IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

# IMPORTANCE OF SLOPE STABILIZATION METHODS

**Dr. Ashok Kumar Sharma[1], Yashwant Ahirwar[2]**

M.Tech.,Ph.D. C.Eng., F.I.E, F.I.N.P Team Leader Cum Senior Tunnel Expert Segmental Consulting & Advisory Services Pvt. Ltd.[1]

M.Tech. (Geotechnical Engineering) SVVV Indore. [2]

**Abstract:** The Slope stabilization is an important aspect of civil engineering, geotechnical engineering, and environmental engineering, as it helps to ensure the safety and stability of structures built on or near slopes, as well as protect the natural environment from damage caused by landslides and erosion. Slope stability is a measure of how resistant a natural or man-made slope is to failure due to collapse or sliding.

Slope stabilization refers to any implemented technique that aims to stabilize an unstable or inadequately stable slope. The purpose of slope stabilization techniques is to increase the Factor of Safety of a slope to a level that is considered adequate. The important geotechnical properties affecting stability of a slope are shear strength of material, particle size distribution, density, permeability, moisture content, plasticity and angle of repose.

**Keywords:** Slope Stabilization, Shear Strength, Permeability, Stabilization Technique.

## I. INTRODUCTION

Slope stability refers to the ability of a slope or hillside to resist the downward movement or collapse of soil and rock materials. Landslides are a common form of slope failure, which can result in significant damage to property and infrastructure, loss of life, and environmental impacts.

Slope stabilization refers to any implemented technique that aims to stabilize an unstable or inadequately stable slope. The purpose of slope stabilization techniques is to increase the Factor of Safety of a slope to a level that is considered adequate. Stabilization techniques are divided in the following main categories:

- Removal and protection: Removing the unstable material that usually lies on the upper layer of the slope and placing protection means, (e.g., nets).
- Soil stabilization: Soil stabilization refers to all the processes that aim to enhance the soil's mechanical properties, increasing its shear strength and, thus, the stability of the slope. The most commonly used techniques include mechanical (compaction, dewatering, mixing, etc.) and chemical (lime, cement, fly ash, etc.) stabilization.
- Support stabilization: Structural supports aim to increase the stability of the slope. Those techniques include the implementation of pre-stressed anchors, rock bolts, piles, soil nailing, geosynthetic reinforcement, retaining walls, shotcrete, etc.
- Water drainage: The presence of water in the soil or the rock mass causes increased pore water pressure. Water pressure weakens the ties between the particles and they tend to slip, a fact that reduces the stability of the slope. Drains are used to reduce water entry and control the groundwater level.

## II. SLOPE STABILIZATION METHODS

Civil and mining engineering projects usually include heavy demolition and excavation activities that lead to the formation of excavated rock slopes. It is essential to maintain the stability of these slopes till the end of the design life for the successful delivery of a project. Therefore, the site selection should be such that the orientation of joint/bedding planes is favourable for a stable excavation.

A well-inspected and thoroughly studied site can reduce the cost of stabilization. Moreover, the site for excavation should be selected in a way that the geological formation of bedding planes dips away from the excavation plane.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

