APPENDIX VIII

SELECTED AVALANCHE STRUCTURAL DEFENSES

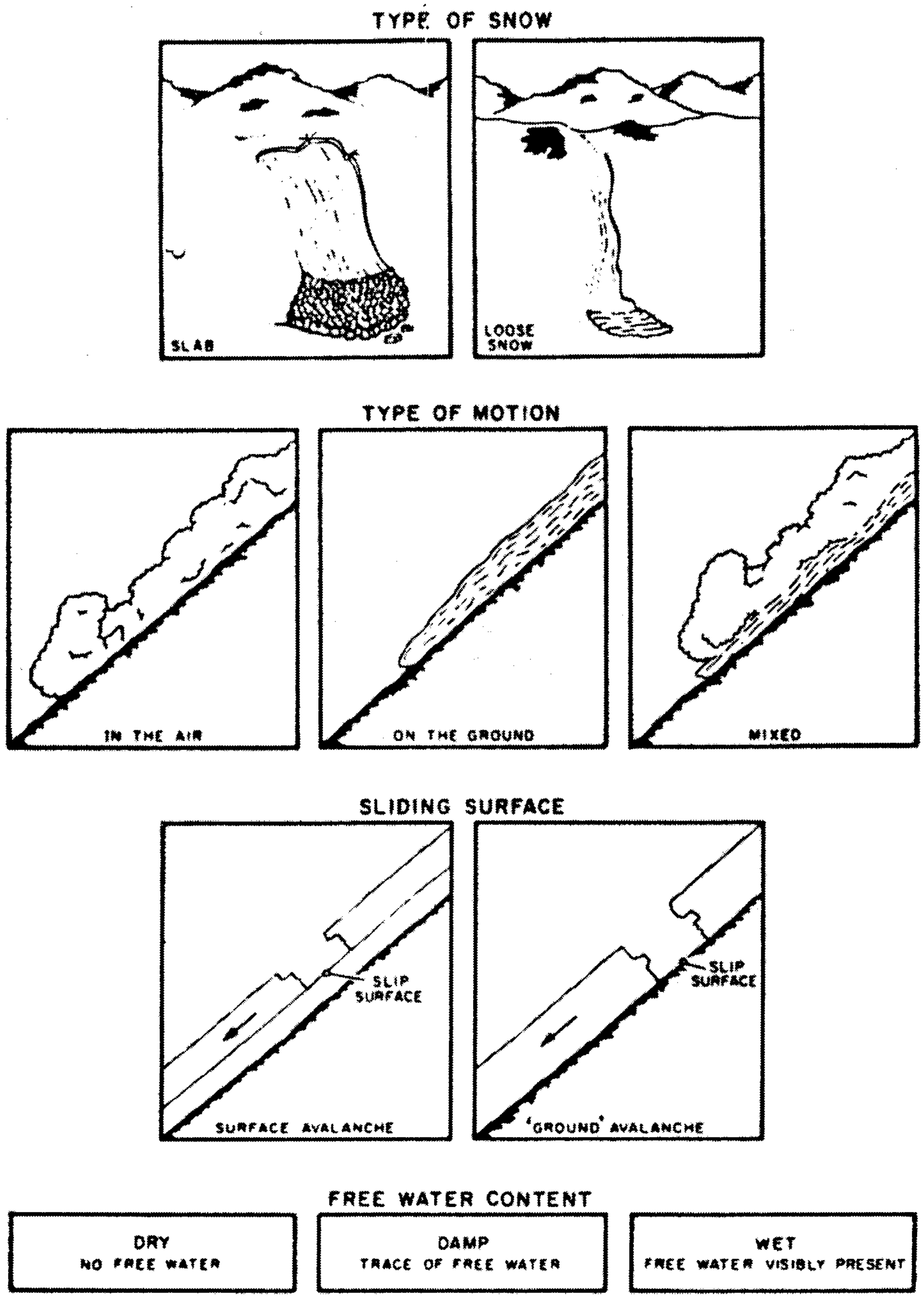


Figure 12. Current U.S. Forest Service avalanche classification.[124] It is conceivable that this classification might be modified in the future to conform more closely with the scheme given in Table II. The term "ground avalanche" should probably be changed to "full-depth avalanche."

