EROSION CONTROL

IN

MOUNTAINEOUS AREAS

February, 1981

Japan International Cooperation Agency

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CHAPTER I EROSIONS IN MOUNTAINOUS AREAS

Section 1 Erosions In Mountainous Areas and Wild Torrens

Erosions in mountainous areas may be classified into the following in accordance with their types and generation sites.

- Hillside Slopes
  - Sheet Erosions
  - Hillside Landslide, Landslide or Landcreep
- Stream Beds
  - Mud Flow
  - Tractive Transportation

Soil which is generated by surface erosions, hillside landslides, landslides (landcreeps), etc. from hillsides are transported over torrentbeds until the majority become accumulated in the alluvial cone down the torrent. Additionally, soil accumulated on the torrentbed become eroded mud flow as well as the flow of water (tractive force), and the transported downstream. Drainage besin where this type of earth and woil movements occur may be segregated into the production zone, the transportation zone, and the sedimentation zone as illustrated in diagram 1-1. Torrents are therefore often devastated by the aforementioned erosions in the soil production zone. Such Streams are called wild torrents. The torrentbed sediment in torrents are vigorously agitated in the form of mud flow, and often cause disasters downstream by transporting immense volumes of sediment. The transportation zone is the span of torrent between the production zone and the sedimentation zone, where only sediment transport occurs. The sedimentation zone is in the form of alluvial cones by the deposited earth and sand from upstreams. These alluvial cone areas often become disaster sites since they are widely employed by mankind. In actual drainage basin, though, these aforementioned three zones are often not in order, and are connected with rivers downstream in orders such as the production zone to the sediment transport zone or in orders the production gone to the sedimentation zone.

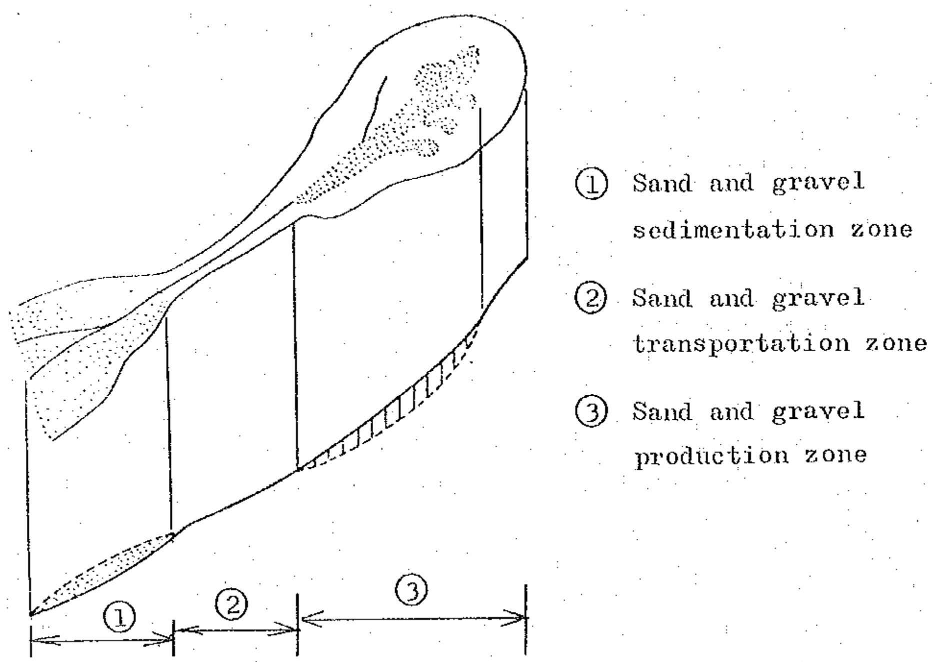


Diagram 1-1 Classification of Wild Torrent

Section 2 Primary and Provocative Causes of Erosion

The ratio and volume of erosion may be thought to be determined by the relative amount of the erosion generation effect (the volume of the provoking cause, force of erosion) and the erosion resistance of the ground or erodibility (the volume of the primary cause). The main factor of erosions is precipitation, and the erosion resistance is determined by the condition of the ground surface.

1. The Primary Causes and Their Dominant Factors

Primary Causes are elements such as geological structure, topography, soil, and forests which determined the erodibility of the land.
The topography mainly effects through slopes, and the steeper the slope, the more erodible the topography for both sheet erosion and landslides.
Soil characteristics are mainly dominated by the parent rock since soil is a weathered form of the parent rock. In general, viscous soil with

greater cohesion exhibit better erosion resistance than sandy soils. Forests greatly reduce erosions with its great functions to protect the soil surface and to secure surface soil with roots. Therefore, erosions are increased when landscapes become bare by timber drain. Smoke demaged lands and bare hills are some of the examples of the aforementioned phenomenon.

Erosions are caused by rock in the final stage crumbling into pebbles and being washed away. Therefore, the geological structure of the land greatly effects erosion. The following two factors describe the potentialty of erodible land. The first is the land being comprised of highly erodible mediums, and the second is when rockes have been transformed into clay and granules. The latter is caused by rock alteration. Terrain comprised with volcanic clastic materials is an example of naturally poor erosion resistance areas. Volcanic clastic materials are comprised of volcanic ash, volcanic gravel, and pumice, etc. and are extremely erodible. Large scale volcanic gullies where valley walls have fallen and wild torrents with large volumes of earth transported in the form of debris flow have been found in volcanoes and their vicinity. Furthermore, the Tertiary Green Tuff display poor cohesion characteristics being volcanic ejecta, and therefore are highly erodible. Hillside landslide and landslides often occur in Green Tuff regions. The change of rocks in the lithosphere into granules and clay are called alteration. This alteration may be segregated into the cataclastic deformation and the hydrothermal alteration. On the other hand, th transformation of rocks into granule within the atmosphere is called weathering, and may be segregated into physical, chemical, and biological weathering processes. Cataclastic process among other forms of alterations, is always accompanied by weathering, and this combination greatly facilitates erosion of rocks.

(1) Alteration of Rocks

1) Cataclastic Process

This is the process where sub-surface rocks are destroyed by immense force under low temperature and pressure. Hereby, these rocks are transformed into so-called fractured rocks. For example, rocks such as shale are broken into small phyllite forms and become black coloured clay. On the other hand, hard sand-stones and granite are broken into block forms. Rocks which are broken physically by cataclastic process often weather chemically and become clay. The area which underwent cataclastic process generally have an expanse with a certain length and width. This expanse is called the fractured zone. This fractured zone appears in coincidence with the geological structure belt. Therefore, mountainous regions along the geological structure belt are highly erodible, and exhibit significance in large scale hillside landslide and landslide occurences. Rocks along this geological structure belt are broken and weathered throughout the region, causing hillside landslides and landslide as well as wild torrents.

2) Hydrothermal Process

Rocks in volcanic regions are transformed at times by hydrothermal alteration. These phenomena may be observed in hot springs. Rocks in hydrothermal alteration zone are chemically transformed by high temperature gas mainly comprised of hydrogen sulfide, sulfur, and steam into clay named hydrothermal deposit or sulfataric clay, exclusive of this region. This clay at times become the cause of landslides.

(2) Weathering of Rocks

1) Physical Weathering

Physical weathering may be segregated into temperature variation as well as freezing and thawing. Rocks are destroyed by the repetition of contraction and expansion when excessive temperature va variations occur since the individual minerals contained exhibit different thermal expansion rates. This phenomenon occurs in areas where the temperature varies greatly during the day and night. Additionally, rocks are also destroyed by the repetition of freezing and thawing of water seeped in cracks since congealed water generates cubic expansion. This phenomenon is the main cause for sub-surface rocks to become destroyed along joints.

2) Chemical Weathering

Chemical weathering may be segregated into oxidation, hydrolysis, and resolution. Cubic volume become increased during alteration by oxidation, and destruction become facilitated since large amounts of iron are contained in rocks. This form of weathering is called oxidation. Hydrolysis is a phenomenon where minerals become structurally transformed by water. This phenomenon plays an important role in the weathering of granites. Rainwater contains large amounts of carbon dioxide which resolve the mineral ingredients of rocks. This form of weathering is called resolution. This phenomenon is most significant in lime stone terrains, where harst topography exclusive of such areas are generated.

3) Biological Weathering

Plant roots penetrate cracks and mechanically destroy rocks. Additionally, carbon dioxide produced by plant putrefaction and respiration are dissolved with rain water which facilitate chemical weathering.

2. The Provacative Causes and Their Amount

Sheet erosions and sediment are proportional to the intensity and amount of rainfall. On the other hand, erosions in the form of landslides as well as muds flows do not necessarily occur frequently in heavy rainfall regions, but is greatly ruled by the intensity of rainfall beyond the extent of the region's normal rainfall intensity. From these points, the probable rainfall described by the return period exhibit great importance.

Snowfall, earthquake, and wind are some of the provoking causes other than rainfall. Snow deposits become avalanches which generate surface erosions and landslides. Besides the generation of avalanches, snow deposits carry away earth along with the flood of melted snow.

Those countries in Circumpacific Volcanic Zone are noted for earthquakes, and large magnitude earthquakes have been experienced. Earthquakes directly cause landslides as well as it is thought to be an indirect cause, by generating fissures in rocks. Drifting sand are caused by the wind in sandy regions and shifting of beach sand dunes occurs.

Section 3 Sheet Erosion

Bare-lands are eroded by rainfalls as though the individual top soil layers are peeled away independently from the surface layer. This form of erosion is called sheet erosion, and is exclusive in that the individual soil particles are washed away independently by water. Sheet erosions are frequently found on bare mountains as well as abservable in granite and Tertiary period Layer hills. Other than the aforementioned, excessive sheet erosions may be seen in bare lands around volcanoes and landslide sites. Furthermore, sheet erosions are becoming more evident in artificial bare-lands produced by developments in recent years.

1. Development of Sheet Erosion

Two regions may be observed from the top and bottom of slopes in sheet erosion generation areas. The first is the region where erosion takes the form of uniformed removal of top soil. The other is observable in the lower regions where erosions are concentrated in the highly evident concave water-paths. The first type is called sheet erosion region and the other is called the rill erosion region (gully erosion region). The volume of erosions caused by rill erosions are considerably larger than those of sheet erosions, and gullies are developed within a short period of time.

Diagram 1-2 Bare mountain

Sheet erosions are greater with larger surface flow of rainfall on the ground. However, though, it is necessary to undersand that raindrops play an important role in generation of ground surface flows. Raindrops clamp, mix up, and splash upon contacting the ground, mixing-up and aplash are the important effects among the three. Narrow gaps between soil grains form paths for raindrops from the ground surface. These two effects clog the aforementioned paths with soil grains forming a thin soil layer which prohibits the infilteration of rain water. Hereby, surface flows become increased considerably.

Surface erosion volumes are relative to the water depth and the flow speed, and is considerably increased when the discharge becomes large. Therefore, uneven surface slopes emerge. Discharge becomes larger in cave regions where the rate of erosion becomes immensely increased. These phenomena genarate further concentration of rain water which accelerate erosions and gully generations.

2. Sheet Erosion Volume

Sheet erosions occur not only on bare-lands, but also on terrains with incomplete surface overlay. Therefore, top soil moves slightly by sheet erosions even in woods and grass lands. Additionally, erosion volume differs greatly depending on the topography, soil, and climate even in terrains with similar surface cover. Chart 1-1 describes the approximate annual volume of erosion on a slope with 15 degree incline. Woods and grass lands exhibit the lowest figures. However, woods lands incomplete overlay present poorer characteristics than well covered grass lands. Erosion volumes therefore are greater in prescribed burning lands and over-grazing forests than well conditioned grass lands.

Chart 1-1 Approximate Annual Erosion Volumes In Accordance With Surface Covering Types

Surface Covering	Devastated Land	Bare Land	Farm Land	Grass Land Wood Land
Annual Soil Erosion Volume (mm)	$10^{2} \sim 10^{1}$	$10^{1} \sim 10^{0}$	$10^{0} \sim 10^{-1}$	$10^{-1} \sim 10^{-2}$

(by Takeo Kawaguchi)

Section 4 Hillside Landslide

1. Generation and Classification of Hillside Landslide

The phenomena where a part of the hillsids slopes lose stability resulting massive instantaneous downward movements of earth and sand is called hillside landslide. Scale of hillside landslides very greatly from small 10m^2 to large hillside landslides in excess of 10ha. Additionally, the thickness of earth fallen by hillside landslides vary from under one meter to over ten meters. Hillside landslides which frequently occur in mountainous regions by heavy rainfalls are of minimal scale individually, but become a cause for disasters when the occurring plots become excessive. On the other hand, large scale hillside landslides, occur at times in mountains at the final stage of rainstorms. Such hillside landslides may cause excessive disasters individually. The predominant provocative cause of hillside landslides may be said to be rainfalls, but it should not be forgotten that melting snow and earthquakes often also cause hillside landslides.

Hillside landslides in this literature are simply segregated into surface and deep layer hillside landslides although hillside landslides are actually classified into various types. Surface layer hillside landslides are when surface soil in the tree root penetration layer or slightly deeper depth collapses and falles, whereas deep layer hillside landslides are when rocks including underlying rocks in deep layers mountains collapse and fall. It is certain that hillside landslides possessing intermediate type of the two aforementioned types frequently occur, but it should also be noted that most of the two types of landfalls exhibit different characteristics. Surface hillside landslides are mainly caused by the surface condition (form) of hillside slope, and the earth causing the hillside landslides are mainly comprised with soil produced by surface weathering of rock bed. These types of hillside landslide are greatly effected by the intensity of rainfall. On the other hand, deep layer hillside landslides often are deeply related to the geological structure of mountainous bodies, where cataclastic process as well as weathering in the depths of rock beds often relate to the formation of brittle zones in rock beds which become sources of hillside landslides. Furthermore, generation of collapses are closely related to the total amount of rainfall.

