

Designing for Disaster: The Impact of Architecture on Landslide Risk and Resilience

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ABSTRACT

As our planet faces increasingly frequent and severe natural disasters, it is becoming clear that human activity is exacerbating many of these events. Landslides are natural hazards that pose significant threats to human lives and property, particularly in areas with steep terrain and unstable slopes. While geological factors play a critical role in triggering landslides, human activities such as architecture practices can also exacerbate the severity and frequency of these events. The construction of buildings, roads, and other infrastructure can alter the natural landscape and increase the susceptibility of slopes to instability, leading to devastating consequences in the event of a landslide. Architects and urban planners play a crucial role in designing and constructing buildings that are not only functional and aesthetically pleasing, but also safe and resilient. However, when it comes to landslides, there is evidence to suggest that some common architectural practices may actually increase the risk of damage and loss of life. The built environment and natural environment are deeply interconnected, and nowhere is this more apparent than in areas prone to landslides. While landslides are often thought of as a purely natural phenomenon, it is increasingly clear that human activity, including architectural practices, can significantly influence their frequency and severity. This paper explores the ways in which architecture practices contribute to the severity of landslides and identifies strategies for mitigating these risks. Factors such as correlation between building height and the likelihood of landslides occurring, design of buildings in landslide-prone areas affecting the likelihood and severity of landslides, construction activities such as excavation and drilling contributing to the risk of landslides, variations in soil composition and soil stability, natural drainage patterns being maintained or modified and the building orientation and placement play significant role in adding to the severity of landslides. This research can provide valuable insights into the factors that contribute to landslides in built environments and inform the development of policies and guidelines aimed at reducing the impact of landslides on human lives and property.

Introduction

A landslide is a geological event that occurs when a mass of earth, rock, or debris moves down a slope under the influence of gravity. Landslides can be triggered by a variety of factors, including heavy rain, earthquakes, volcanic activity, and human activity such as construction or excavation. The significance of this research lies in the fact that landslides are a significant natural hazard that can have devastating consequences on human lives and infrastructure, particularly in areas with steep terrain and unstable slopes. The movement of material can be slow or rapid, and it can cause significant damage to property, infrastructure, and the natural environment. Landslides can also pose a significant threat to human life, particularly if they occur in populated areas. Different types of landslides include rockfalls, debris flows, and earthflows, among others. Understanding the causes and mechanisms of landslides is important for identifying and mitigating potential hazards, as well as for managing the impacts of landslides when they do occur.

There are various architectural practices that may worsen the impact of landslides for example The type of site chosen for construction , which may have non desired features that worsens landslides like having steep slope or eroded soil. Other factors may include hydrology and geology of site, Faulty construction patterns or altering the natural drainage pattern. There are various design parameters that can be dealt with to analyse and mitigate effects of landslide. This may include answering the questions like what is the correlation between building height and the likelihood of landslides occurring or what role does building orientation and placement plays in the risk of landslides occurring in architectural contexts.

Therefore With the increasing threat of landslides in built environments, it is imperative to investigate the role of architecture practices in exacerbating the severity of these hazards. By identifying the factors that contribute to landslides in built environments and exploring potential solutions for mitigating these risks, this research aims to pave the way for a safer and more resilient built environment.

Factors that Impact Landslides

There are various factors responsible for landslides like Geology and topography of site. The type of soil, rock, and topography of an area can influence its susceptibility to landslides. Steep slopes, weak soil, and rock formations that are prone to weathering and erosion are more likely to experience landslides. Another factor is Precipitation. Heavy rainfall and snowmelt can saturate the soil and increase the weight and pressure on slopes, triggering landslides. Earthquake can also be one of the reasons to cause landslide. The shaking and ground motion caused by earthquakes can destabilize slopes and trigger landslides. Human activities like Construction, mining, logging, and other human activities can alter the natural landscape and

increase the risk of landslides. Changes in land use, such as deforestation, can also affect the stability of slopes and increase the risk. Climate change can also impact landslides in several ways, such as changing precipitation patterns, increasing the frequency and intensity of extreme weather events, and altering the stability of slopes through changes in permafrost and soil moisture.