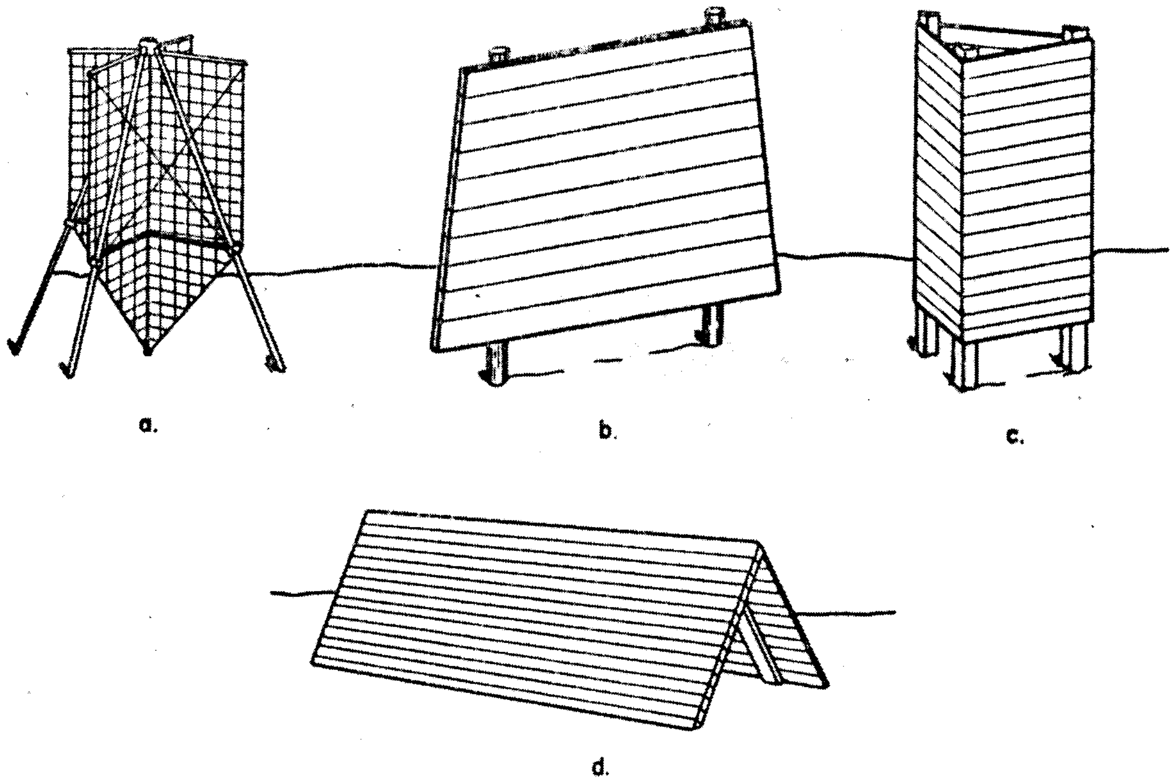
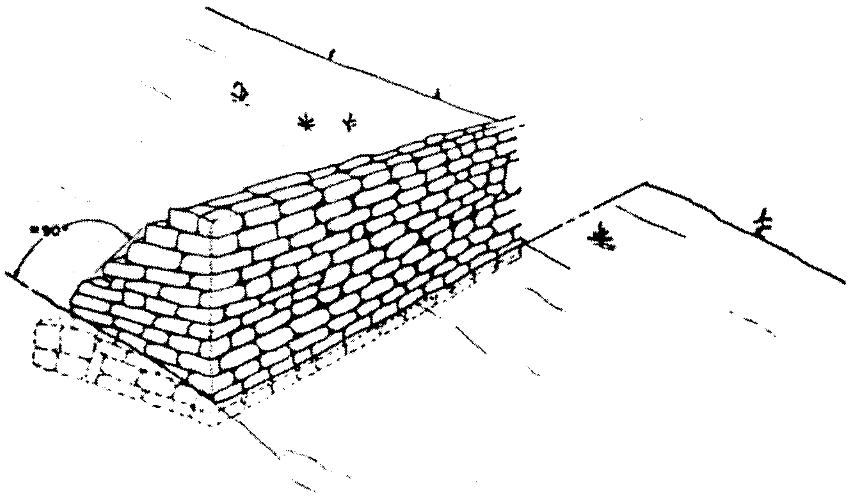
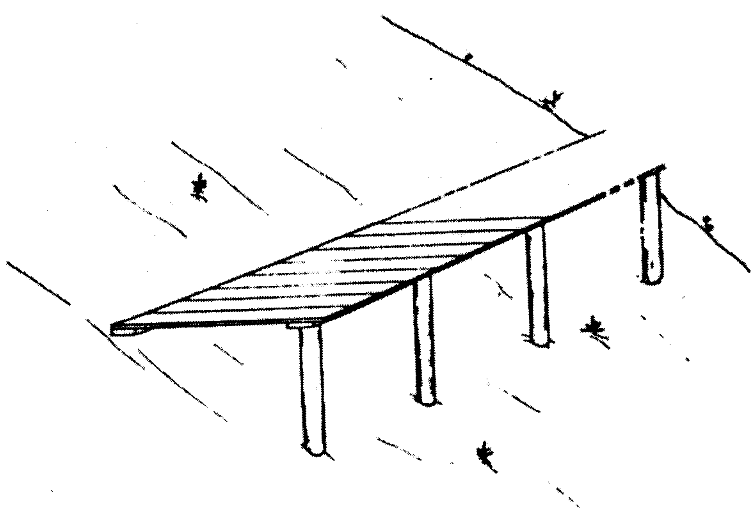


Figure 23. Wind baffles for modification of snow deposition patterns. (a) cruciform baffle (Treibschneekreuz), (b) "billboard" baffle, (c) triangular screen, (d) "tent" baffle.

Supporting works take a variety of forms, but most of them can be put into one of two categories: (a) retaining barriers whose support surface is inclined approximately normal to the slope plane, (b) steps or terraces whose support surface is close to horizontal. Early stabilizing structures included masonry retaining walls (Fig. 24a), cut-and-fill terraces (Fig. 25), timber barriers (Fig. 26a), and wooden terracing platforms (Fig. 24b), all laid out in ranks aligned at right angles to the line of greatest slope. Nowadays the favored type of supporting structure is a retaining barrier erected with its support face tilted some 15° downslope from a perpendicular to the slope plane. Manufactured materials such as steel and aluminum sections, precast concrete members, and steel or nylon netting are now widely used, although wood is still an acceptable material, especially in combination with metals. Obviously, natural barriers are much to be desired, and so the reestablishment of tree growth is an important long range goal in many schemes for the support of snow in avalanche starting zones. Reforestation is in itself a complicated problem, involving ecological considerations and introducing requirements for special structures (fences, tripods, terraces, etc.) to protect new growth.[65]



a. Masonry retaining wall – inclination of the supporting surface varying roughly from the vertical to a direction perpendicular to the slope plane.



b. Wooden ramp or platform – supporting surface close to horizontal.