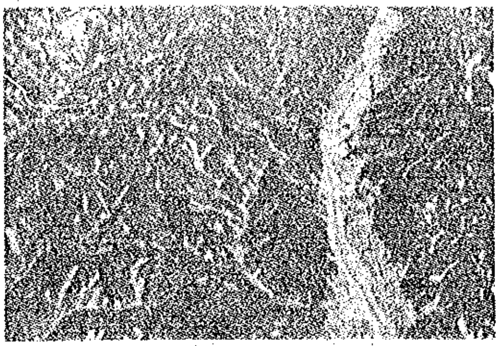


Diagram 1-3 Surface Layer Hillslide Landslide

Diagram 1-3 Deep Layer Hillside Landslide

2. Surface Layer Hillside Landslide

Diagram 1-4 describes example of a rainstorm which generated a hillside landslide. The graph indicates the danger of hillside landslide generation when there is an additional strong rainfall after water saturated surface soil. Mud flows are often generated in the lower foot to torrents when surface hillside landslide occur on hillside slopes. The following facts are known about the geneartion of surface hillside landslides on hillside slopes.

1) Occurs in the wide range between gentle slopes of 20 degrees and steep slopes of 45 degrees regardless of the geological structure.

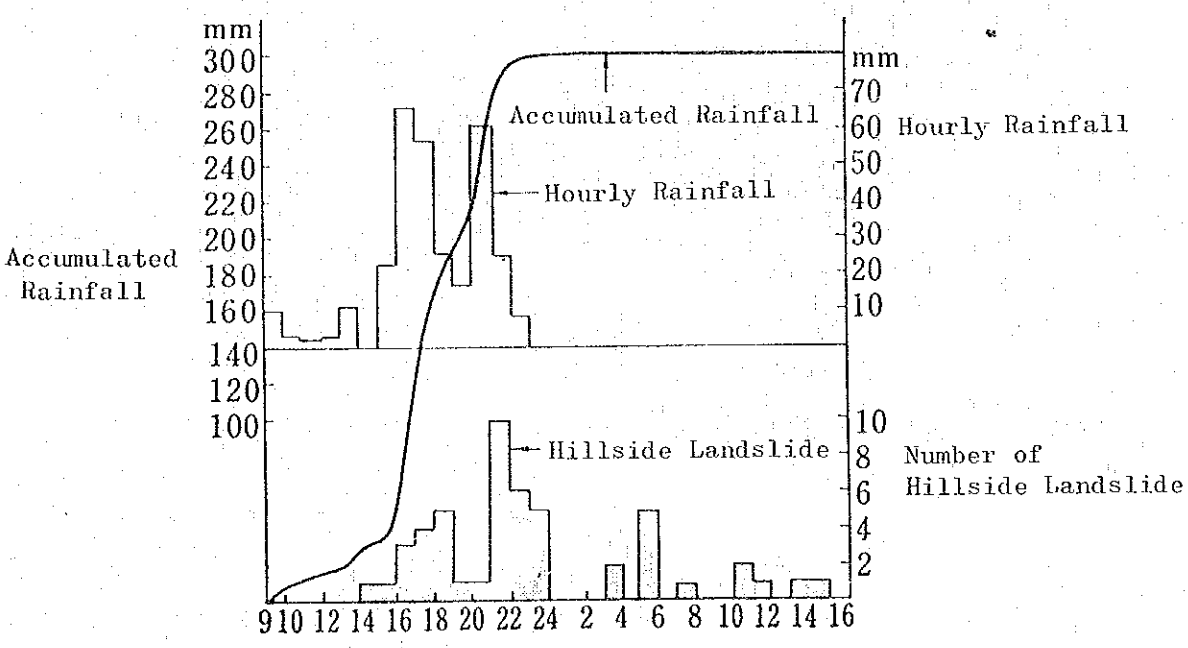


Diagram 1-4 Relation Between Rainfall and Hillside Landslides (Surface Landslides) in Kobe Japan (Hosono)

2) Majority of landslides occur within sunken regions of hillsides, and the points of generation are mostly near the inflection points of slopes.

3) Landslide generations tend to increase considerably in cutover areas.

Surface hillside landslides are when parts of the surface soil lose synamic stability by the flow of rain water generated temporarily within the surface soil, and become fallen out.
Almost all rainfall are absorbed into the ground in forests since permeability is great in such regions. Therefore, majority of rain water are transmitted into the depth of the earth during normal rainfall. However, when un-permeable layer exists below ground surface, the increased amount of rain water during rain stomrms generate a flow of rain water toward the slope with this layer as a border. This rain water flow destroys the dynamic stability of the soil horizon, and generates catastrophe. Catastrophes are easily caused particularly in places where the water discharge appears out to the ground surface in mid-hillsides.

3. Deep Layer Hillside Landslide

Parts of the mountainous body at times may fall from areas with reduced strength of rocks such as fractured zones where rocks become altered as well as in the depth of rock beds where rocks become weathered.
This type of hillside landslide is larger in scale than surface hillside landslides, and occur regardless of the topography. This type of hillside landslides exhibit similar features with landslides described in the following section, in that slippage generation exist within the rock bed as well as the relation of the ground water movement with the generation of catastrophe.
Deep Layer falls generated in fractured zones which can not be clearly segregated from landslide (landcreep) are at times called landslide type (landcreep) type hillside landslides. Furthermore, hillside landslides accompanying large amounts of ground water eruption at the point of catastrophe may be observed. In such case, one of the causes for catastrophe is thought to be the increased amount of ground water from rain storms which destroy and seal the ground water routes, and therefore producing excessive hydraulic pressure within the mountainous body.
The following precautionary phenomena similar to landslides (landcreeps)

may be observed at the generation of this type of hillside landslide:

1) Mud mixture and change in the discharge volume of ground water may be observed.

2) Minor falls may be observed in hillside foots and points of ground water discharge.

3) Cracks are generated in upper hill sides.

Section 5 Landslides (Landcreeps)

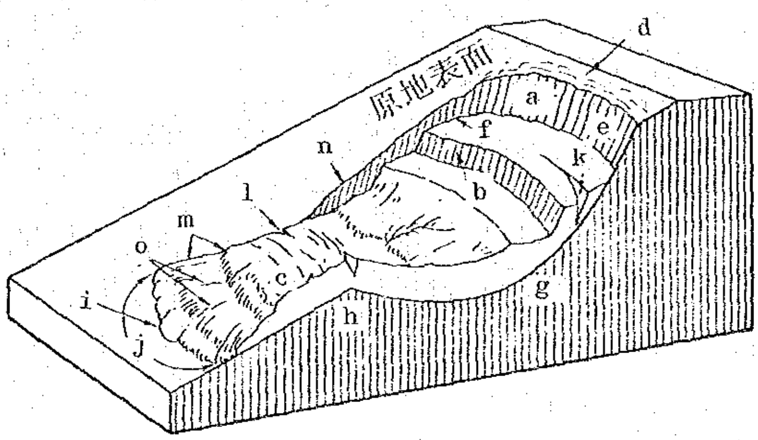
Landslides (landcreeps) are when fairly large areas of the ground creep slowly downward by ground water effects, etc. Landslides are observable throughout Japan. Landslide may be considered as a form of deep layer hill-side landslide with a particular style of movement in the broad sense. Chart 1-2 lists the differences between landslide (landcreep) and hillside l landslide.

Chart 1-2 Landslide (Landcreep) and Hillside Landslide Comparison Table

	Landslide (Landcreep)	Hillside Landslide
Geological structure	Frequently generated in particular geological structure areas.	Minimal relation with geological structures.
Soil Nature	Slides mainly with viscous soil as the sliding surface.	Frequently occurs in sandy soil such as MASA, YONA, and SHIRASU also.
Topological Features	Occurs in gentle slopes with 5 to 20 degrees incline. Most frequently observed in areas with upland type terrain above.	Frequently generated in steep slopes with incline in excess of 20 degrees.
Activity Condition	Continuous Recurring	Sudden
Movement Speed	Generally slow. Mostly 0.01-10mm/day.	Fast. Over 10mm/day.

Clod	Minimal clod distortion. Usually moved while maintaining the original form.	Clod become deranged
Provocative Cause	Effected greatly by ground water.	Rain fall. Particularly effected by the intensity of rain fall.
Scale	Large 10^4-$10^6 m^2$.	Small
Precursory Signs	Generation of cracks, subsidence, Protuberance, and ground water differentiations	Minimal precursory signs. Generally occur suddenly.

Many of the landslide generation areas are sites where previously occured landslides and deep layer hillside landslides have recurred. Therefore, entirely fresh landslide generations are relatively minimal.
Landslide regions usually exhibit exclusive topological features called landslide terrain. (Creeping land).



(a) Sliding
(b) Secondary cliff; scrap
(c) Toe
(d) Crown
(e) Summit
(f) Top part
(g) Sliding surface
(h) Spur
(i) Tip
(j) Toe Edge
(k) Tension Fracture
(l) Compression Fracture
(m) Upbearing Ground
(n) Side
(o) Original Ground Surface

Diagram 1-5 Individual Landslide Terrain Names (Sankaido, Yamada, Watamasa, Kobashi, "Realities and Countermeasures of Landslides and Slope Disintegration")

Sliding Cliff or scrap are found in the top-part of landslides, with sunken and level terrain immediately below, followed by gentle slopes. This sliding cliff and the sunken terrain below are exclusive of land slide terrains. Ground water eruptions are usually observed in the sunken terrain, and often comprise swamps, marshlands, and ponds. There Sliding cliff and ground water eruptions are clealy evident in the early stages of landslide, but become less noticeable over prolonged periods of time since Sliding Cliff become disintegrated, and as ground water eruptions become covered with debris which fill the sunken land. Secondary and third land slides occur once a landslide terrain is formed, and the number of Sliding cliff and level planes become increased, resulting in the formation of scalariform terrain. Crevice are caused by tension in the vicinity of Top-sliding cliff and by compression in the end regions during the initial movement stages of landslide. Furthermore, a particular type clay called landslide clay are found in the underground sliding surface.

1. Classification and Characteristics of Landslides

Majority of landslide cases are found in specific geological structure areas.

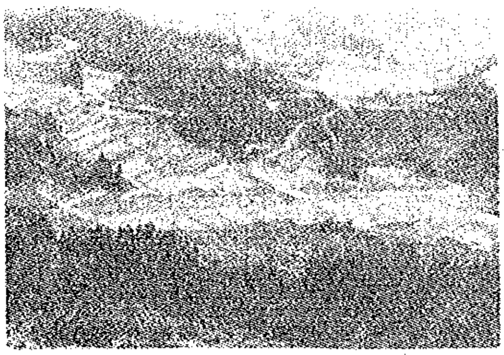


Diagram 1-6 Landslide Land

Majority of landslide are distributed among the Tertiary period layers, fractured zones, and hydrothermal alteration regions since these areas feature natural diathesis for landslide generation.

1) Tertiary period Layer Landslides

Since formation of Tertiary period Layer was relatively recent, and therefore, rocks of this layer are soft and exhibit poor coagulability.

Additionally, tertiary period layers exhibit excessive weathering and are easily transformed into clay since diastrophism was excessive during this period. Therefore, this layer may be considered to possess ample diathsis for landslide generations. 70% of landslides in Japan are concentrated in this tertiary period layer. On the countrary, landslide are not generated throughout the tertiary period layers, but tend to be concentrated in specific layers called the Miocene epoch in the tertiary period.

(2) Fractured Zone Landslide

This type of landslide are generated in fractured zones along the geological structure belt, and are also frequently generated along minor geological structure belts. Generally, mountains where this type of landslide are found exhibit steep inclines, and often cause catastrophic landslide during heavy rainfalls. Normal creepage is minimal, and is only few centimeters per year. Therefore the danger of landcreeps are often undetected in this type.

(3) Hot Spring Region Landslide

This type of landslide are caused by hydrothermal alterations, and are generated in volcanic and not spring areas. Landslide movements of this type tend to be vigorous, and exhibits great dengers of disasters once slippage occurs.

2. Generation of Landslides

Several provocative causes are inter-linked when landslide are generated. Provocative causes are mostly natural, such as rainfall, but artificial causes are increasing along with the progression of developments in recent years.

(1) Natural Provocative Causes

Rainfall increase the moisture content of the sliding plane and greatly reduce the resistance as well as soften the landslide clod and facilitate vigourous flows. Additionally, rainfall generates increased ground water pressure in landslide clod which further increase the pore water pressure, and adds to the generation possibilities of landslide. On the other hand, the amount and strength of rainfall

are not directly related to the creep speed and generation of landslide, and their relations between the cause and effects are complex. Fractured zone landslide are often caused by heavy rainfall, and landslide in high flow rate tertiary period layers are generally generated in conjunction with extended rainfalls.
Melting snow exhibit identical effects to the aforementioned extended rainfall. Furthermore, earthquakes often generate landslide.
Aside from the aforementioned, landslide are also generated by stream bank erosions where slope edges become washed away.

2) Artificial Provocative Causes

Stability of the clod become disrupted, and commence creepage when artificial factors effect slopes barely maintaining stability.
For example, landslides are generated by the cutting of slopes and excavation of tunnels during road work. Additionally, landslides are also generated by addition of fresh loads caused by embankments and erection of structures. Other causes which are relatively requently observed aside from the aforementioned are landslides generated by the change in ground water within surrounding hillsides due to submersion of dams as well as by the up and down quokes of the dam water level.

Section 6 Mud Flow

Mud flow is a phenomenon where muds are washed down streambeds along with water. Large and small pebbles of various sized debris are intermixed with water and are washed downstream. Such form of sediment movement is called the massive transportation or mass movement. On the contrary to this phenomenon, in normal soil flow, the individual gravel on the streambed is transported by tractive force. This form of gravel movement is called the individual transportation. Massive boulder movements of boulders found on streambeds in water depths equivalent to, or shallower than the size of boulders cannot be explained with the general soil flow terms based on tractive force. Additionally, mud flows exhibit exclusive characteristics in their velocity of impact as well as movements in the bends of streams. With the aforementioned factors in consideration, mud flow are defined clearly apart from regular soil flow, and are distinguished in their unification with water. Furthermore, it should be noted that the intermixture ratio of debris against water varies among what are so-called mud flow.

1. Generation of Mud Flow

Generation of mud flow may be widely classified into the following:

1) Soil silted on steep incline streambeds are suddenly motivated with the current caused by heavy rainfall and become mud flow. Normally, water discharge are below the silted soil, but appear on the ground surface when the silt become water logged during heavy rainfall. Hereby, the silt become rapidly loosened, and mud flow are generated.