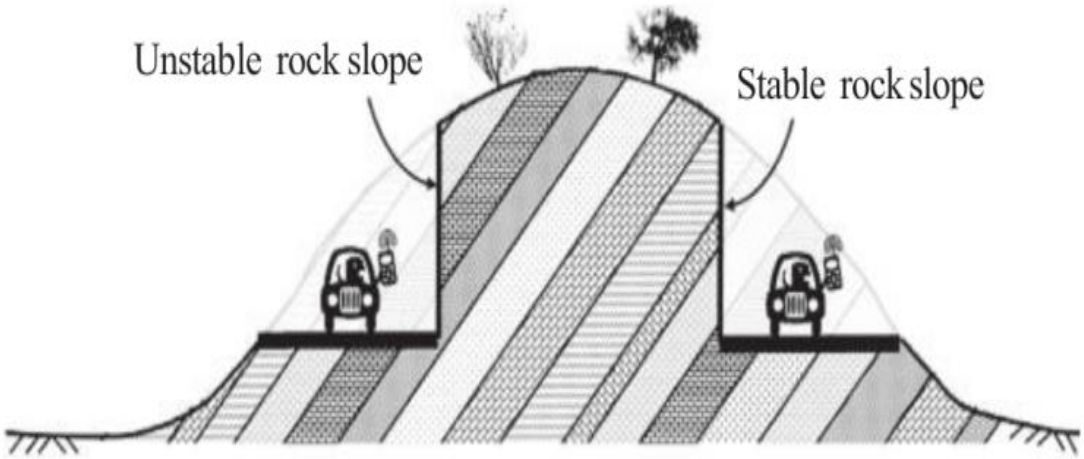


Figure 1.1 Slopes excavated for highway project

There are numerous scenarios where site selection cannot be made merely based upon geological formations due to certain technical requirements. In those cases, slope stabilization techniques should be used to increase the stability of slopes.

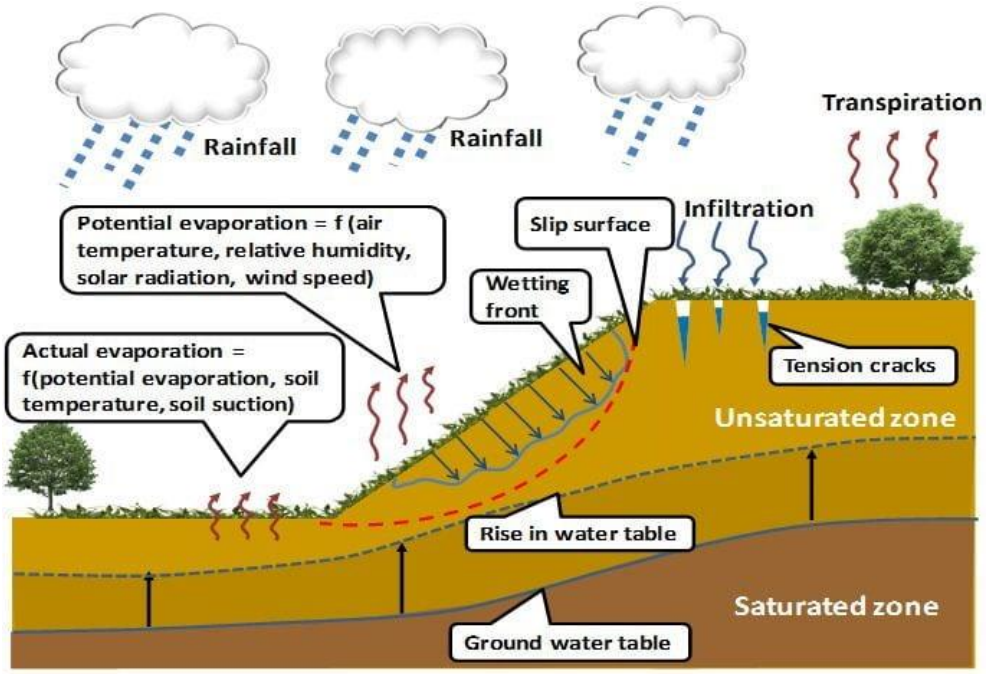


Figure 1.2 Showing the process

### A. Slope Stabilization Methods and Classification

The most commonly used slope stabilization techniques are categorized as follows:

i. Geometric techniques: The application of geometric techniques brings about a change in the geometry of slope.
ii. Hydrological techniques: The adoption of hydrological techniques lowers the water content of soil/rock material by reducing the groundwater table.
iii. Chemical and mechanical techniques: Chemical and mechanical stabilization techniques increase the shear strength of the critical plane of soil/rock mass by external means. In addition, the shear strength of the slope can also be increased by minimizing the external forces triggering the slope failure.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