Figure 24. Old-style supporting structures.

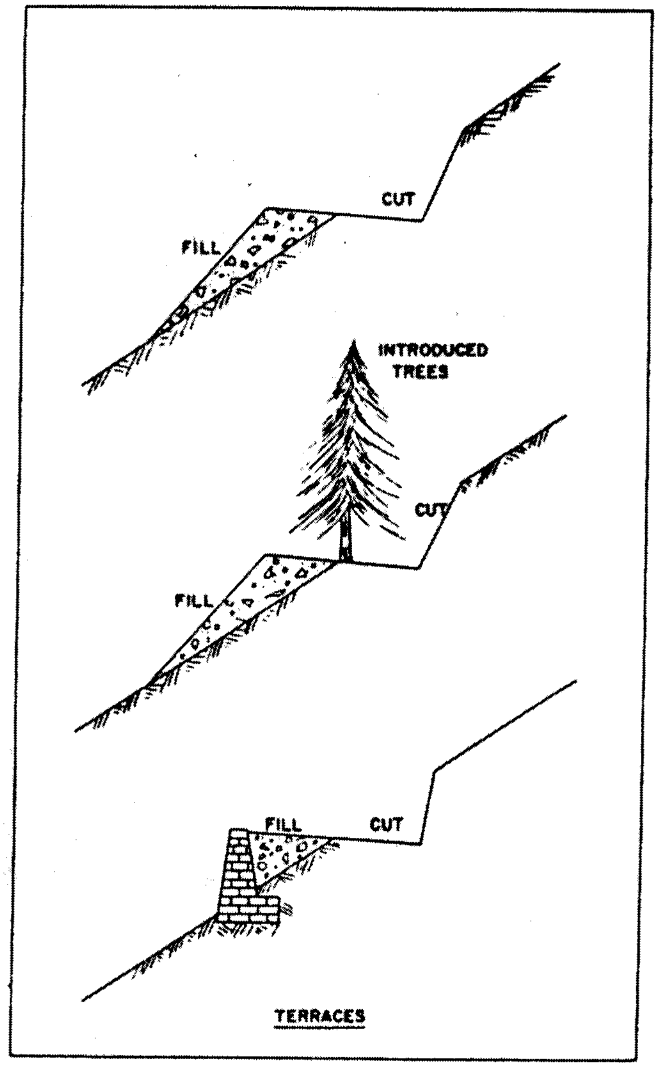
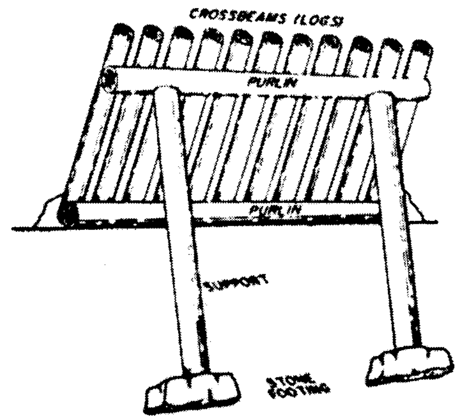
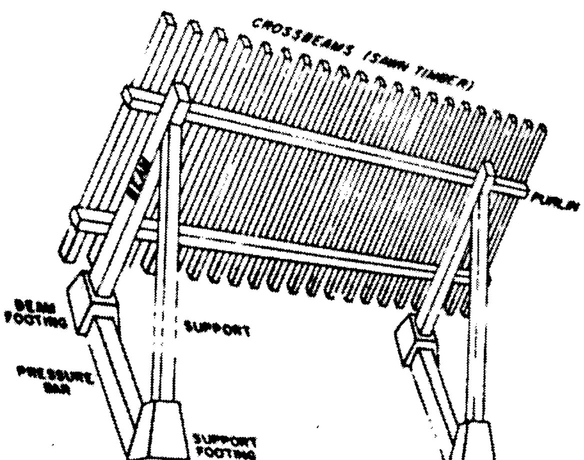


Figure 25. Cut-and-fill terraces.