2) The fallen earth produced by washouts during heavy rainfall are combined with effusion water and are rushed downstream to become mud flow. Large scale catastrophes such as valley head erosions often become rapidly washed down and transform into mud flow. Often in such cases, the devastation by mud flow are not only caused by the impact of the fallen earth, but by the combination with the loosened silt washout.

3) Mud flows are also generated by the downstream silt washout caused by the impact of intercepting earth which are rushed downstream at the collapse of fallen earth temporarily clogging the stream.

4) Aside from the aforementioned, mud flows are known to be generated by the loosening of viscous landslides as well as by volcanic activities.[1]

1) Mud flows have been generated by massive volcanic ash and pumice effused by volcanic activiti s being washed out by rainfall or by snow melted by volcanic activities effecting the terrain likewise heavy rainfall. This type is often called mud flow. (Mt. Tokachi/1925)

2. Characteristics of Mud Flow

Mud flows exhibit the following characteristics:

1) Mud flow exhibit an exclusive form with large boulders at the head while being washed downstream as illustrated in diagram 1-7.

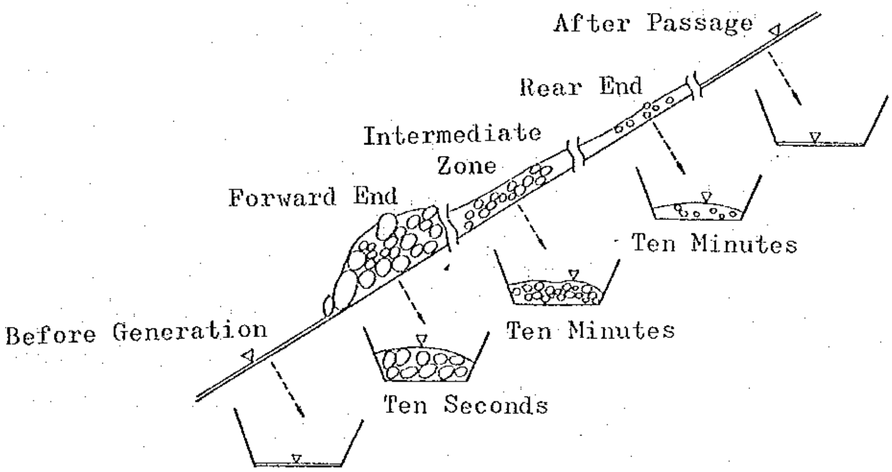


Diagram 1-7 Mud Flow Condition in Mt. Yake in Japan (Ministry of Construction Schematic)

2) The speed of mud flows are determined by its scale and the mixture ratio between debris against water as well as the incline of streambeds, etc. Additionally, they vary in accordance with the positions of generation, progression, declination, and dissipation of mud flows. Flow speeds vary from slower 1 - 2 meters per second to faster flow with speeds in excess of 20 meters per second. Flow speeds of large scale mud and stone flows cannot be reduced with several check dams, but minor mud flows are simply brought to a silt and a stop on a single check dam.

3) Mud flows are mostly generated on streambeds with incline in excess of 15 degrees. Mud flows come to a natural halt when the incline reduce to less than 10 degrees, and begin to form mud flow deposite. Large boulders are often found in the advancing end of these deposite (Diagram 1-8). Additionally, mud flows including large bebbles are hardly found in regions with less than 5 degree incline.

Diagram 1-8 Mud Flow Silt

4) Mud flows exhibit strong strait-line movement characteristics, and therefore destroy and overcome obstacles during advancement. This phenomena indicates that mud flow possess abundant inertia. Water level difference may reach 3 - 4 meters between the in and out sides of the flow in bends of streams. Therefore, large boulders are often left on the outer side hillsides.

5) U-formed valleys exclusive of streambeds after the passage of mud flows are formed.

CHAPTER II FOREST FUNCTION ON DISASTER PREVENTION

Section 1 Forest Function on Disaster Prevention and its characteristics

Trees may be considered to be living green structures with foundations in the ground. On the other hand, trees improve and secure their base of living which is the soil. This phenomenon becomes greatly strengthened in a gathering of trees which is the forest. Therefore, environment of surroundings terrains and atmosphere become greatly effected. The following describes the disaster preventative functions among the various phenomena observed in forests.

Forests function likewise to large surface structures, and therefore, large atmospheric movements are precluded, which in turn reduce the wind speed in the vicinity. This effect is called the windbreaking effect of the forest. Windbreaks, shifting sand control forests and so on are made using this effect. Furthermore, fog prevention forests are made as well as increased rainfall functions are generated with the atmospheric movement preclusion effect as well as the function to hold intra-atmospheric moisture of the forest. On the other hand, tree trunks of forests are used somewhat like protection fence for coastal salty wind protection, and flood prevention. Furthermore, the obstacle effect of forest crowns are employed for firebreaks and sound shields.

Forests produce a silting layer on the ground surface comprised of organic substances, which protect the ground surface and soften the top soil, making it fertile. Additionally, the top soil become stabilized and secured with the penetration of tree-roots in the sub-surface layers of the ground. Humus and defoliation on the ground surface prevent surface erosion generations by rainfalls and ground surface flows. Furthermore, surface soil stabilization by roots prevent land falls and falling rocks. Moreover, the soft and porous forest surface soil facilitate rain water infiltration which in turn decrease the flood discharge volume, and enhance water sources conservation. These phenomenon is called the water regulation effect of the forest.

Disaster prevention utilizing forests are considered to be highly useful as discribed in the following:

1) Large areas may be covered with forests. Erosion prevention in mountainous regions as well as water conservation and run off regulation may be accomplished with sand arresting structures or check dams, but abundant effects may be attained in large areas with forests although the individual forest effects may be small.

2) Forests may be produced at far less cost than architectural structures since they grow.

3) Forests planted for disaster prevention often are beneficial for environmental preservation as well as timber production.

4) The largest of the forest effects is the "OVERALL FOREST EFFECT". Forests provide multiple disaster prevention effects simultaneously as well as function as a source for timber production, environmental preservation, and vecveatiou, etc. Each individual effect may be accomplished more effectively by other measures, but the true importance of forests lie not in individual but in these overall effects.
The aforementioned are the disaster prevention effects of the forest. On the contrary, though, it must be noted that these effects must not be overestimated. This precaution is due to the forest foundation lying in the sub-surface depth of 1 - 2 meters below the ground.

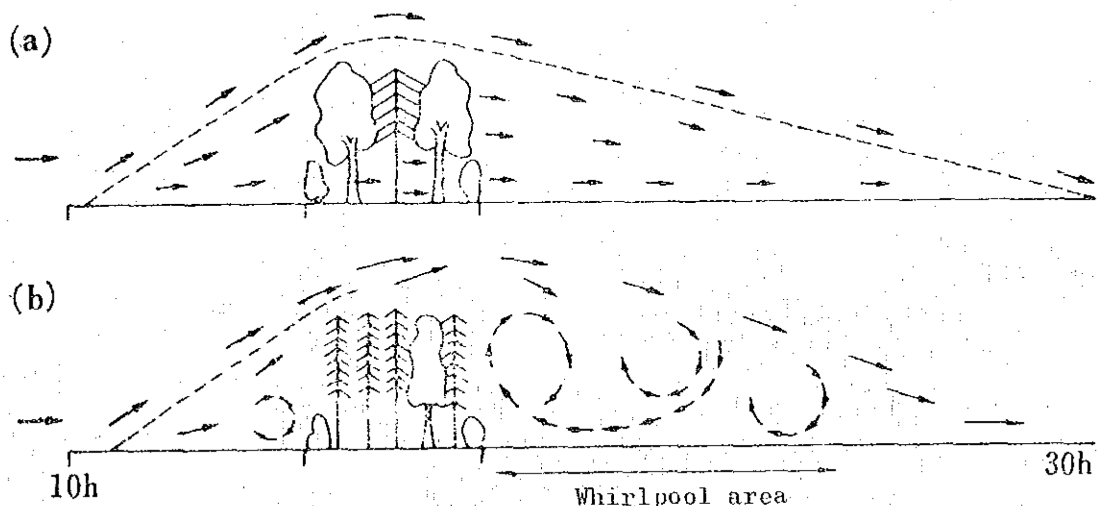
Section 2 Forest Function on Windbreaks

The utilization of forests as windbreaks may be segregated into inland (farmstead) and coastal windbreaks. Coastal windbreaks also function for shifting sand control, fog prevention, and salty wind prevention.

1. Inland Windbreaks

Tree belt width of inland windbreaks are generally narrow and the number of planting rows are less than seven. Additionally, the width is considered to be most efficient at 30 meters including renewal areas. Intra-forest ventilation effect become reduced when tree belt widths are excessive, resulting in decreased wind retardation areas.
The most ideal plantation of tree belts are in the right angle against the main wind, employing evergreen trees.
Major windbreak effects of forests appear in the lee side, but are

some what attained in the windward side also. The size of windbreaking zones are closely related to the density of forests.
When the forest density is large as illustrated in diagram 2-1 (b), ample wind retardation effects are attained. Hereby, air eddies are formed in the lee side, and the wind blown over the tree belt become rapidly lowered. With this reason, the windbreaking effect distance become shortened. On the other hand, in ideal density tree belts as illustrated in (a), portions of the wind are blown through with the rest blown over the tree belt. Air eddies therefore, are not generated in the lee side. Wind speeds may not be considerably decreased in such cas case, but the tree belt filters the wind, and therefore, windbreaking effects are attained over a large area.



(a) Ideal Density Tree Belt
(b) Overcrowded Tree Belt

(h) Tree Height

Diagram 2-1 Wind Current in the Vicinity of Windbreak
(by TOKUJI KASHIYAMA)

Ideal density is a condition where trees hold approximately 60% of the area when viewed from the front with averaged openings.
Diagram 2-2 illustrates the windspeed measurements taken at about one meter off the ground which is the determination factor for the employment of windbreaks.
The diagram illustrates the difference in the windspeed with and without tree belts in the form of ratio. Windspeeds are lowest in the ideal density tree belt, where the windspeed is reduced to about 30% at a distance equivalent to three to five times the height of the tree belt.

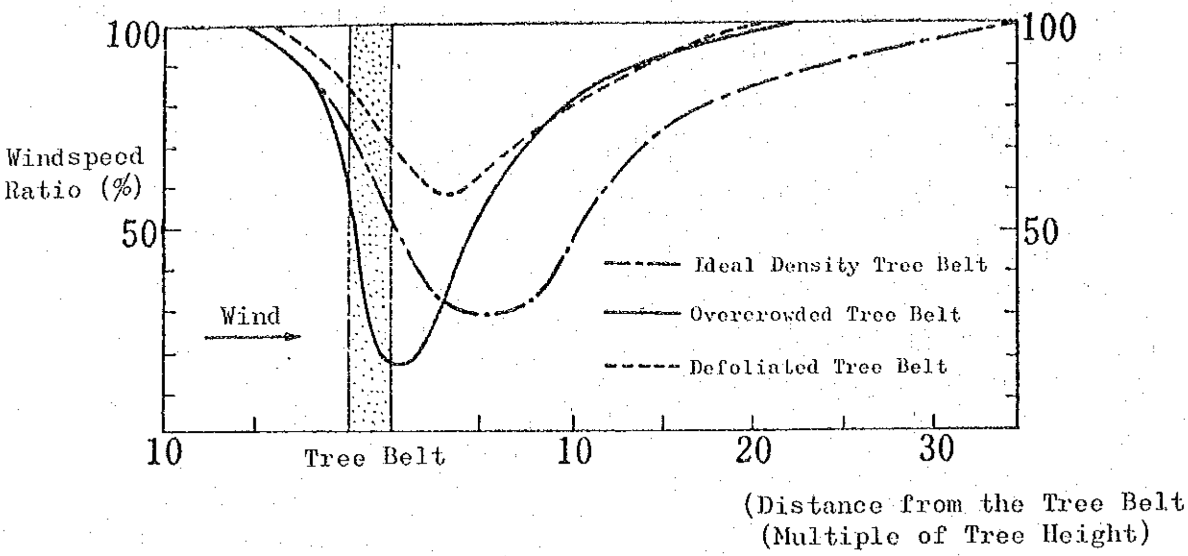


Diagram 2-2 Windspeed Reduction Effects of Narrow Tree Belts (Approximately 1 Meter Off The Ground) (By TOKUJI KASHIYAMA)

Additionally, it may be observed that windbreak effects are recognized with the reduction of wind-speed of 30% in distant zones of twenty times the height of the tree. Furthermore, windbreak effects are also recognized in zones of three to five times the geight of the tree in the windward side of the tree belt.

This windspeed transition effect of windbreaks prevent temperature near ground surface and ground surface temperatures from dropping as well as prevent atmospheric humidity reduction. Furthermore, effects such as reduction of water evaporation from the ground surface and weathering prevention are attained.

2. Coastal Windbreaks

Coastal windbreak tree belts tend to be wide since trees planted along the coast are hampered from growing by the crucial terrain conditions, and windbreak effects are therefore attained the growth of inland trees based on the sacrifice of the aforementiones water front plantation. The aeration rate and windspeed lowering distance are reduced in coastal windbreaks than inland windbreaks since the tree belt width become increased. On the other hand, inland direction sand shifting prevention effects are considerable with coastal windbreaks due to wide tree belts and the reduction of windspeed. Additionally, coastal windbreaks exhibit superb entrapment effects of salt contained in sea-breeze and sea fog. Heavy damages occur on agricultural products, power lines, and communication facilities, etc during typoons since salt wind with approximately 100 times the normal salinity density are known to have been blown inland. Diagram 2-3 illustrates an example of these effects of coastal windbreaks. The reduction of windspeeds, salt density, and sea fogs in the front and rear of the windbreak may be clearly observed in this graph.