**(a). Geometrical Techniques**

Slope stabilization using geometrical techniques can be achieved by:

1. Flattening the slope
2. Eliminating part of the soil/rock
3. Eliminating load from the top of the slope and therefore reducing the shear stresses on critical planes
4. Constructing pressure berms at the toe of the slope and thereby providing extra safety against toppling failure
5. Replacement of slipped material by free-draining materials and therefore reducing the build-up of pore water pressure
6. By re-compaction of slip debris to provide more resistance against loading

**(b). Hydrological Techniques**

Slope stabilization using hydrological techniques can be achieved by:

1. Installing surface and subsurface drain pipes and therefore reducing pore water pressure
2. Use of inverted filters
3. Use of thermal techniques, such as ground freezing and heating methods.

**(c). Chemical and Mechanical Techniques**

Slope stabilization using chemical and mechanical techniques can be achieved by:

1. Using grouting to increase the shear resistance of slope
2. Constructing restraining structures, such as concrete gravity or cantilever walls
3. Construction of gabion structures, baby crib walls, and embankment piles in order to provide resistance against toppling
4. Constructing lime and cement columns
5. Installing ground anchors, rock bolts, root piles, etc. to provide effective tension to rock blocks
6. By planting shrubs and grasses to reduce soil erosion

**B. Construction Techniques of Slope Stabilization**

Slope stabilization techniques are categorized into three groups:

i) Reinforcement support: It includes rock bolts, dowels, tied-back walls, shotcrete, buttresses, etc.

ii) Unstable Rock removal: It involves methods like re-sloping, cutting, etc.

iii) Protection: This comprises the construction of ditches, mesh, catch fences, warning fences, rock sheds, tunnels, etc.

**(a). Rock Reinforcement Support**

Rock reinforcement support involves the application of external elements to strengthen the rock to avoid failure.

Figure 1.3 Rock bolting & wire mesh

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

**b). Rock bolts and Anchors**

The most beneficial supports are rock bolts and anchors as they protect blocks of rock from sliding away from the discontinuity planes.

The installation mechanism of rock bolts and anchors governs their effective compression capacity. The most effective way to install rock bolt is by fixing them perpendicular to the joints so that the joint discontinuities are easily trapped.

In the case of fractured rock slope, rock bolts and anchors are used in combination with concrete walls to cover the locations of fractured rock. Rock bolts installed to improve the stability of slope.