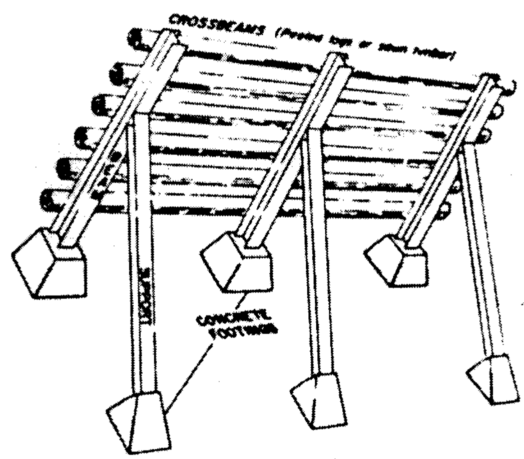
A good supporting structure has a threefold purpose: (a) to provide direct support to the deposited snow, thus relieving downslope shear stresses; (b) to break the continuity of the snow cover along the fall line, hence limiting the effects of longitudinal strain; and (c) to check incipient slides. In order to meet this triple need, a structure must have the strength to resist both the static forces induced by creep and glide of the snow and the dynamic forces which may be imposed by snow slides which start between successive ranks of barriers; it must also extend from the general ground plane far enough to divide the snow cover. Considering these things it appears that, while terraces may occasionally be expedient and economical, fabricated structures erected approximately perpendicular to the slope will generally be the most efficient and economical answer to the problem. The design of these structures is considered separately later.



a. Simple snow rake (crossbeams upright) built from round timber.



b. Snow rake built from sawn timber on a concrete foundation.



"I" Beams or steel pipe used for beams and supports

c. Snow bridge (crossbeams horizontal) with concrete foundation, steel frame, and timber crossbeams.[120]

Figure 26. Supporting structures for avalanche starting zones. Rakes are more resistant to thrust concentrated near ground level, and they are less susceptible to damage from dense snow which slides after melting back from the barrier in spring.

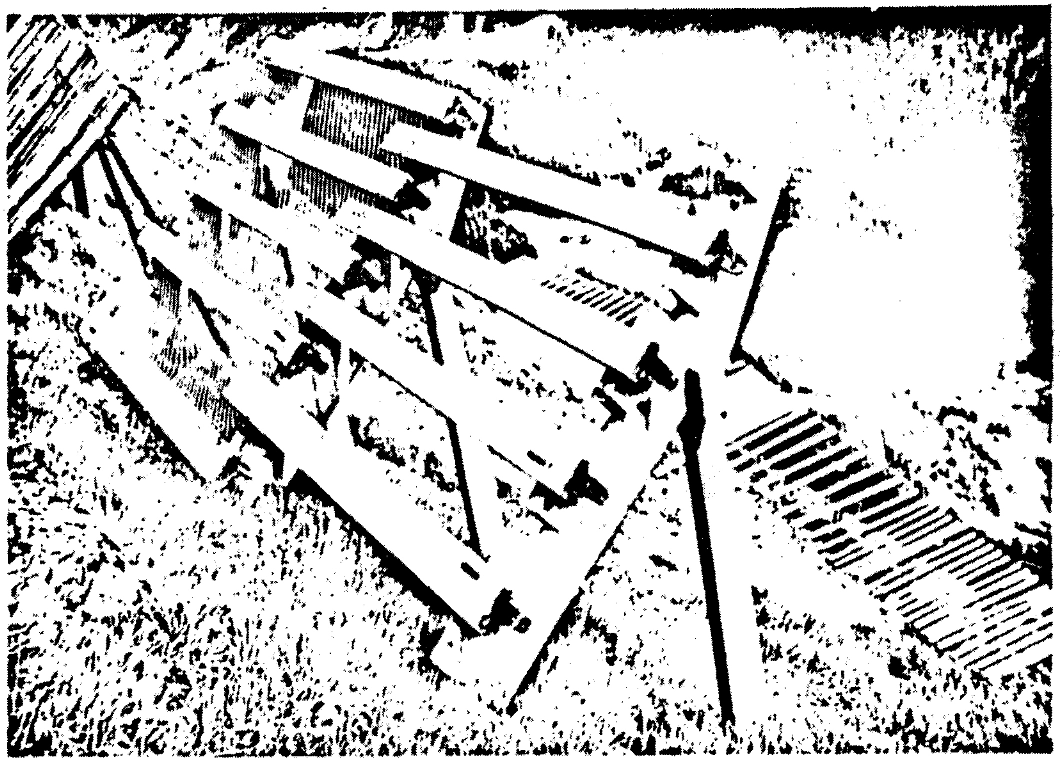


Figure 27. Prestressed concrete supporting structure at the Dorfberg experimental site, Davos, Switzerland. (Photo by E. LaChapelle.)