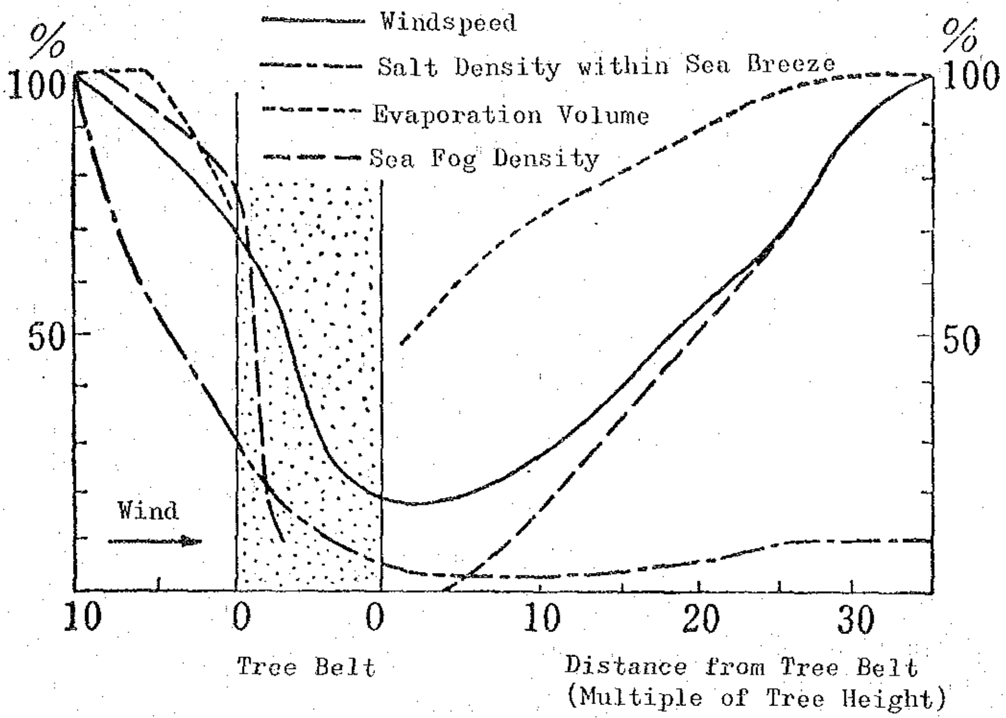


Diagram 2-3 Effect of Wide Coastal Windbreak Tree Belts
(Approximately 1 meter off the ground)
(TOKUJI KASHIYAMA)

Section 3 Forest Function on Erosion Prevention

Ground surface in forests are often covered with litter. Therefore, sheet erosion are rarely generated in wood lands. However, sheet erosion generations become increased when bare lands are produced by cutting of timber as well as by disturbance of wood lands since forest soils are soft and easily washed out.

Additionally, it must be noted that roots penetration exhibit ample surface soil stabilization effect, and therefore presnet abundant hillside landslide prevention capability. On the contrary, though, it must also be noted that the hillside landslide prevention capability of forest are said to be limited.

1. Forest Function on Surface Erosion Prevention

The ground surface is covered with thick humus layer, defoliation, fallen branckes when the crown is sealed in wood lands. Undergrass growth are observed when the humus layer, defoliation, and fallen branches are reduced in sparse density woods. In many cases, these surface covering matters function fully to absorb the impact from rain-drops which is the cause of sheet erosions. It is by this function of covering matters that wood lands are free of surface runoff and exhibit high infiltration capacity. Even when partial surface runoff is generated, the flow becomes absorbed and dispersed by the surface overlay or soil grains are prevented from washing out by root penetration, and therefore are precluded from developing into large scale erosion such as gullies. However formation of partial bare lands become facilitated, accompanied by increased erosion when trees are cut down as illustrated in Chart 2-1.

Chart 2-1 Cutting Conditions and Annual Eroded Soil Volumes of Natural Japanese Red Pine Forest (Pinus densiflora)

Position of the Cutting Area and the Proportion with the Area	Annual Eroded Soil Volume (zon/ha)	Comparison of Annual Eroded Soil Volumes (Uncut : 1)
Overall Cutting and Stump Removal	28.53	78
Overall Cutting	3.66	10
3/4 Cutting Upper Area on Slopes	2.06	6
1/2 Cutting Upper Area on Slopes	1.14	3
1/4 Cutting Upper Area on Slopes	0.75	2
Uncut	0.35	1

Stand Age 30 years, 30 degree incline test ground (40 x 20m), in Okayama Prefecture.

(TAKESHI KAWAGUCHI)

Errosion volumes are greatly increased when ground surface are deranged upon felling.

Aside from the aforementioned, forests reduce the stand temperature change with the crown and surface overlay as well as prevent frost-lifting generated by the repetion of soil freezing and fusion.

Additionally, tree roots secure rocks and gravel in regions where rock beds and gravel appear on the ground surface, and also free crowns function greatly to prevent rocks and gravel from falling.

2. Forest Function on Hillside Landslide Prevention

Hillside landslides tend to be generated more often in unstocked areas such as grasslands and cut-over areas than stocked areas. It is thought that this is due to the surface soil being secured by the penetration in the sub-surface ground. This relation between the surface soil securing effect of root systems and generation of hillside landslides may be explained as described in the following:

Hillside Landslides Generation Prevention Effect (A): The root system spread throughout the sub-surface stabilize the surface soil and prevent generation of hillside landslides.

Hillslides Generation Effect (B): Large volumes of rain water are infitrated into the surface soil during heavy rainfall, facilitating the generation of surface layer hillside landslides.

Surface soil in forested hillside slopes are normally stabilized with the aforementioned root system effect (A). The effect (A) is storonger than effect (B) during normal rainfall (A > B), and therefore the terrain stability is maintained. However, hillside landslides become generated depending on the area during heavy rainfall when the effect (B) exceeds effect (A) (A < B).

It is when heavy rainfalls are encountered after trees have been cut down, and therefore enhancing the effect (B) that the conditions where the effect B exceeds effect A are liable to occure.

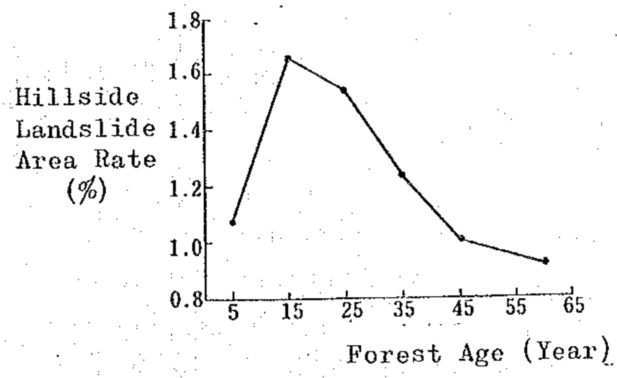


Diagram 2-4 Forest Age and Hillside Landslide Generations (NANBA)

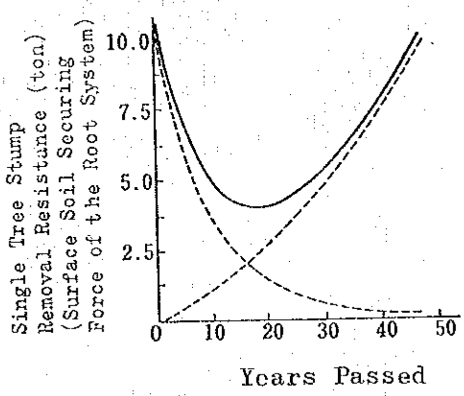


Diagram 2-5 The Change In Cedar Stump Removal Resistance Over The Years (KITAMURA, etc./Original Schematic)

This phenomenon is clearly observable that hillside landslides are frequently generated in thicket lands 10 to 15 years after falling as illustrated in diagram 2-4.

Diagram 2-5 illustrates the mechanism of this phenomenon. The surface soil securing effect of the root system become rapidly reduced over the years when the roots become rotten after fell. On the other hand, the surface soil securing effect of pole size trees become increased over the years. surface soil securing effect of root systems in general cut-over lands are described by the total of the two, and therefore is illustrated with the true line in the diagram. It is hereby observed that the effect (A) becomes most reduced around 10 years after feeling, facilitating the generation where the effect (B) exceeds effect (A) (A < B). It is therefore necessary to pay close attention when cutting trees down in landfall generation regions. It is important from these factors to plan the cutting to method prevent reduction of the surface soil securing effect of the root system by avoiding clear cutting and employing measures such as selective cutting as well as regeneration by sprouts.

Naturally, landfalls effected by tree cutting are surface layer landfalls, and therefore, generation of deep layer landfalls are considered to be far from this phemonenon.

Section 4 Forest Function on Runoff Control

Forests reduce the discharge volume of floods as well as prevent the discharge from decreasing during dearth of water periods. The former phenomenon is calles the flood control function and the latter is called the water resource conservation function of the forest.

1. Hydrological Cycle and Rainfall Runoff

Water on the earth are constantly circulated. Rainfall on mountains and level lands are stored on the ground surface or within the earth, with a portion later returning into the atmosphere through evaporation or transpiration. The remaining water flow into rivers. The form of these rain water storage, evaporation, transpiration, and river effluence vary greatly according to the condition of the ground surface.

For example, conditions of rain water storage or river run off greatly depend on the urbanity of the subject area such as forest land, bare land and city land etc. The water regulation effect of forests so to say, is to consider what function among the aforementioned hydrologic cycle forests share in contrast to other ground surfaces. Rainfall on hillside vegetation drop on the ground surface and become effluded into rivers after travelling through various routes. Graphs indicating the continuous measurement of river discharge is called a discharge curve (Hydrograph). The hydrograph (Diagram 2-6 is comprised of various rain water named ground surface, intermediate [1], and ground water effluence, travelling through the various sections of the hillsides. Effluence into rivers tend to be delayed with the depth of rain water infittration into the ground. The increased water during rainfall mainly consist of surface runoff and interflow, and river runoff during no rain periods are comprised with ground water effluence.

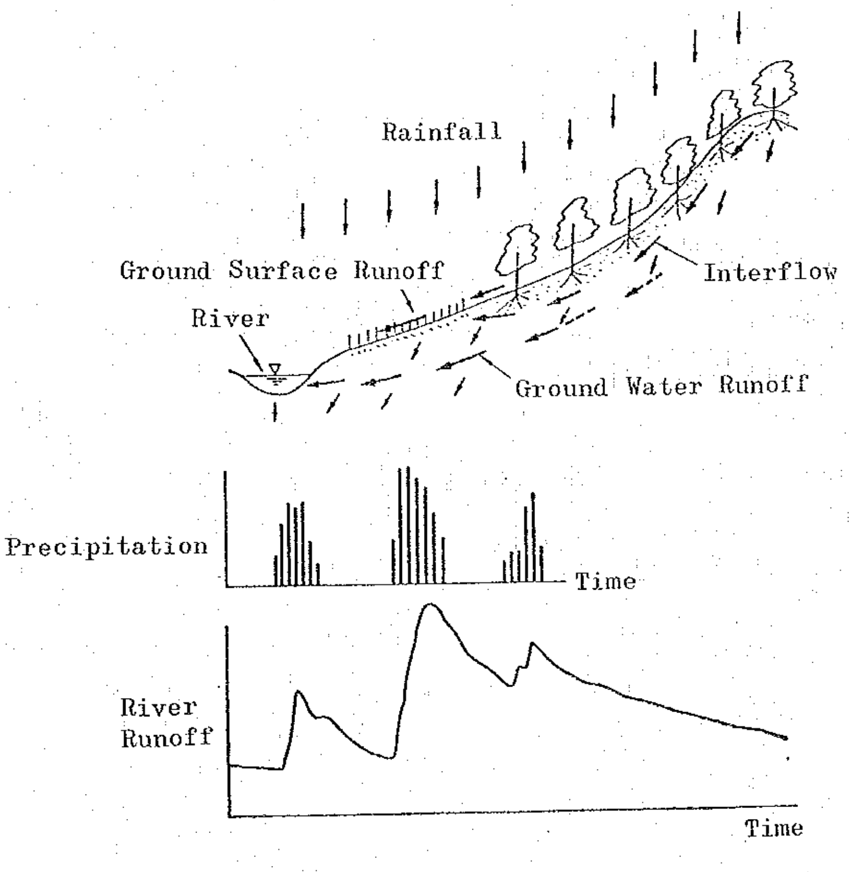


Diagram 2-6 Rain Water Runoff on the Hillside and Discharge Curve

When the intensity of rain fall is more than the percolation capacity of subsoil, rain water flows down the slope along the boundary layer of the surface and subsoil in case that the surface soil are more porous than subsoil as in forests.

This phenomenon is called the interflow.

2. *Forest Function on Flood Control and Head Waters Conservation Flood*

Flood discharge is increased along with the increase of the volume of surface runoff during rainfalls. On the contrary, flood discharge are decreased with the increase of rain water infiltration into the ground to become ground water, and instead, the river discharge increase during dearth of water periods.

The effects of the forest on rainwater discharge are explained in the following.

1) Forest soil are porous, and infiltrate most of the rainfall under the ground. Therefore, ground surface flows are hardly generated. Infiltration capacity is the *measurement of the ground surface* ability to infiltrate rainwater. Chart 2-2 describes the change in the infiltration capacity according to condition of the ground surface in the form of final infiltration capacities. The infiltration capacity where the infiltration capacity become constant when the ground become water logged by rainfall, is called the final infiltration capacity. It is obvious from this chart that forests exhibit superb infiltration capacities.

Chart 2-2 Variations and Infiltration Capacities of Vegetations

Type of Vegetation	Last Infiltration Capacities (mm/hr)
Coniferous Forest	246
Broad Leaved Forest	272
Cut-over Area	160
Grass Culture Area	191
Newly Hillside Landslide	99
Forest Road	11

2) Surface soil in forests tend to maintain porosity into greater depth than other vegetative land, and therefore exhibit better rain water storage as well as infiltration to the depth of the earth compared to other ground surface conditions.

3) Large amounts of rain water are stored in the surface soil in forests to supplement water shortage caused by transpiration. Therefore the amount of rain water becoming river discharge tend to be slighly less than other ground surface conditions.

The change in the flood discharge based on the aforementioned features of forests, when lands become bare or when trees are cut down are explained in the following:

i) The infiltration capacity of the grounds surface become considerabley reduced when the aforementioned features 1) and 2) of the forest are eliminated due to increased bare lands caused by loss of forests by fire or by excessive ground surface devastation. In such case, most of the rain water become surface runoff, and the flood discharge increase considerably. An example of this phenomenon is illustrated in diagram 2-7. The diagram explains the forest restoration by planting on bare lands with the accompanying flood discharge reduction.

ii) The aforementioned features 1) and 2) are maintained, and the feature 3) become changed when proper soil preservation are performed after cutting. The rain water volume to supplement the water shortage of the soil become reduced by decreased transpiration caused by forest cutting. Therefore, flood discharge are somewhat slightly increased in contrast with forests.

