



**Article Title: Building Design Techniques to Withstand Landslides**

## **Building Design Techniques to Withstand Landslides**

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### **ABSTRACT**

Landslides are among the many natural disasters causing massive destructions and loss of lives across the globe. India has a high degree of vulnerability towards the occurrence of Landslides. Landslides and avalanches are among the major hydro-geological hazards that affect large parts of India. Around 15% of the country's region is prone to landslides. The Himalayas of Northwest and Northeast India and the Western Ghats are two regions of high vulnerability. Some major recent incidents are Kerala (2018), Himachal Pradesh (2018), Uttarakhand (2018), Tamenglong-Manipur (2018), and Kalikhola, Manipur (June 2017). Landslides are a natural phenomenon, but it involves many human activities which lead to the mass movement of landmass. In recent times we find the causes of landslides increasing day by day and the primary cause is deforestation. To survive, one needs to keep a check on these human activities. Landslides can result in enormous casualties and huge economic losses in mountainous regions. In order to mitigate landslide hazard effectively, new methodologies are required to develop and a better understanding of landslide hazard are required. To reduce future risks, it is important that a lot of attention is paid to the structural design of the buildings. This paper is aimed to propose some techniques and materials to resist landslides that allow the local communities to continue living on landslide prone slopes without causing damage to buildings.

**Keywords:** Geosynthetic Materials, Slope Mitigation, GI Frame, Landslides

### **1 Introduction**

Landslides, also known as landslips, are several forms of mass wasting that may include a wide range of ground movements, such as rock falls, shallow or deep seated slope failures, mudflows, and debris flows. Landslides occur in a variety of environments, characterized by either steep or gentle slope gradients, from mountain ranges to coastal cliffs or even underwater, in which case they are called submarine landslides. On 16th August 2018, severe flood affected the South Indian state Kerala due to heavy rainfall over the region. Over 483 people died and 14 went missing and an estimated property damage around 400 billion dollars by the data from National Centre for Earth Science Studies 1,848sq.cm in Kerala, extending along steep slopes of Western Ghats mostly in Wayanad, Kozhikode, Malappuram, Idukki, Kottayam and Pathanamthitta districts, is highly prone to landslide according to Natural Hazard Proneness Assessment. Our challenge is to keep our cities and our planet liveable, safe, healthy and attractive throughout this century.



**Article Title: Building Design Techniques to Withstand Landslides**

Our cities need to become more resilient to be able to tackle these challenges. Buildings in the areas which are prone to natural disasters like landslides need to be designed and constructed with suitable disaster mitigating features. In addition to that, the sustainability of such structures and their impacts on the environment also demand due consideration. There are several technologies available which sensing rapid changes in our environment and also to monitor landslides. By using suitable technologies in our building helps to protect the structure and also the livings.

## **2 Recent Works**

The numerous engineered solutions to deter landslides have been studied recently by various agencies and engineers which was an inspiration for creating this report.

## **3 Proposed Work Explanation**

Landslides have three major causes: geology, morphology, and human activity. Landslides occur when the slope undergoes some processes that change its condition from stable to unstable. The major one is shear stress occur in slopes. Shear stresses can be built up within a slope by a number of processes. These include over steepening of the base of the slope, such as by natural erosion or excavation, and loading of the slope, such as by an inflow of water, a rise in the groundwater table, or the accumulation of debris on the slope's surface. Short-term stresses, such as those imposed by earthquakes and rainstorms, can likewise contribute to the activation of landslides. Landslides can also be activated by processes that weaken the shear strength of a slope's material. Shear strength is dependent mainly on two factors: frictional strength, which is the resistance to movement between the slope material's interacting constituent particles, and cohesive strength, which is the bonding between the particles. Coarse particles such as sand grains have high frictional strength but low cohesive strength, whereas the opposite is true for clays, which are composed of fine particles. Another factor that affects the shear strength of a slope-forming material is the spatial disposition of its constituent particles, referred to as the sediment fabric. Some materials with a loose, open sediment fabric will weaken if they are mechanically disturbed or flooded with water. An increase in water content, resulting from either natural causes or human activity, typically weakens sandy materials through the reduction of inter particle friction and weakens clays through the dissolution of inter particle cements, the hydration of clay minerals, and the elimination of inter particle tension. In order to make land less prone to landslide certain steps can be followed.

### **3.1 Slope Mitigation**

Landslide is the most frequent geo-environmental natural hazard which significantly affect human life and environment. Pre identified landslide hazards require special building standard and construction practices in order to reduce vulnerability to damage. Several slope



**Article Title: Building Design Techniques to Withstand Landslides**

mitigation techniques can be used to protect our structure primarily. The proposed techniques are:

### 3.2 Contour drain

At landslide prone areas, using contour drains is helpful to prevent percolation in to the ground. It may be made along different contours at reasonable intervals. For sub surface drainage measures use horizontal drain, vertical drain and deep trench drains can be adopted. And for grading of slope benching or terracing, flattening of slope, removal of load at slope head portion and enlarging the toe of slope, these methods can be used.