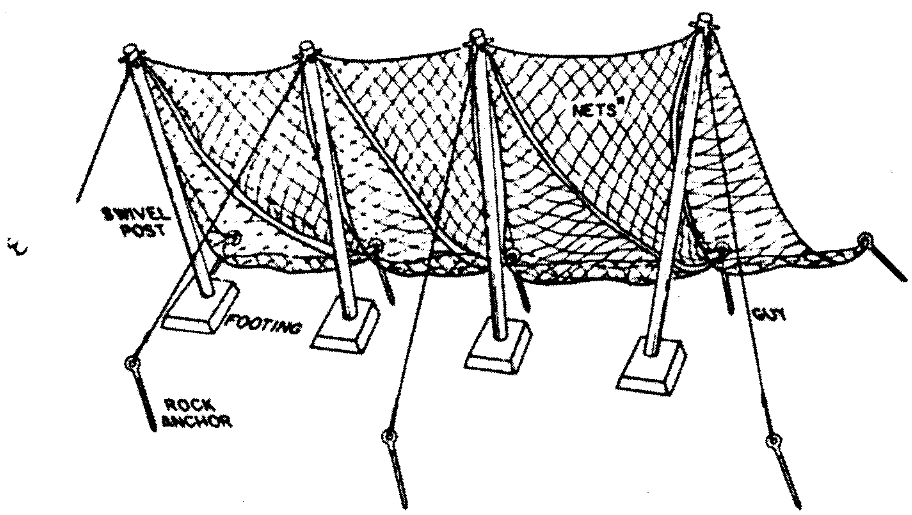
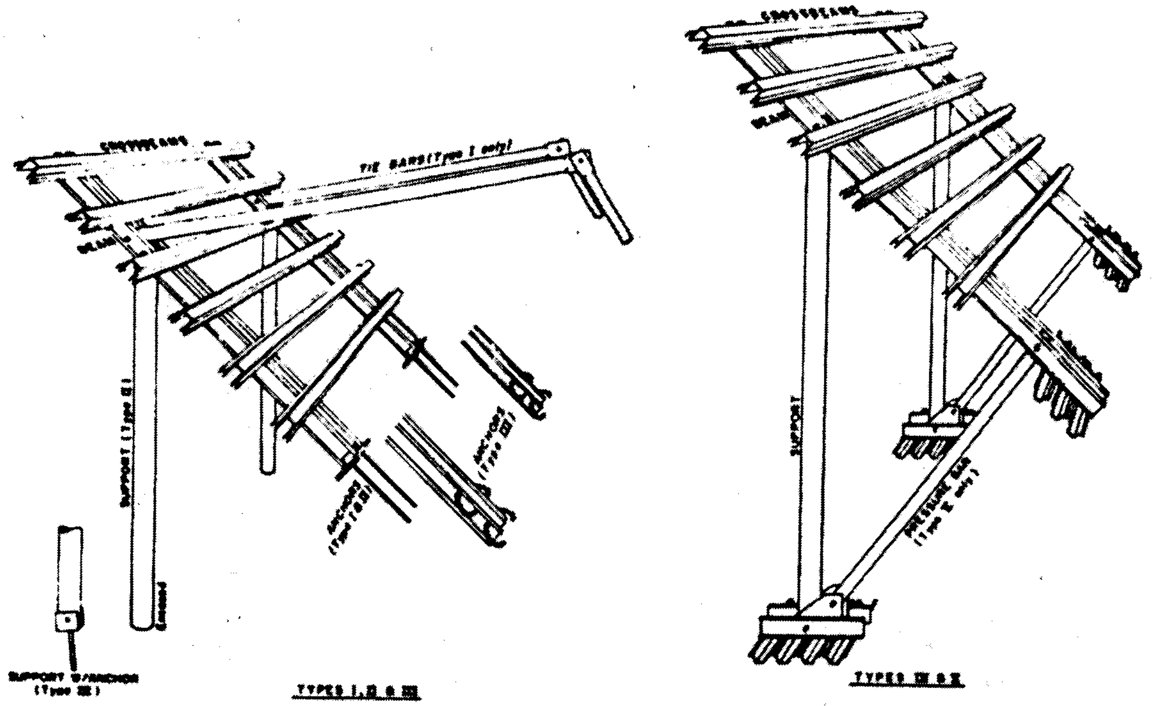
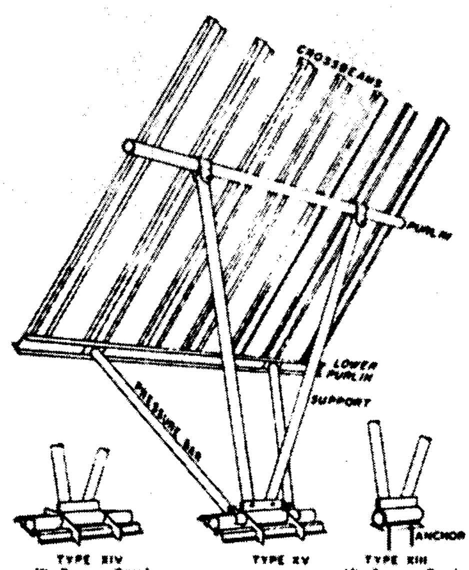


Figure 28. Snow net. Nets are usually wire rope, about 8 mm (≈0.3 in.) diam with 12 mm (≈0.5 in.) diam edge ropes. Nylon nets (of the kind used as aircraft arresters) have been used, but prolonged exposure to ultraviolet radiation is thought to cause deterioration. Mesh size is about 20 to 25 cm (8 to 10 in.). Common sizes for triangular nets are (base x height): 1.7x2.5, 2x2, 3x3 and 3x4 m (≈5.6x8.2, 6.6x6.6, 9.8x9.8, 9.8x13.1 ft). Typical sizes for rectangular nets are 1.5x2.0 and 2.0x2.5 m (≈4.9x6.6, 6.6x8.2 ft). Posts are 3 to 4 m (9.8 to 13.1 ft) long, 10 to 17 cm (3.9 to 6.7 in.) diam, and anchor ropes are 1.3 to 1.6 cm (0.51 to 0.63 in.) diam. (For design, see ref. 28, 97.)