The following explains the relations between the forest and river discharge during water famine periods:

Increase in the ground water storage volume results increased river discharge during famine periods since river discharge during this period are comprised mainly with effluence from ground water storage in mountainous regions. Forests exhibit better infiltration capacity than any other types of vegetation or ground surface, and therefore, the greatest volume of rain water are infiltrated underground. Viewing from this point, it could be said that forests play an important role in increasing the river discharge during famine periods.

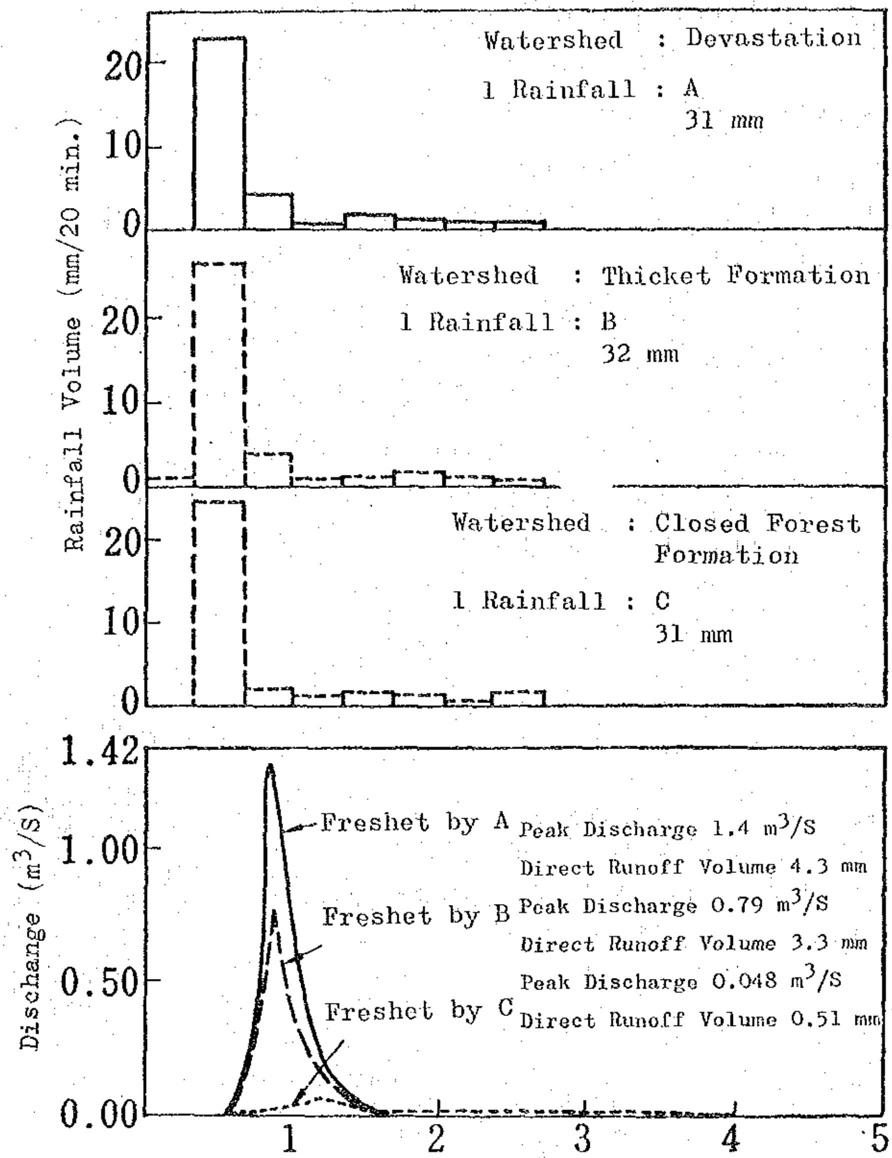


Diagram 2-7 Example of Direct Runoff Reduction and Runoff Time Extension due to Silviculture in Devastated Areas
(Hideaki NAKANO/"Forest Hydrology" 1976 Japan)

Forests dissipate moisture stored in the soil into the atmosphere through transpiration. This dissipation through transpiration reduces the volume of rainwater infiltration to the ground water storage. Therefore, it is desirable to reduce the volume of dissipation through transpiration in order to increase the discharge during dearth of water periods. However, forest cutting aimed at the reduction of transpiration expose the forest to the danger of ground surface devastation, resulting in generation of surface run off and increased erosion volumes. For example in Japan, transpiration volumes in most parts are relatively less than rainfall, and therefore it is more important from the viewpoint of water resource conservation to enhance rain water infiltration underground than reducing the transpiration volume. Transpiration volumes generally tend to become reduced and rainfall increased with the elevation in altitude at identical points. With these factors in consideration, it may be concluded that it is important to develop well conditioned forests in high elevation far up areas of water source which can infiltrate abundant volumes of rain water underground, while reducing dissipation through transpiration in order to increase the ground water storage.

CHAPTER III DESIGNING AND CONSTRUCTION OF HILLSIDE WORK

Section 1 Objectives of the Hillside Works

Hillside collapsed by heavy rain or earthquakes lacks vegetation overlay, and the surface is swept away. Therefore, the surface layer soil is washed down the slope with each succeeded rainfall, and devastation become further progressed. Additionally, the swept down soil and gravel accumulate on streambeds, and become potential cause of large scale disasters such as floods.

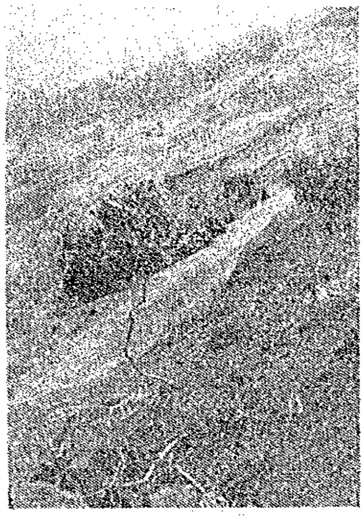


Diagram 3-1

Soil inadequate for the growth of vegetation appears on such devastated hillsides, precluding the early stage entry of plants. Devastated subject requiring restoration, such as where the vegetation overlay had been artificially removed by forest development, subject frequently found and subject potential danger for disasters. We hereby must study effective hillside work methods in order to prevent disasters through restoration of denuded lands for enhancement of the disaster prevention effects of forests, which in turn stabilize the terrain and assure water resources.
Hillside devastation are generally accompanied by wild torrents.
Therefore hillside works explained in this chapter are usually designed and

executed in combination with torrent works explained in the following chapter.

Section 2 Planning the Hillside Works

Designing stages of hillside works may be segregated two procedures. The first is by planting vegetation upon careful accomplishment of foundation work, and the other is to plant vegetation with minimal alteration to the topography. The former method exhibits high rates of success, but is time consuming and costly. The latter method is economical, but risks the generation of partial erosions. Therefore, it is important to apply the most adequate type of work method and procedure in accordance with the conditions of the subject topography upon surveying the work execution area, since either method exhibit the aforementioned benefits as well as shortcomings.

Section 3 Surveying for Designing the Hillside Works

Topographic survey results of areas in the vicinity of scheduled work execution site are used as the basic data for designing hillside works. Topographic surveys are accomplished by traverse, using equipments such as transit and pocket compass, etc., in order to obtain information on the topographic conditions of the devastated land and vicinity for the production of a plane schematic. Major surveying points during this survey must be on immovalbe points, since they will be used as control points for future surveys and execution of works. The scale should be between 1/500 to 1/1000 with a contour interval of 5 to 10 meters.
Profile leveling or Longitudinal leveling determines the type, layout, and extent of the work, and is performed to estimate the soil volume of grading works explained in the following Section 4, during hillside foundation works. This form of survey is accomplished with a level or a pocket compass. Directions of surveys and survey lines are to be determined upon studying the change in landscape changing points, proposed structure erection sites, and land classification *(1).

*(1) Land classification is a term for classifying lands into stream bed area and hillside landslide area, with further classification of hillside landslide area into denuded hillside area and sedimentation area.

Cross sectional leveling is performed in order ro estimate the basic figures for various foundation works, and selection points of this survey are in accordance with these of the Profile leveling
Close attention must be paid to the directions of survey lines in order to attain accurate figures. Levels or pocket compasses are employed for this survey depending on the accuracy desired.

Section 4 Types of Hillside Works

Restoration of devastated hillsides by replanting is accomplished by applying hillside foundation work first in order to clear and stabilize the uneven hillside surface. This is then followed by the application of hillside seeding and planting work in order to permanently stabilize the hillside surface with vegetation overlay.
The types of hillsides works are mainly segregated by the utilized materials, and the commonly methods are as listed in the following.

- Hillside Work
  - Foundation Work
    - Grading Work
    - Retaining Work : Wet Masonry, Dry Masonry, Concrete, Square Crib, Concrete Plate, Wire Cylinder (Gabion), Fascine Masonry, Fence Work, etc.
    - Buried Work : In accordance with the work types of the Retaining work
    - Drainage Work
      - Water channel Work : Wet Masonry, Dry Masonry, Concrete, Concrete Piping, Sodding, Stone Plastering, Wire Cylinder (Gabion), Corrugated Piping, etc.
      - Closed Conduit Work : Wire-Cylinder(Gabion), Gravel Fascine, Concrete Piping, Vinyl Chloride Piping, etc.
  - Planting Work
    - Sodding Work: Triple sheet sodding, Quintuple Sheet sodding, Sodding Step, etc.
    - Simple Terracing Work : Stone, Miscanthus, Concrete Plate, Sod, Fascine bundle, Straw, Log Other planting Material, etc.
    - Convering Work : Straw, Straw Mat, Fascine, Other Planting Material, etc.
    - Slope Seeding Work : Manual Seeding, Seed Shooting, Strip Seeding, Overall Seeding, Helicopter Seeding etc.
    - Planting Work

Although various types of work methods and procedures are available as listed in the table, determination among foundation or planting works should be only made upon studying the actual topography as well as the survey data, for the employment of the most appropriate method in compliance with the topography, soil, and climate of the proposed work site area with the ease of material procurement and transportation in consideration. Furthermore, designs must be processed separately even within the same job for well vegetated areas such as the sedimentation zone and poor soil condition regions where woil dressing is required.

Section 5 Hillside Foundation Work

1. Grading Work

Hilldides devastated by landslides exposes uneven surface as well as steep inclines, and are highly unstable. This surface unevenness become further dissected with each rainfall due to the sheet flow concentrating in the sunken sections of the hillside.

Inclines must be reduced as necessary and the surface must be smoothed on such hillsides since the applied measures are easily destroyed.

Works performed for the improvement of such conditions are called grading works.

The most ideal state of the grading work is when the overall uneven surfaced slopes are graded with the angle of repose of the particular soil quality as illustrated in chart 3-1.

However, it is highly important to plan and execute this work in conformance with form of the topography, since removal of large soil volumes are not only costly, but risks the danger of silt deposited in the sunken sections to shift and coause unexpected disasters by rainfalls.

Diagram 3-2 Execution of Grading Work

Chart 3-1 Soil Variations and Angles of Repose

Condition / Type of soil	Dry	Low Moisture Content	High Moisture Content
Clay	20° ~ 37°	40° ~ 45°	14° ~ 20°
Sand	27 ~ 40	30 45	20 ~ 30
Ballast	30 ~ 45	27 ~ 40	25 ~ 30
Regular Soil	20 ~ 40	30 ~ 45	14 ~ 27

The works are started from the top of the slope downward to the valley. Soil are removed from protruded sections, and are used to fill the sunken areas. Retaining structures must be erected prior to the execution of this work since secondary disasters may be generated by rain or snow falls when these filling silts are excessive although these soil have been sufficiently compacted.
Grading works are normally performed with tools such as picks, shovels, and mattocks.

2. Hillside Retaining Work

This work is performed to erect structures on necessary points of hillsides in order to reduce the slope incline, support collapsible slopes, prevent washout of grading soil, and to preserve drainage work.
Therefore, these structures must be erected on sturdy foundations where they are safe against the earth pressure from the top as well as free of slippage generation in the bottom, since such structures are required to maintain the hillside soil rigidly and stably under any condition.
Furthermore, measures such as step formation are necessary to leave spaces between the first structure and the second structure in order to decrease the generated pressure.
Moreover, it is necessary to prevent from damaging the tops of retaining structures by grading soil fillings and rock falls since retaining structures are often erected prior to grading work.

1) Wet and Dry Masonry

This method is employed commonly when natural rocks and stones which are materials for masonry are readily available on the job site. Artificially produced materials such as concrete blocks to have superseded natural stones. Concrete block retaining work vary in types such as employment of conventional stone material formed blocks with conventional execution procedure, assembly and erection employing square rigging likewise architectural technology using plaster and steel reinforcement, and others with intermediate process of the *aforementioned two. However, it must be further noted that the* determination of the type of work process must be made in compliance with the condition of the work site.

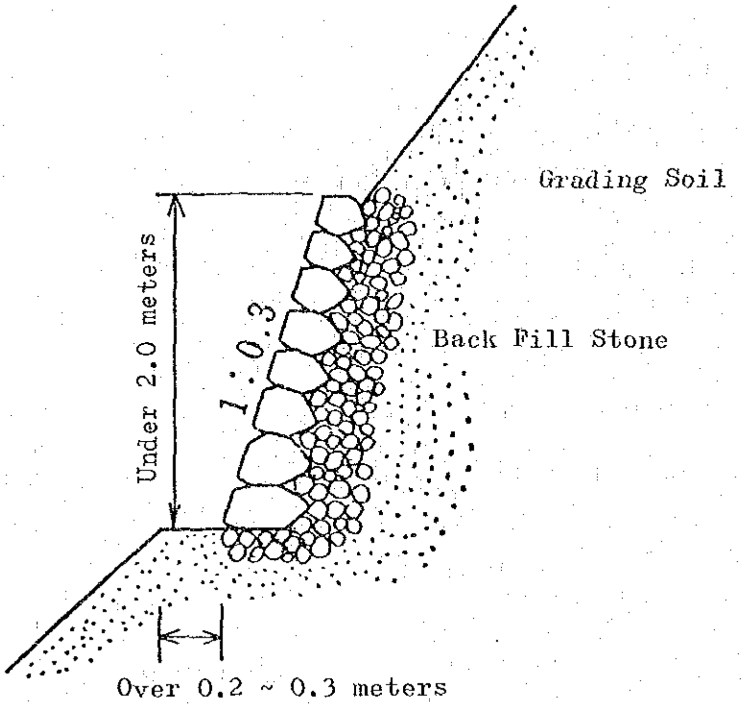


Diagram 3-3 Dry masonry Retaining Work

This work must be executed on rigid foundations with surface slope ratio of 1:0.2 (i.q. vertical = 1, horizontal = 0.2) to 1:0.3 since the own wiehgt is excessive. Additionally, the height must be kept below 3 meters to maintain safety against the earth pressure. Furthermore, joint should be provided every 10 - 15 meters when the overall span exceeds 20 meters to preclude expansion of the damage in case of catastrophe, along with the basic principle to install drainage holes.