There are some major architectural factors that leads to worsening of Landslides. This includes the type of site that is been chosen, architectural failures that includes Foundation failure, slope failures retaining wall failure etc. Hydrological factors such as natural drainage pattern obstruction and underground seepage. Faulty construction patterns such as overloading , improper grading, poor drainage, inadequate slope stabilization, cutting into the slope and improperly designed foundations.

Geological and topographical factors that significantly impact landslides.

While choosing the site for construction there are various site factors that must be taken care of to prevent the occurrence of landslides. There are a few factors on site that impact landslides. Areas with Steep slopes such as hillsides or mountainous regions, are more susceptible to landslides. When the slope angle is too steep, the weight of the soil and rocks can overcome the force of gravity, causing the slope to fail. It's best to avoid building on steep slopes, especially those with angles greater than 30 degrees.

Areas with Weak Soil that has a high water content can be more susceptible to landslides. When soil is saturated with water, it becomes heavier and less stable, increasing the risk of landslides. Therefore building on soil that is prone to liquefaction or saturation should be avoided. Areas with Heavy rainfall can increase the risk of landslides, especially in areas with weak soil or steep slopes.

Excessive rainfall can saturate the soil, making it more prone to sliding. Therefore building in areas that experience heavy rainfall or flooding should be avoided. Areas with Earthquakes can trigger landslides by shaking the ground and destabilizing the soil. Areas with a history of seismic activity are more prone to landslides. It's best to avoid building in areas with a history of seismic activity. Areas with Human Activity such as construction, mining, or excavation, can destabilize the soil and increase the risk of landslides. Therefore To prevent landslides, such sites should be avoided for construction.

Soil erosion

Soil erosion can have a significant impact on landslides like Weakening of Soil. When soil erodes, it can remove the soil's binding agents and decrease its strength. This can make the soil more prone to sliding and increase the risk of landslides. Another impact could be Loss of Vegetation. Vegetation helps stabilize soil by anchoring it in place with their roots. When vegetation is lost due to erosion, the soil becomes more vulnerable to sliding and can increase the risk of landslides. Changes in Soil Water Content can be another

reason for landslides. Soil erosion can change the soil's water content, making it more prone to liquefaction. This can increase the risk of landslides during earthquakes or heavy rainfall. Formation of Channels: Erosion can create channels or gullies that can transport water and debris, increasing the risk of landslides downstream. Formation of Scarp: Scarp is a steep slope that can be created at the base of eroded hills. When soil on the hillside erodes and falls, it accumulates at the base, creating a scarp. This can increase the risk of landslides in the area.

Hydrology

Natural drainage patterns play an important role in preventing landslides by directing water away from slopes and hillsides. Natural drainage patterns help direct water away from slopes and hillsides. When these patterns are obstructed, such as by debris or soil accumulation, water can accumulate in the soil, increasing its weight and decreasing its stability. This can increase the risk of landslides during heavy rainfall or storms. The excess water can also cause the soil to become saturated, which reduces its strength and increases its vulnerability to sliding.

Another phenomenon is Piping. Piping is a phenomenon that occurs when water creates underground channels in the soil, causing the soil particles to collapse and the soil to become unstable. Obstructed natural drainage patterns can cause water to pool and infiltrate the soil, creating channels that transport soil particles and causing the soil to become more vulnerable to piping. Piping can lead to landslides by creating voids in the soil, which can cause the overlying soil to collapse and slide down the slope. Another factor is underground seepage.

Underground seepage can cause soil particles to displace, reducing the soil's strength and cohesion. This can happen when water infiltrates the soil and fills the voids between soil particles, increasing the pressure within the soil. As the pressure increases, the soil particles can become displaced, reducing the soil's strength and stability. This reduction in soil strength can make the soil more vulnerable to sliding and increase the risk of landslides. Underground seepage can alter the slope's gradient by eroding the soil or altering its structure.