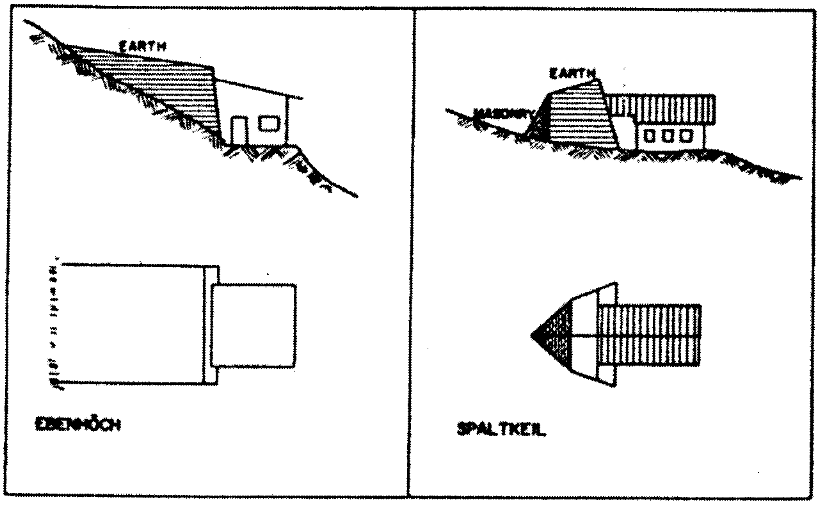


a. Snow bridges.



b. Snow rakes.

Figure 29. Designs for construction of supporting structures in aluminum and steel. (After Guler.[39])



a. Protective ramp. b. Protective wedge.

Figure 31. Deflecting structures.

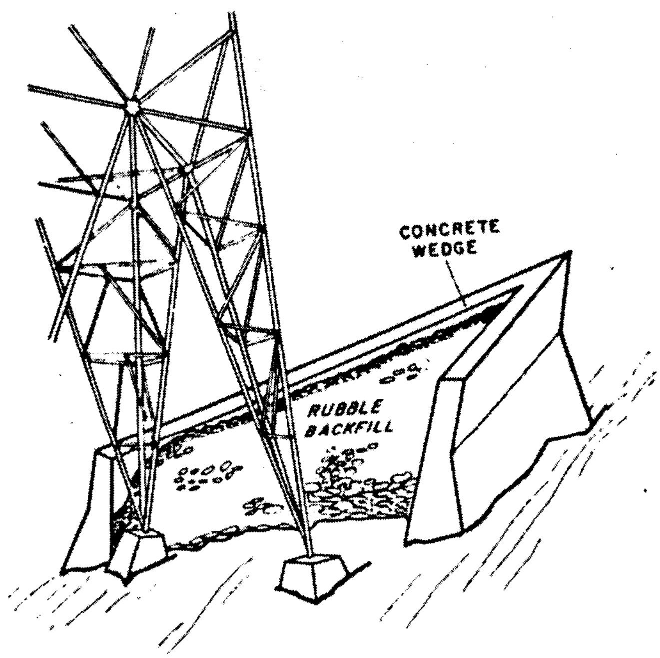


Figure 32. Concrete wedge for the protection of a pylon.

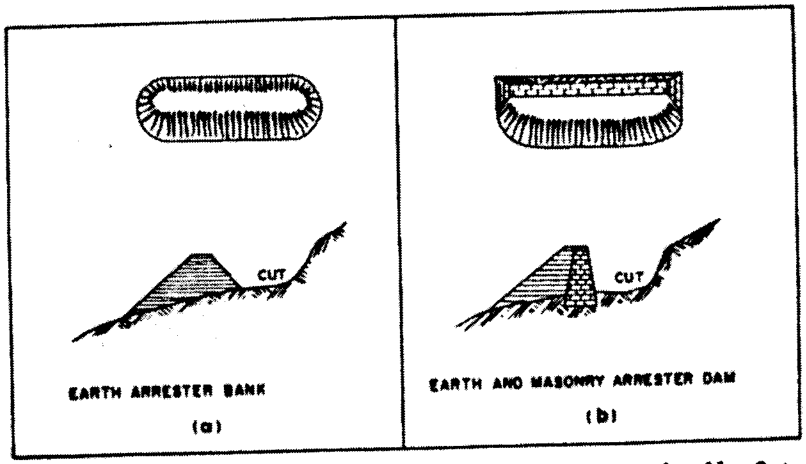


Figure 34. Cut-and-fill arrester dams, typically 3 to 5 m (10 to 15 ft) high. Arrester dams have not proved to be very reliable.