Diagram 3-4

Concrete Retaining Work

2) Concrete Retaining Work

Concrete retaining works are applied when absolute slope stability and rigidity are required in hillsides with potential of slippage generation where other methods cannot be executed due to excessive earth pressure as well as on hillsides with the ease of concrete application. The height should be kept below 4 meters to maintain safety even when foundation works have been accomplised to a considerable extent, since the supportability of foundation layers in collapse sites are uneven, and often accompanied with steep inclines.
The sectional forms are disigned in accordance with the back earth pressure. When the earth pressure is high, the back slope, therefore, should be determined in conformance with the condition of the work site based on the crown width at 30 centimetres and the front slope ratio of 1:0.3.
The rear slope should be right angled or minus slope ratio of 1:03 when the earth pressure is low.
The back filling is provided to iniform and relax the earth pressure on structures as well as to rapidly drain the water infiltrated from the back, and its thickness should be over 30 centimetres.
Additionally, vinyl chloride pipings, etc. are laid in order to drain the water in the back to the front to reduce the pressure.
Expansion Joint provided for the prevention of destruction by temperature change and are executed in the identical manner with those for the masonry work. Additionally, these expansion joints should be halving joints instead of straight joints. Asphalts and Elastites are mainly used for sealing mediums.

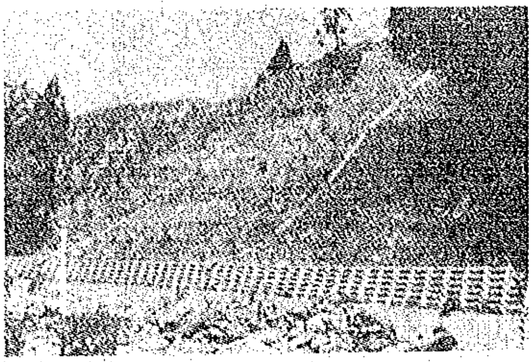


Diagram 3-5 Square Crib Retaining Work

3) Square Crib Retaining

Structures may be easily broken with masonry and concrete works by ununiformed settlement, as well as soil horizon shifts in poor ground with uneven supportability. The square crib retaining work is the method employed in the aforementioned case.
Square cribs are square reinforced concrete bars assembled on the work site into a square and filled with gravel and rubbles.
Concrete work on collapsed hillsides with disproportioned ground bearing power often presents difficulties of material transportation and onsite miding. Therefore, the square contrete bars employed in this method are considered to be beneficial with the ease of transportation as well as the simplicity of execution, requiring only assembly due to being factory products. The sectional dimensions of the square bars are to be considered in accordance with the size of the earth pressure in this method, since the earth pressure is resisted with the weight of the gravel and boulders filled within the cribs. However, individual heights must be kept below 3 meters since the strength of a single square bar is limited. Additionally, retaining effects are known to have been enhanced by providing two rows with clearance in between. Furthermore, protective works are performed at times to prevent the top from becoming demaged by falling rocks.

4) Concrete Plate Retaining Work

The two types of this work method are as explained in the following. The first is by mounting two or three steps of 1.0 x 0.3 x 0.03 meter concrete plates in the back of concretes piles and refilling this rear side to attain retaining effects upon completion. The latter is by linking 1.0 x 0.3 x 0.03 meter surface plate to 0.25 x 0.2 x 0.03 meter supplementary plate with 0.5 meter vinyle pipes and filling with soil and gravel as illustrated in diagram 3-6.

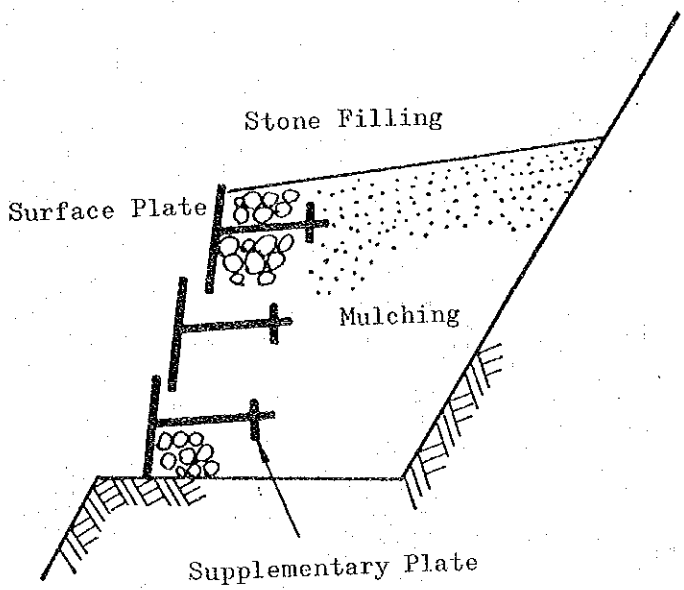


Diagram 3-6 Supplementary Panel Type Concrete Retaining Work

Additionally, this method exhibit features such as the ease of transportation as well as on-site assembly. However, it is important to verify the safety when employing this method since the earth pressure resistance is small compared to other retaining works. The height must be kept below 1.2 meters with 4 steps even with the supplementary panel system, and below 0.9 meter with 3 steps with the standard type. Stability may be further increased by replacing the filling gravel with concrete.

Wire Cylinder (Gabion) Retaining Work

This method is employed on grounds which may be destroyed with retaining work employing concrete and masonry, etc. due to slippage and differential settlement of the gorund. The height must be kept below two meters in order to minimize the damage when the cylinder comprising wires break, since the durability of wires are limited, regardless of diameter or corrosion resistant treatments.
Securing piles are placed every 2 meters to unite the individual cylinder steps in order to prevent slippage. Select rot retarding timber or apply rot prrofing coating on these piles in order to extend their effect over a prolonged period of time.
Additionally, stone filting with mixed diameters stones larger than the size of the wire mesh in order to reduce the porosity and increase the resistance against the settling and shifting of the ground.
Furthermore, at job sites where good quality boulders are readily available, filling materials are easily obtained, with a secondary effect to clear the work site.

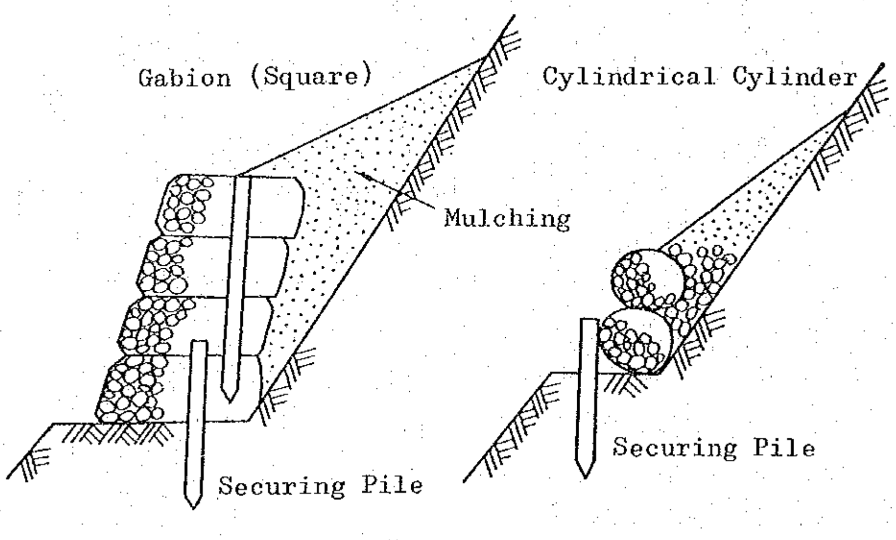


Diagram 3-7 Wire cylinder (Gabion) Retaining Work

6) Fascine Retaining Work

This is a pile of 40 - 50cm long 10cm diameter fascine bundles piled alternately with 10cm thick layer of mulching. This method exhibits increased moisture storage of the slope resulting in early stage growth of vegetation. However, although this method is ideal for execution during the winter in excessive congelation areas, the height must be kept below 1 - 1.2 meter due to the easy rotting of fascine bundles and low earth pressure resistance. Furthermore, execution in surface run-off concentration areas should be avoided since covering soil are easily washed out by surface run-off. The surface incline should be under slope ratio of 1:3, with twigs such as willow, which has good reproductive power from sprout, intermixed in the fascine bundle. Moreover, it is important to plant the soil covering with weeds such as miscanthus for early stage growth of vegetative overlay in order to increase the retaining effect with vegetation.

Fence Retaining Work

Fence retaining work is performed in order to prevent the filling soil from becoming washed out as well as improve the environment of the planting by producing fences filled with soil in the back in the horizontal direction along the hillside. Logs and fascine are used as materials for this fencing. Logs and fascine, though, are only used for temporary measures or when early stage restoration of stability is anticipated due to the poor durability. Piles securing the fence must have a top end diameter over 9cm with a length of 1.5 - 2m. These piles are driven into the hillside in the bisecting direction of the vertical and perpendicular on slope directions as illustrated in diagram 4-9. Piles are driven in this angle since they may be removed or fractured by falling rocks when placed vertically, or reduced in resistance against earth pressure when placed perpendicularly on slope. The standard pile driving depth is over 1/2 - 2/3 the length of the pile with one meter space. Early stage vegetation growth may be attained resulting in improved ground securing effects, by intermixing species with storing sprouting characteristics into the fascine.

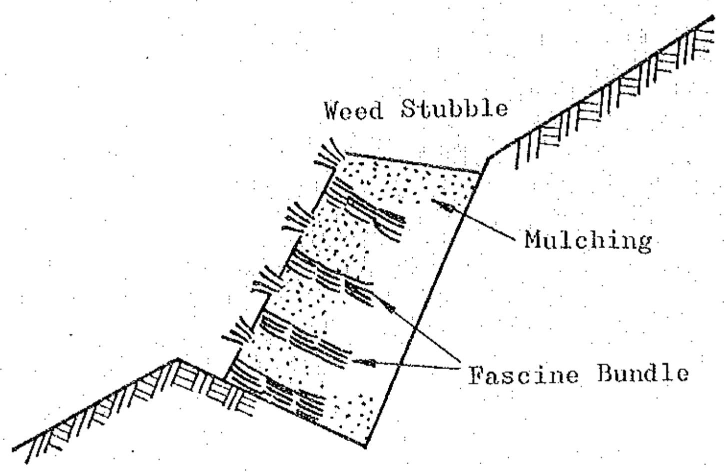


Diagram 3-8 Fascine Retaining Work

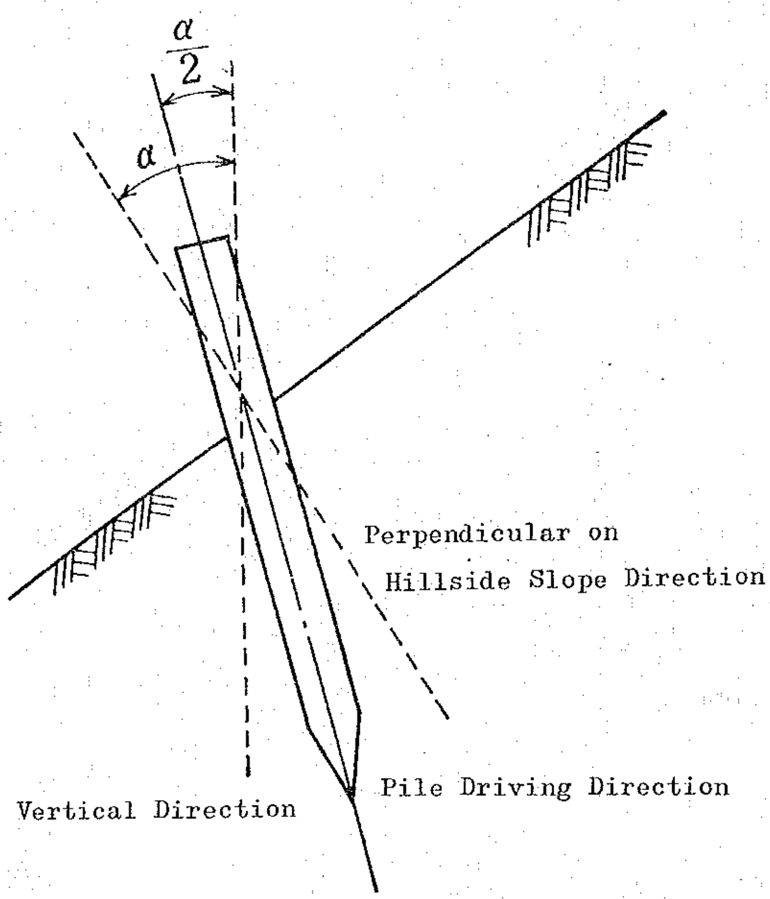


Diagram 3-9 Driving Direction of Securing Pile

3. Buried Work

This method is employed when hillside slope restoration is difficult unless the waste soil is deposited deeply into the sunken sections due to excessive grading soil volume. This work is applied underground in areas where surface structures may be destroyed when the aforementioned soil become shifted with water. Structures are in accordance with retaining works. Additionally, concrete, stone masonry, wire cylinder, fence, and square cribs are designed.
The layout with buried work must be designed where the deposited soil become lower than the angle of repose. Furthermore they must be built rigidly on safe and sound foundation.

4. Drainage Work

Drainage work may be segregated into the water channel work, performed for the collection and drainage of surface water in order to prevent hillside erosions caused by the surface runoffs produced by rain and springs as well as to protect surface structures, and the closed conduit work placed underground in order to drain ground water which soften the soil horizon and cause clod slippage.