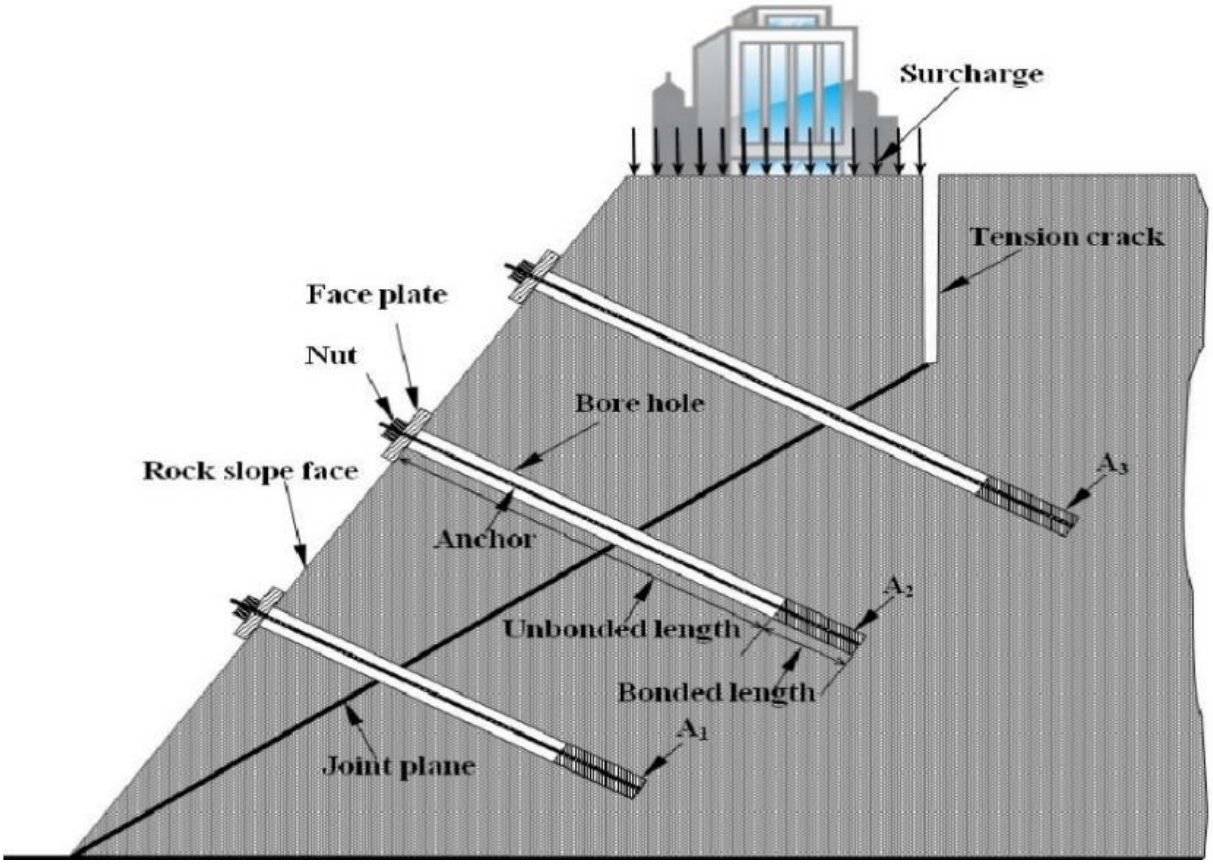


Figure 1.4 Rock bolting positioning

**(c). Steel Rods**

Steel rods, also known as dowels bars, are installed and grouted into the rock mass to act as reinforcement.
The difference between rock bolts and steel rods lies in their installation methods as rock bolts are stressed during the installation, whereas steel rods are not.

**(d). Shotcrete**

Fine aggregates and mortar are the main constituents of shotcrete. Generally, shotcrete is applied pneumatically and placed in a layer of 50 to 100 mm.

The application of a layer of shotcrete to the rock face can protect the zones or beds of closely-fractured rock. Besides, shotcrete also prevents small blocks of rock from falling. Thus, the process of progressive failure of producing large, unstable overhangs on the face reduces. Although its primary function is surface protection, shotcrete also provides some support against sliding of the overall slope & improves the tensile and shear strength of slopes, thereby reducing the chances of slope failure.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

Figure 1.5 Shotcrete application in slope stabilization

Figure 1.5 shot creting in progress

**(e). Grouting**

Grouting is a technique of injecting a fluid grout into the rock mass to replace the air or water present in its fissures and cracks. The grout consists of a mixture of cement and water. However, sand, clay, rock flour, fly ash, and other similar materials can be used as a replacement to cement. As a result, the cost of stabilization work reduces, especially where fissures and cracks are large in volume.

If a cavity is present in the slope face, a concrete buttress can be built to avoid rock falls and support the overhang.