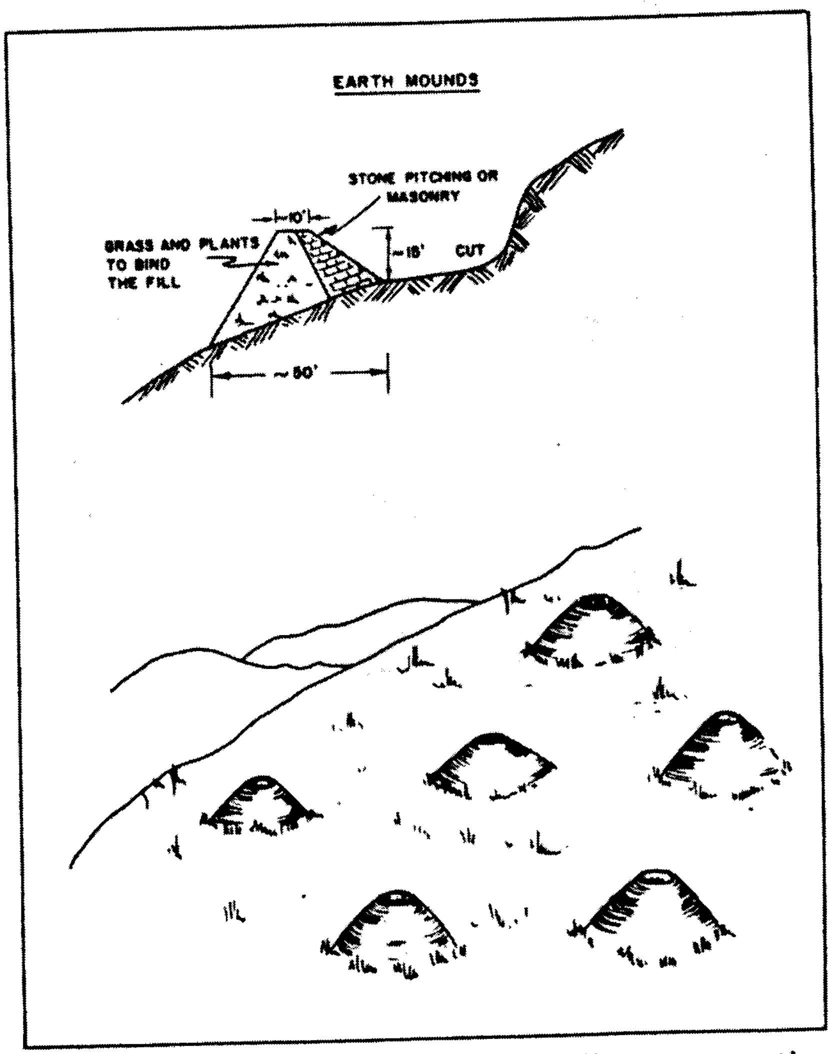


Figure 35. Earthen mounds for retarding or arresting slides.

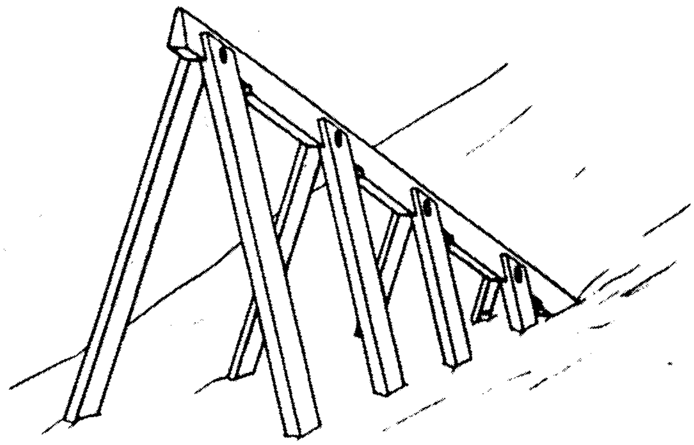


Figure 36. Precast concrete breaker ("concrete tripod").

Mounds are most effective against avalanches whose motion is largely on the ground (Fliesslawinen). Large, dry snow avalanches with much airborne motion tend to override them.

If it is undesirable to tear up the slope surface to build mounds, breakers can be built of other materials. Figure 36 shows a breaker built from precast concrete members ("concrete tripod").

Controlled release of avalanches

In sparsely populated areas and along lightly traveled highways it may be economically impossible to undertake avalanche defense construction, although human life still has to be protected. Under these circumstances the best solution appears to lie in deliberate release of avalanches while the danger zones are evacuated. This approach is widely used throughout the western United States and in Alaska by Forest Service personnel, highway departments, resort operators, and industrial concerns.

Whenever significant accumulation occurs in avalanche starting zones, access to slide paths is barred and attempts are made to dislodge the snow, usually by means of explosives. Not only does this ensure that slide paths are clear during avalanche descent, it also prevents the development of very large avalanches by periodically removing snow which might otherwise accumulate to dangerous proportions.

"Triggering" of avalanches, both natural and artificial, is discussed later.

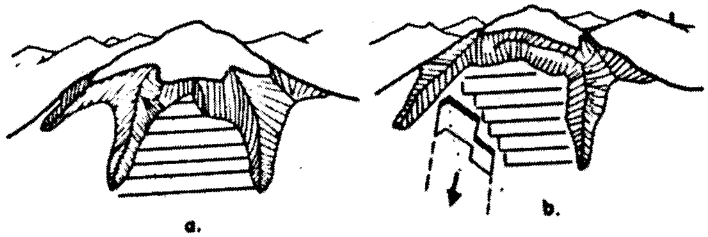
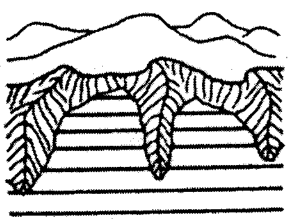
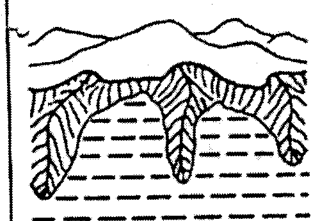
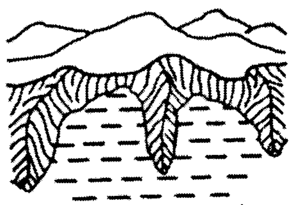
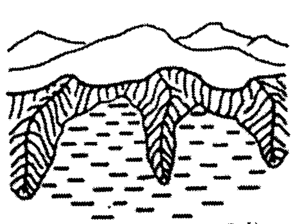


Figure 38. Schematic plans of defense works. (a) Complete protection extending laterally to natural terrain boundaries, (b) partial control with rows staggered to avoid slide damage at the free end.