(1) Water channel Work

Layouts vary depending on the form of the work-site/topography, but are placed along the concave slopes on the collapsed surface.
The flow section is determined with the catchment area. Calculations to obtain the sectional area, are explained in following Chapter.
The safety factor in hillside channels should be 5, considering the soil, gravel, and stump deposition. Additionally, there are arc, trapezoid, and quadrangle formed sections.
The incline of a waterway must be made constant since soil may deposit in the changing point of gradient resulting in decreased flow sections. The waterway must be split in conjunction with hillside retaining work at changing points of gradient. Additionally, gradient must be reduces in conjunction with hillside retaining work similar to the aforementioned changing points of gradient, for the flow surface become eroded with run-offs when the angles of incline are excessive. The length of a single span should be basically less than 20 meters considering the risks of differential settlement caused by the self load of the

water channel and by slidingdamages. Bed gindle ① are to be provided in places where the overall length exceeds 20 meters.

Waterchannel works may be segregated into stone slastering channel with wet and dry masonry, sodded channels covered with sod, concrete waterchannel, concrete piping, corrugated pipe channel, and wire cylinder channel in accordance with their structural material.

① The Bed Gindle is also called a supporting line, and is a dam formed structure with the top in the bottome of the waterchannel. This structure rectifies the waterchannel gradient to enhance safety as well as prevents damages by precl ding the water from flowing beyond the waterchannel.

1) Stone Plastering Channel

This type of waterchannel have been employed by mankind since ancient times with flow sections in the form of an arc or trapezoid. The two types of this channel are the wet masonry method where the stone plastering secured with concrete, and the drymasonry method where concrete is not employed.

Wet masonry are performed with DOHGOME concrete as the securing agent for the stone consolidation on a foundation with over 20cm back fill in regions where water concentration on hillsides are abundant, resulting in excessive soil washout by run-offs by rainfall, as well as in unstable ground caused by landslides, etc. Dry masonry are performed on back-fills at times in places where nomal water volume is munimam, such as on thetop of relatively steep gradient hillsides or in low water concentration hard soil regions. Run-off resistance become increased by supporting the stone consolidation by securing piles into the DOHGOME gravel packed carefully into the back space.

Dry Masonry Arc Formed Channel   Wet Masonry Trapezoid Formed Channel

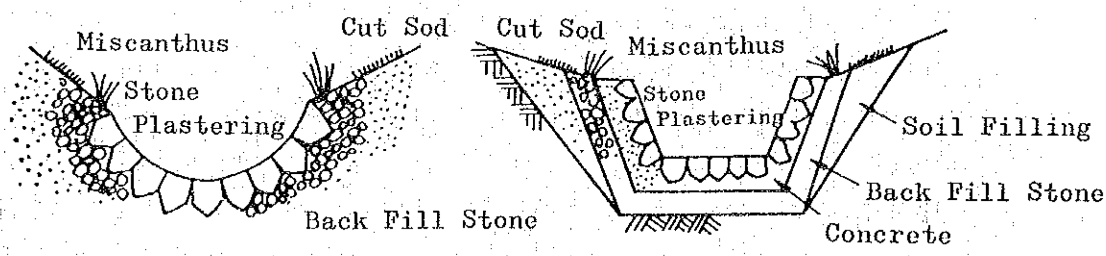


Diagram 3-10 Stone Plastering Channel Work

2) Sodded channel

Sodded channels are employed for branch waterchannel in large scale denuded lands as well as in minor denuded areas with small discharge.

Application of this work is not only simple, but is economical as well when good quality sods are available in the vicinity of the work site. Additionally, this is one of safer methods against differential settlements.

Furthermore, execution must be planned for the season where the growth of the cut sod are rapidly attained. The MEGUSHI or pin stick employed should be comprised with strong sprouted trees in order to attain stability through vegetation. The standard sodded channel form and dimensions should be an arc with 1.2m arc span with 0.3m depth considering the ease of construction and waterway wafety.

The employed sods are to be prepared upon calculation of the area with the equation below.

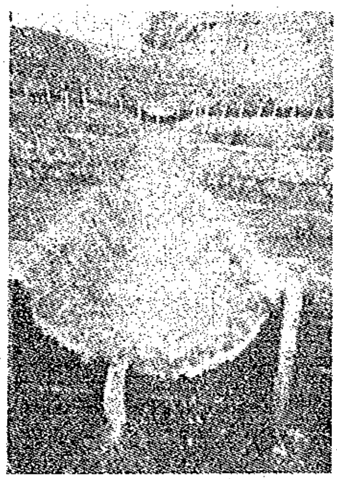
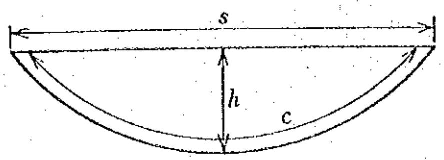


Diagram 3-11 Sodded Channel

$$A = cl$$

$$C = S + \frac{8h^2}{3s}$$



A: Sod Planting Area
C: Sectional Arc Length
l: Waterchannel Length
s: Waterchannel width (Arc Span)
h: Waterchannel Depth

3) Concrete Waterchannel Work

This type of waterchannel is located with anticipation for efficiency equivalent to wet masonry stone plastering channel work, and are employed for trunk channels. The sectional form of waterchannel produced with this method are either trapezoid, or quadrangle. Bed gindles are added in order to reduce the incline for speed control when abrasion are expected to be generated on the inner surface due to fast run-off speeds.

Standard bottom thickness is over 0.3m with the width at the crown of the sides at 0.15 - 0.2m. Additionally, standard side wall front is slope ratio of 1:0.3 to 1:0.5 with the rear side slope perpendicular or minus ratio of 1:0.1. Slope ratio of 1:0.1 to 1:0.2 it to be placed on side walls when earth pressure is expected to be excessive. Construction of this type of water-channel must be made on rigid foundations since the self load is excessive, with all loads applied to the bottom, and therefore, may become destroyed by differential settlement.

4) Concrete and Corrugated Pipe Waterchannel

This method is employed in places where execution of other methods are difficult because of water, or in areas where concrete cannot be laid on the work site due to excessive run-offs during rainfall, as well as where materials cannot be transported resulting in prohibition of onside concrete application due to the topography. This method is become to be employed more widely due to efficient execution.

Concrete pipe is produced in factory, it is made to place concrete in the form with reinforcing bar, and to compact it by vibrators, and to cure it for some terms.
Corrugated pipe is factory product of steel half-circle and have been employed in many case, since it is lighter than concrete pipe, and is convenient in view of treatment and carriage.
Close attetion must be paid for securing these waterchannel when executing this method since conditions are different from level topography. Additional, the major sources for destruction are differential settlement and erosion of the refilled soil caused by run-offs outside the side walls. Therefore, care should be taken when executing protective works for the foundation in the bottom as well as for the outer sides of the side walls.

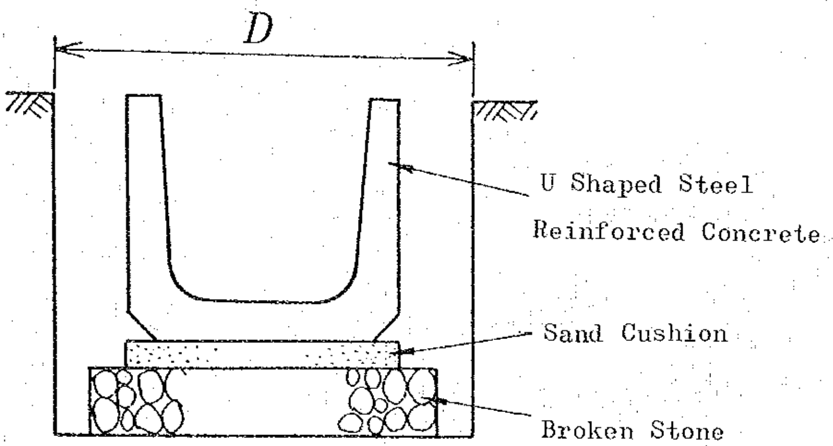


Diagram 3-12 Concrete Pipe Waterchannel Sectional View

5) Wire Cylinder (Gabion) Water Channel
The flexibility of this method is employed in soft soiled areas and in work sited where ununiformed shifting of partial soil may occur.

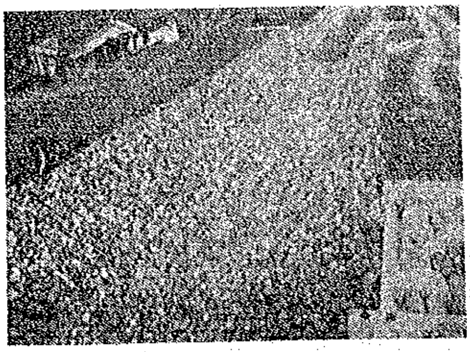


Diagram 3-13 Wire Cylinder (Gabion) Water Channel

Additionally, this method is highly economical in work sites where boulders and gravel employable for fillings are readily available. There two types of wire cylinder waterchannel are the rectangular waterchannel employing rectangle wire cylinders, and the arc formed waterchannel employing the round wire cylinder. The wire cylinders in this method control the channel. Therefore, wire cylinders are secured with securing piles in steep gradient areas, to prevent wire cylinders from being destroyed by the movement of wire cylinders themselves caused with the discharge. Furthermore, close attention should be paid to the execution of the waterchannel bed, so as the collected water become rapidly drained without infiltration.

2) Closed Conduit Work

This is an underground waterchannel provided to guide the ground water which is a cause of landslide generations rapidly out of the area or to surface drainage channels. Designing and method of execution should be determined in accordance with the conditions of spring, sub-surface water and ground water flow. Segregations of this work are made with the materials employed, such as gravel, wire cylinders, fascine, and vinyl chloride pipes.
Gravel covered conduits are widely, used in areas with large volumes of ground water. 5-15cm of gravels are packed as illustrated in the sectional view diagram 3-14, and are then covered with sod or fascine overlay which are topped with soil filling in order to prevent the closed conduit from becoming clogged by soil entry. Drainage effects may be performed over extended periods of time by laying impermeable materials such as vinyl chloride sheets in the bottom to prevent erosions.
Extended effects cannot be expected with the employment of fascine which exhibit poor durability and water catchment, but used when transportation or acquisition of gravel are difficult.
Wire cylinder closed conduits are similarly structured to gravel closed conduits, but exhibit superb preservation effect of a single, stable underground waterway in steep gradient as well as stratum change regions sue piles being driven in approximately every 2 meters to preclude movement.

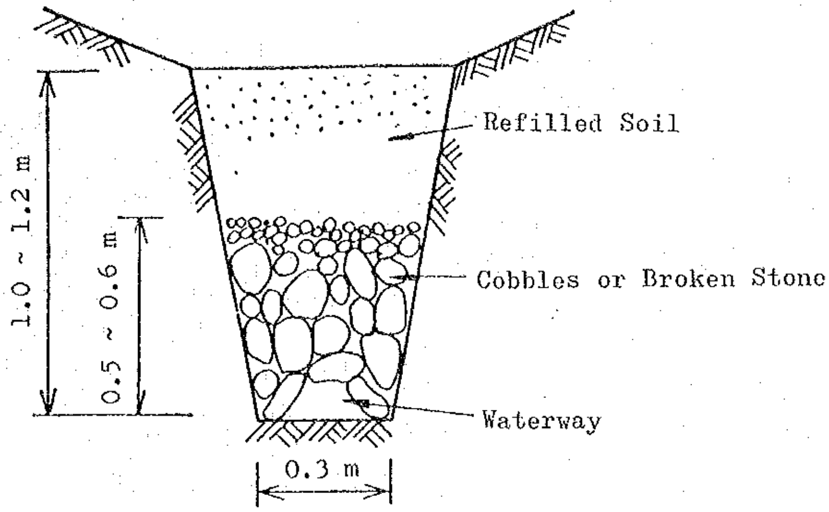


Diagram 3-14 Closed Conduit Sectional View

Closed conduits made of drains comprised with vinyl chloride pipes, etc. maintain effects over extended periods of time even in relaxed waterway gradient regions. However, selection of types and sizes must be made in accordance with the ground water volumes, soil conditions, and the degree of gradient.

Section 6 Hillside Planging Work

Soil movements on devastated hillsides may be temporarily stopped with the various aforementtioned foundation works. However, though, soil structure which is the base of vegetation growth of such surfaces are poor, and are inadequate for rapid vegetative overlay due to delayed natural entry of vegetation. Structures erected for hillsides foundation works may be destroyed with hillsides reverting back to the original devastated condition when heavy rainfalls or avalanches are encountered prior to the development of the stabilization effect of vegetative overlay.

Following the execution of hillside foundation works, overall replanting should be performed to prevent generation and increase of erosion. Additionally, restoration of the water regulation and conservation effects of forests should be simultaneously considered. Therefore, vegetation methods such as planting on horizontally cut-away steps in hillsides as well as overall replanting are performed. In either case, continued stabilization of the slope with full-grown forests must be considered, starting with grass overlay initially, followed with induction of trees.

1. Sodding Work

This method is applied on denuded collapsed hillside with poor surface soil as well as dry hillsides. The purpose of this work is to improve the environment of trees as well as to disperse and infiltrate surface run-offs and to delay the run-off speed in order to prevent sheet erosion and facilitate the growth of the vegetation.

Depending on the volume of sods employed, this method may be segregated into triple sheet, quintuple, and step sodding work, etc.

0.3-0.5m width horizontal steps are cut out every 1.0-1.5m lineal height from the slope, and the surface slope is executed ratio of 1:0.3 and is covered with cutting sods. Tree is planted in the back of the terrace by filling back with soil.

Vegetatition, growth may be facilitated by applying fertilizers as well as by laying rice straw as the primariry fertilization agent, and moisture preservation. Artificial vegetation blocks and vegetation sacks 1
work are applied in work sites where transportation and acquisition of natural sod are difficult. 1 .

The standard lineal height of sodding works should be 1m up to approximately 20 degrees incline hillsides, and 1.5 - 2m for steeper slopes.
The height should be decided in accordance with soil nature. In other words erosions on slopes may be decreased by blocking sandy soil low, and mixed soil such as clayish viscous soil hight.

Terraced sodding work is a term given to sodding works applied continuously with multiple steps on hillsides, which are employed for securing deposited silts in the sunken sections of hillsides as well as spurs.
Furthermore, masonry or concrete foundations as well as closed conduits are often used in combination with this work for safety.