Figure 1.6 Slope protection work

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

## III. STABILIZATION STRATEGIES TO REDUCE SLOPE FAILURE

**(d).** The objective behind slope stabilization is to reduce the risk of slope failure to enhance public safety. Some standard stabilization techniques used in practice to improve public safety are mentioned below:

1. Flattening of overburden slope
2. Cutting of unstable rock blocks
3. Scaling of loose materials/blocks
4. Providing drain pipes and drain holes
5. Use of dowel bars
6. Installing rock anchor to avoid moving along discontinuity joints
7. Use of rock bolts to enhance the jointed rock mass
8. Constructing concrete or masonry walls with weep-holes
9. Constructing rock trap ditches at the toe of the slopes
10. Providing rock catch fences/walls along the slope to make the surrounding locations safe for public usage
11. Providing hanging chains or webs to slow down toppling of blocks
12. Providing free-hanging mesh net to direct loose rock pieces to fall only near the slope toe
13. Constructing berms/benches as a rock fall collector
14. Providing mesh secured by bolts and gunited to protect friable formation
15. Constructing rock fall barriers (gabions and concrete block, reinforced soil barriers, etc.) at the toe of slopes
16. Building and constructing rock sheds and tunnels
17. Providing caution signals in rock fall locations

Figure 1.7 Mesh secured by bolts to arrest falling rock blocks

Figure 1.8 caution signals in rock fall locations

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

Figure 1.9 Concrete walls with weep-holes

**C. Active and Passive methods of slope stabilization:**

Stabilization methods such as rock bolts and anchors avoid the detachment of rock blocks from their initial position. For this reason, they are recognized as active procedures.

Walls, ditches, capture fences, rock sheds, and tunnels are passive methods as they do not interfere in the procedure of rock detachment.

**D. Conditions required for the selection of a stabilization technique:**

The conditions for selection of the stabilization technique are:

1. Geotechnical requirement (geology, rock/soil properties, groundwater, and stability analysis)

2. Construction requirement (types of construction equipment, access to the construction site, construction expenses, etc.)

3. Ecological requirement (garbage disposal, aesthetics, etc.)

The choice depends upon the level of stabilization required, its design life, and the costs involved. The preliminary expenses will also influence the selection of the stabilization technique, which will ensure its efficiency for a longer period.

## IV. CONCLUSION

**Importance of Slope Stabilization:**

The importance of slope stability analysis in geotechnical engineering cannot be overstated. Unstable slopes can lead to disastrous consequences, such as landslides, rockfalls, and slope failures, which can result in loss of life, property damage, and environmental degradation.

1) This increases the stability of the soil and also increases the strength of the slope. It can protect the slope from the soil erosion, raindrop impact, quick run off the road and others.

2) Slope stability analysis is vital to preventing slope failures in a variety of engineering applications including landfill design, roads, dams and embankments, to name a few.

3) Five factors influence slope stability of an embankment: 1) Shear strength of the soil; 2) Unit weight; 3) Embankment height; 4) Slope steepness; and 5) Pore pressure within the soil. Failure generally occurs in two ways.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 11, Issue 3, March 2024

DOI: 10.17148/IARJSET.2024.11303

4) Slope stability problems are a consideration of soil mass stability and satisfying force and moment equilibrium. An inclined mass of soil needs to withstand its own weight, surcharge, and water conditions, either flow or hydrostatic. The soil shear strength along a sliding plane provides the stabilizing force.

5) Road construction sustainability and stability are very important. This grades the road and also makes it safe and secured. Slope stability is considered as the basic requirements of any road that are built on inclined plane. The purpose of the slope stabilization is to prevent the rain impact, run off velocity of the road and also the soil erosion, for uninterrupted movement of traffic.

## REFERENCES

[1]. MorTH (fifth revision)- Section: 300 & 700, Earthwork, Erosion Control & Drainage, Geosynthetics.
[2]. MorTH (fifth revision)- Section: 3100 & 3200, Reinforced Earth & Soil Nailing
[3]. IRC SP 89-2010.-Guidelines for Soil and Granular Material Stabilization.
[4]. IS 14680:1999- Landslide Control-Guideline.
[5]. IS 8237:1997-Code of Practice for Protection of Slope for Reservoir Embankments.
[6]. IS 14448:1997-Code of Practice for Reinforcement of Rock Slopes with Plane Wedge Failure
[7] IRC:56-2011- Recommended Practice for Treatment of Embankment & Road side slopes for erosion control