Table VI. Arrangement of supporting structures (from Swiss Guidelines).

Arrangement	Advantages	Disadvantages
 Continuous	Continuous obstacle for loose snow slides. Tension stresses in the snow cover seldom develop. End forces are reduced to the ends of the work ranges (total snow pressure stresses are minimized).	Limited applicability on irregular terrain or broken ground and when the snow depths change locally. Large continuous areas of snow still exist where tensile and shear stresses can develop. Damage may be propagated laterally.
 Interrupted	A good fit to terrain configuration and to local changes in snow depths is possible. Damage from moving snow will be localized to single sections. Cheaper than the continuous arrangement in certain cases.	Loose snow can flow through the intervals. Each individual structure is subject to end forces.
 Echelon and staggered  Combination of discontinuous arrangements	Most adaptable to the terrain configuration in all directions. All permanent tensile and shear stress zones are divided. Gliding of snow cover between the works is reduced.	Stressing by end force corresponds to an isolated structure. Cost per unit length of structure is higher than the continuous and the interrupted arrangements.

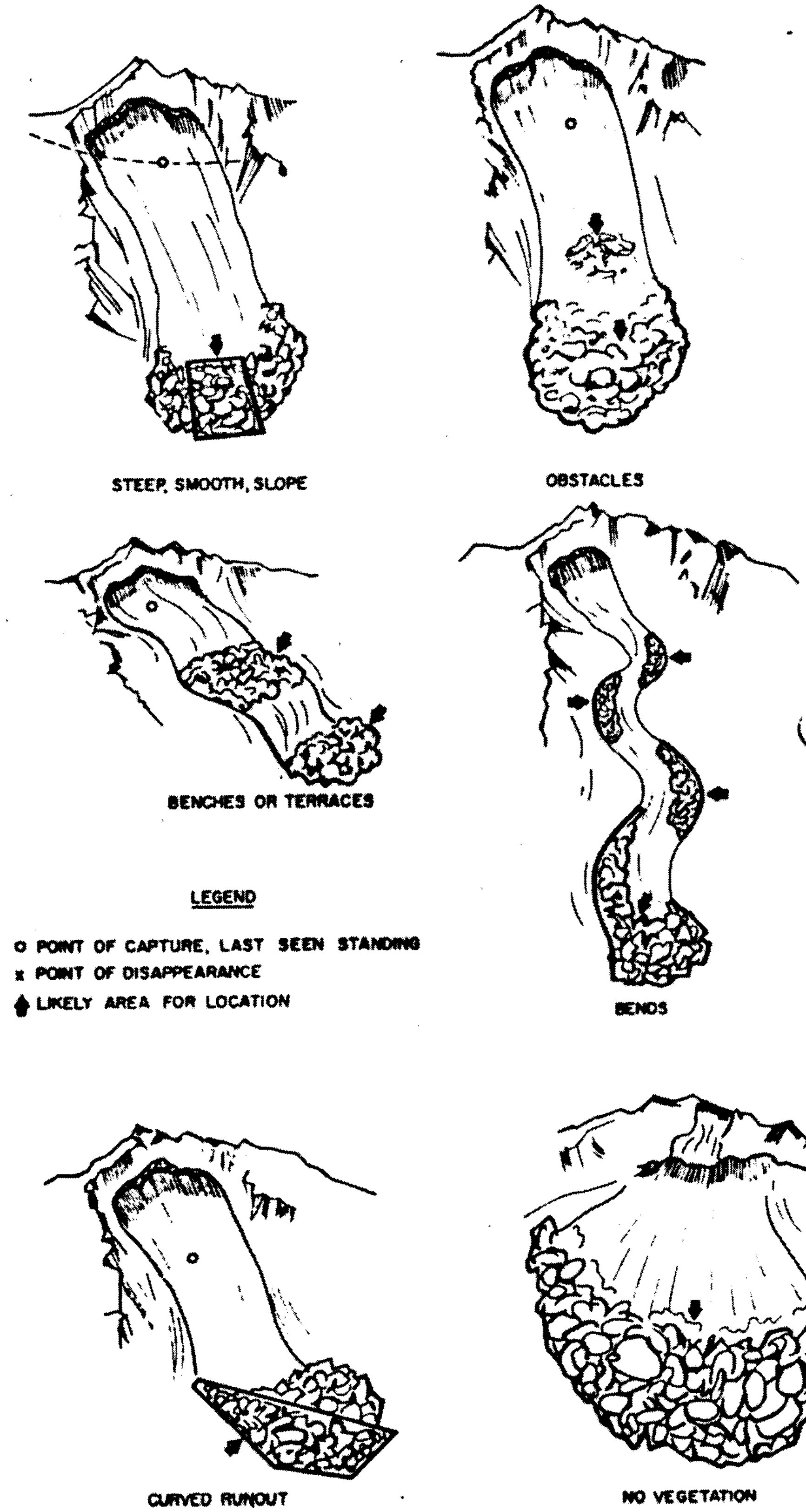


Figure 70. Probable areas for the location of bodies buried in avalanche debris. The diagrams show possible effects of terrain features and capture locations on deposition pattern. (After ref. 9.)