Vegetation blocks are compressed and formed mixtures of soil, fertilizers, and cut rice straw planted with plant seeds. Vegetation sacks are meshed sacks filled with soil, fertilizers, and plant seeds.
Either of the two may be intermixed with the most appropriate combination of the aforementioned ingredients in accordance with the soil at the work site.

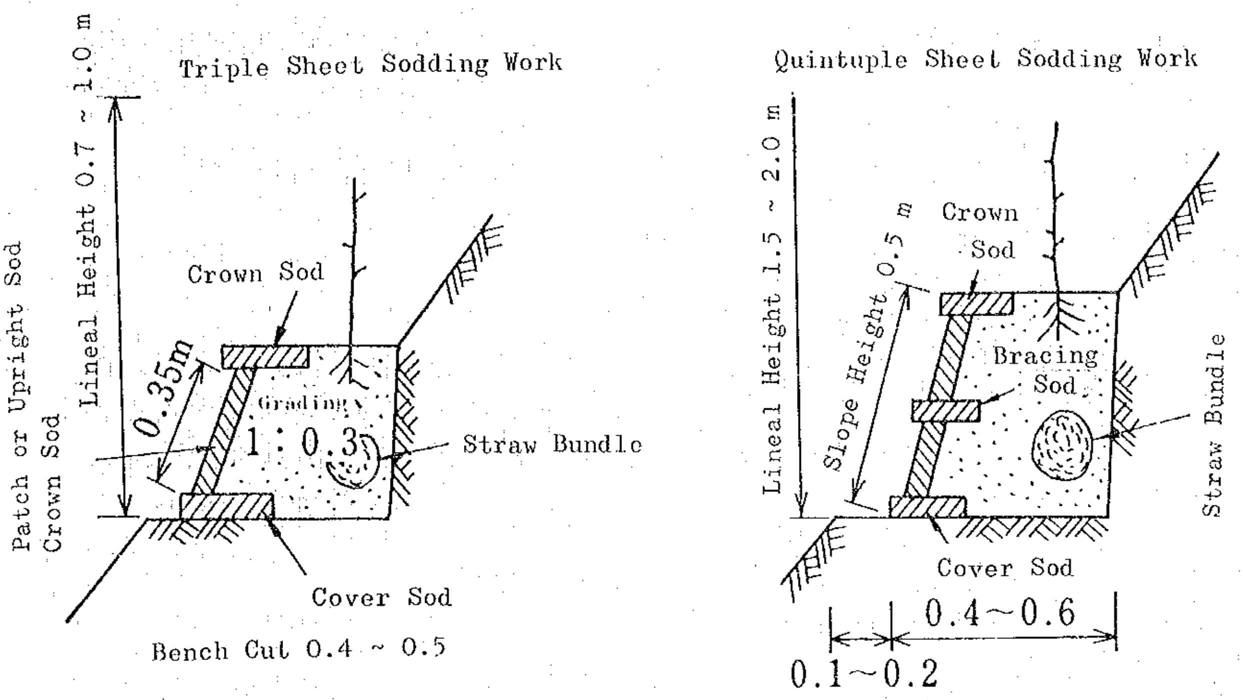


Diagram 3-15 Sodding Work Sectional View

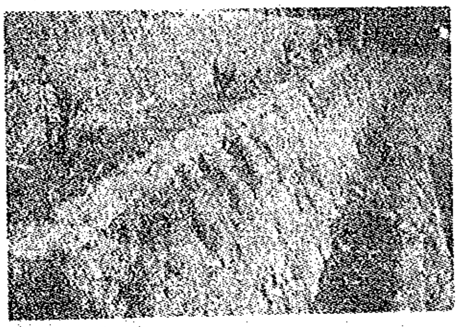


Diagram 3-16 Terraced Sodding Work

2. Simple Terracing Work

This is a form of terracing work which is simpler than sodding work, and is used on work sites with relatively abundant surface soil.
As with sodding work, the objective of this work is to prevent surface erosions by dispersing the surface run-offs on the slope surface

as well as to enhance early stage growth of vegetation with the improvement of the environment by increasing the water infiltration underground. Simple terracing works are applied by simply cutting steps out on hillsides to plant weed stubs or to apply secondary replanting products in strips, or by filling the terraces made of fascine or masonry with soil, as well as by applying secondary replanting products directly on the slope in strips.
Vagetation growth may be enhanced by employing straws for the primary fertilizing agent.

(1) Miscanthus Simple Terracing Work

This work is used in work sites with good soil condition where sodding works are not needed, and are often executed in combination with other treatments. This work is employed in work sites such as on the top of retaining works at the bottome of hillsides as well as where terracing is difficult due to steep incline, with soil adequate for the growth of Miscanthus.

Diagram 3-17 Miscanthus Simple Terracing Work

On hard soiled terrain, the miscanthus is planted in the berm of the terrace with a lineal height of 1.0 - 1.2m and a width of 0.3 - 0.4m cut out from the slope. Additionally, on soft soiled terrain, miscanthus growth may be expected by planting in horizontal strips with a lineal height clearance of 0.5 - 1.0m without cutting steps out from hillsides.

However, the aforementioned standard figures need not be adhered when covering works explained in the following part is to be performed on the slope in between the miscanthus step work.

(2) Sodded Simple Terracing Work

This work is identical to the aforementioned miscanthus simple terracing work with the subsidation of miscanthus with sod. This work is highly economical in work sites where sods are readily available in the vicinity.

Gradient between terraces are increased when terracing works are applied on steep slope hillsides. Therefore, these steep gradient must be mitigated with covering works to protect the slope.

On the other hand, replanting effects may be satisfactorily achieved in deep soil, good soil guality, gentle gradient sites by planting sod directly without terracing.

(3) Stone Simple Terracing Work

This work may not only be facilitated in work sites where boulders, gravel, and rubbles are readily available, but also aid in clearance of work sites. However, this work is not suggestable for employment in severe frost lifting or heavy snowfall regions.

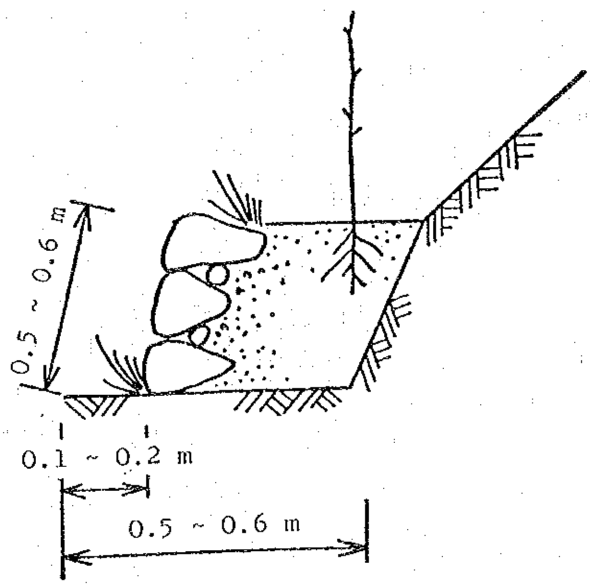


Diagram 3-18 Stone Simple Terracing Work

0.5 - 0.6m width steps are cut out every 1.0 - 1.5m lineal height. Stones are then piled for less than 0.5m height, followed by filling the back with soil. The surface slope should be more than ratio of 1:0.3 for these stone piles considering the safety, with weed stubs such as miscanthus planted on the crown and base for protection. Stones should be pilled in the longitudinal direction considering stability since stability is increased with longer brace length, using hard, weather resistant stones.

4) Fascine Simple Terracing Work

As illustrated in diagram 3-19, this work is performed to enhance the planted vegetation growth by cutting to from so to speak a pot with soil filling in the back of the bascine bundle. This method is employed in places where rapid stabilization of the soil by the early stage growth of weed stubs and miscanthus stubs may be expected since fascine rot rapidly. In other words, the applicable place is where the rainfall is relatively minimal, with the soil being viscous and the gradient gentle, as well as free of surface run-off concentration.

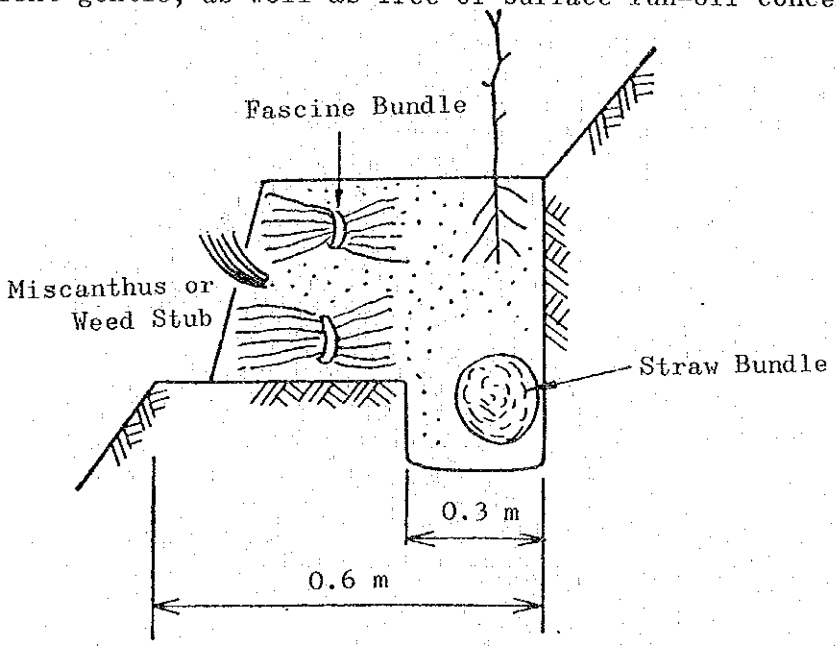


Diagram 3-19 Fascine Simple Terracing Work

1.5m lineal height, 0.8m width steps are cut on hillsides, piled with several layers of 0.1m diameter, 0.4m length fascine bundles until height between 0.3 - 0.5m is attained, and are then finally covered with soil.

Simple Terracing Work with Secondary Replanting Products

These factory manufactured secondary products for replanting work are becoming to be used widely in recent years due to their efficiency for reducing transportation costs as well as cost effectiveness. These products may be segregated into those with soil dressing effects and those without

Those with soil dressing effects are employed in places where natural ground is exposed as well as poor soil conditioned areas. They are mainly comprised with soil intermixed with peat and fertilizers, or organic fibers as the parent material which are then blended with highly germinative power plant seeds with expectations for early stage slope stabilization by the rapid growth of vegetation upon execution. Products which do not exhibit soil dressing effects are mainly cloth and rice straws applied with plant seeds and fertilizing agents, and are used in areas where the sedimentary is deep, exhibiting adequate vegetation growth conditions. The actual execution of this work is nothing more than cutting horizontal 0.5m lineal height ditches on hillsides in order to bury the products followed with earth covering upon completi on.

3. Covering Work

Steep gradient slopes may fall or become washed out by rainfall, freezing, needle ice, and wind when left untreated. Works performed in order to prevent afor mentioned falling or washing out and to prevent the washout of planted vegetation as well as to preserve the moisture for the germination and growth of vegetation with overlays are called covering work. Covering Works have been executed with fascine, rice straw, straw mats, an and nets conventionally, but are becoming to be superseded with secondary replanting products possessing effects of both covering and seeding works.

(1) Fascine Covering Work

Fascine covering work is to lay fascine closely horizontally on the slope with wooden cramp and piles driven in to secure.

This method is employed in work sites where fascine is readily procurable as well as where piles may be rigidly driven.

The clearance between the wooden cramp should be 1m, to fasten fascine and piles are to be driven into the center and sides of it.

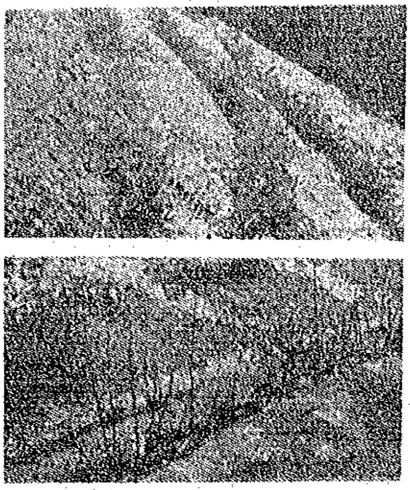


Diagram 3-20 Fascine Covering Work

(2) Straw Covering Work

This method is employed in places where the slope gradient is relatively gentle with easy drying features as well as minimal surface run-offs.

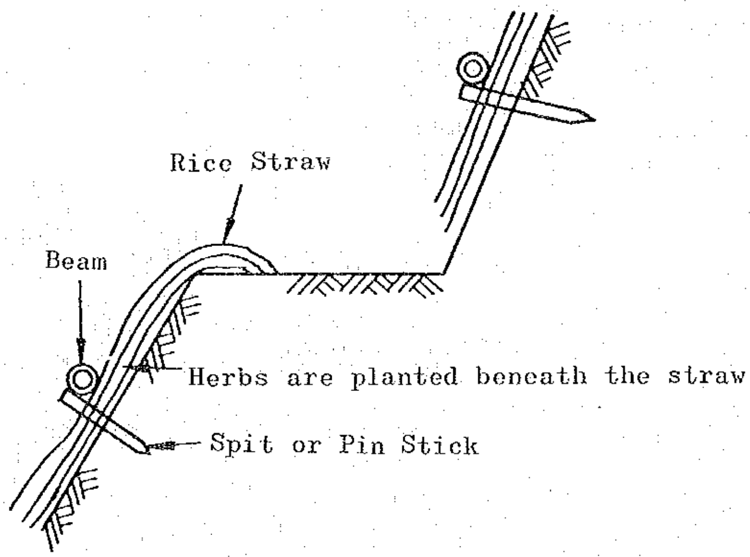


Diagram 3-21 Straw Covering Work

Straws should be secured with ropes, beams, and spit in order to prevent from littering by winds and rainfall. Straws may be superseded with miscanthus in places where they are readily available.

(3) Straw Mat Covering Work

Erosions on light soiled slopes may be enhanced with each succeeded rainfall finally resulting in the collapse of the slope. Additionally, there is highly erodible by frost heaving and needle