or shaped like a shogi-piece, sake bottle, or a stomach. (see Fig. 3-30).

(a) Square  (b) Shogi-piece  (c) Sake bottle shape  (d) Stomach shape

Figure 3-30. Examples of Plane Shapes of Sand Catching Works

To prevent excavation and removal of deposited sediment in sand catching works from obstructing the torrent banks upstream and downstream from the works, as necessary, sediment check dam work or groundsill work are executed as dividers in the upstream and downstream courses to maintain the torrent bed. If the inlet abruptly widens, sediment settles near the inlet and the deposition of the sediment advances upstream, reducing the river area in the upstream channel causing the water to overflow its banks. While it varies according to conditions of the torrent flow and the execution location, the widening angle $\theta$ of about $30^\circ$ is appropriate based on past experience (see Fig. 3-31).
Figure 3-31. Widening Angle of Sand Widening Works

The following is the general sand catching works design procedure.

Table 3-11. Sand Catching Works Design Procedure

<table>
<thead>
<tr>
<th>Location of the sand catching works</th>
<th>Shape of the sand catching works</th>
<th>Sediment storage capacity</th>
<th>Quantity of sediment removed</th>
<th>Revetment design Groundsill work and check dam design Sediment transport plan</th>
<th>Design of other structures</th>
</tr>
</thead>
</table>