Faulty construction patterns

Another Reason for landslides is faulty construction patterns that lead to worsening of landslides. This may include overloading. When heavy structures, such as buildings or retaining walls, are built on a slope, they add weight to the soil and can increase the stress on the slope. This additional weight can cause the soil to compress, reducing its ability to hold its weight and leading to slope instability. Additionally, heavy objects can create an imbalance in weight distribution, which can cause the slope to shift or slide. Another practice

is Improper grading. Grading is the process of changing the natural slope of the land to create a level surface for construction. Improper grading can result in an unstable slope by changing the distribution of weight and altering the flow of water. If a slope is graded too steeply or in the wrong direction, it can increase the risk of landslides.

Poor drainage system also impacts landslides. Drainage systems are important in preventing landslides by allowing water to flow away from the slope, reducing the amount of water that accumulates in the soil. Inadequate slope stabilization also adds to the reasons. Slope stabilization measures, such as retaining walls, soil nails, or drainage systems, are important in preventing landslides by providing stability to the slope. Failing to implement adequate measures can result in slope failure and landslides. Excavating or cutting into the slope can destabilize the soil, particularly if the cut is steep and the soil is prone to failure. When a building's foundation is not designed or constructed to resist the forces of landslides, it can fail during a landslide. This can cause the building to shift or collapse. Retaining walls are structures designed to hold back soil and prevent landslides. When retaining walls fail during a landslide, they can cause the soil to collapse and the building to shift or collapse. When a building's structural system is not designed or constructed to withstand the forces of landslides, it can fail during a landslide. During a landslide, the weight of the soil and debris can cause the roof of a building to collapse.

Examples

If we talk about some of the very disastrous landslides, **The Malin landslide** in Maharashtra was primarily caused by geological and environmental factors such as heavy rainfall and soil instability. However, there were some architectural reasons that contributed to the severity of the landslide. According to some reports, the village of Malin was located on a steep slope and many of the houses were constructed on the hillside, which may have contributed to the instability of the soil. Additionally, some of the houses were constructed with heavy concrete roofs, which increased the weight on the soil and potentially contributed to the landslide. Moreover, the village lacked proper drainage and wastewater management systems, which may have led to soil saturation and increased the risk of landslides. The lack of proper construction practices and building codes in the region also contributed to the severity of the landslide. Overall, the architectural reasons for the Malin landslide were primarily related to the location of the village on a steep slope, the use of heavy roofing materials, and the lack of proper drainage and wastewater management systems.

The Kedarnath landslide in Uttarakhand was primarily caused by extreme rainfall, flash floods, and cloudbursts, which led to the destabilization of slopes and soil erosion. One of the main architectural reasons for the severity of the Kedarnath landslide was the haphazard construction of buildings and infrastructure in the region. Many buildings, particularly hotels and guesthouses, were constructed in ecologically

sensitive areas, such as riverbanks and steep slopes, without proper geotechnical assessments or building codes.

Moreover, the lack of proper drainage and wastewater management systems in the region also contributed to the severity of the landslide. The accumulation of rainwater and melting snow on the slopes increased the weight on the soil and destabilized the slopes.

Furthermore, the construction of roads and hydropower projects in the region also contributed to the severity of the landslide. The excavation of slopes and construction of tunnels and bridges weakened the natural stability of the hills and increased the risk of landslides.

Overall, the architectural reasons for the Kedarnath landslide were primarily related to the haphazard construction of buildings and infrastructure in ecologically sensitive areas, the lack of proper drainage and wastewater management systems, and the construction of roads and hydropower projects in the region.

Conclusion

All the reasons mentioned above are primary causes that may add to the severity of landslides. There are mitigative measures for each problem and its cause. Building on flat or gentle slopes can minimize the risk of landslides. Areas with slopes less than 15 degrees are considered low risk for landslides. Building on stable soil can help prevent landslides. Areas with good drainage can minimize the risk of landslides by reducing the water content of the soil. Building on solid rock can provide a stable foundation and minimize the risk of landslides. Solid rock is less prone to erosion and movement compared to soil. The use of appropriate building materials such as reinforced concrete, steel, or masonry can help prevent architectural failures during landslides. In conclusion, preventing landslides caused by architectural reasons involves a combination of strategies that include site assessment, proper design, drainage systems, slope stability analysis, soil stabilization, and monitoring. By following these strategies, architects and engineers can design buildings and other structures that are suitable for the terrain and environment, and reduce the risk of landslides.