### 3.3 Retaining Walls:

The retaining wall need to build to protect in areas which are prone to landslides. It needs to be built in a level ground to retain the soil. In order to avoid clay soil back filling, it is better to excavate deep enough for the base material and one course of wall material. To mitigate landslide crushed stone is proposed as base material. It gave proper strength. It is costly but once we compacted it, it will stay intact. Then concreting, the depth of the base slab should be a minimum of two feet from the bottom. The base slab is typically fifty to seventy percent of the total wall height measured from the bottom of the base to the top of the stem. After you dig the footings and build the forms, you must add reinforcement, such as rebar. If the wall is higher than four feet, you should pour each footing separately. Allow the concrete to properly cure then create contraction joints. They should be placed every four to six feet. Finally, remove the forms and install waterproofing and the drainage system. To increase slide-resistance, include a footing key.

### 3.4 Crib Wall

It is a supporting wall constructed by laying cribs at right angle to each other. Crib retaining wall or crib log retaining wall is one of the oldest type's retaining wall. They consist of cribs or cells made of timber, concrete, and plastic/fibres. The cribs or-interlock areas are filled with free-draining materials or earth back-fill, eliminating the hydrostatic pressure and enabling a free escape of water. A crib retaining structure with live plants between crib layers is called vegetative crib wall. In this article, wooden logs and bamboos are considered as crib elements.



**Figure 1: Crib Wall**



**Article Title: Building Design Techniques to Withstand Landslides**

## 4 Materials

Here are some materials which are environment friendly and also are very helpful in constructing retaining structures and landslide resistant buildings.

### 4.1 Geo synthetic Materials

Geosynthetic materials that helps to reinforce soil and similar materials. These are commonly used to reinforce retaining walls, sub base or sub soils. Geogrids are commonly made of polymer materials having high tensile strength. There are two types of Geosynthetic materials: geofabrics and geoblocks. Geofabrics are essentially two dimensional sheets that separate, reinforce, filter, and drain. The second type, geoblocks or geogrids, are polyethylene interlocking paving units. Geoblocks are three dimensional and commonly used for soil strengthening under roads. The Geosynthetic materials proposed here is mentioned below.

### 4.2 Geotextiles

Geotextiles are permeable fabrics used for reinforcement, protection, filtration, drainage and separation, and they are commonly used in conjunction with soil or rock. Geotextiles fall into two categories, woven and non-woven. Woven geotextiles use perpendicular fibres woven to make up a cloth like material. The fibres of non-woven geotextiles are more random and are often made of synthetic polymer.

### 4.3 Geogrids

Geogrids is used for stabilization and reinforcement, geogrids are open, mesh type materials commonly used to reinforce retaining walls or sub soils below roads. They are strong in tension. Geogrids can be either uniaxial or biaxial and are used in place of traditional gravel for soil stabilization. They also provide separation between soil and aggregate layers. It consist of equally spaced longitudinal and transverse ribs. Under pullout conditions, the longitudinal ribs are responsible for tensile resistance, while transverse ribs contribute to a passive resistance.



**Figure 2: Geogrid**



**Article Title: Building Design Techniques to Withstand Landslides**

#### **4.4 Geonets**

Geonets are similar in structure to geogrids but come in biplanar (two sets of intersecting ribs) and tri planar (parallel central ribs with intersecting smaller sets). These polymeric nets are used for in plane drainage, erosion control, and foundation wall drainage or leak detection for landfills or solid waste.

#### **4.5 Geomembranes**

Geomembranes are liners with low permeability that control gas or liquid migration. This type of geosynthetic material is used for water containment, landfills, and mining. These liners are made out of thin polymeric sheets infused with polymer sprays, asphalt, or elastomer.

#### **4.6 Prefabricated Vertical Drains**

Often called earthquake drains or wick drains, prefabricated vertical drains (PVDs) have a plastic core encapsulated by a geotextile material. The purpose of these drains is to pull water from soft, compressed soil so it consolidates faster.

#### **4.7 Geosynthetic Clay Liner**

A geosynthetic clay liner (GCL) is a barrier made up of bentonite clay that is sandwiched between geotextiles. The function of a geosynthetic clay liner is to act as a hydraulic barrier to leachate, water, other liquids, and sometimes gases. This highly impermeable liner is cost effective and used in place of thick layers of clay, which is expensive.

#### **4.8 Geocells**

Geocells, also called cellular confinement systems (CCS), is webbing with a cavity-like structure. This material is used for stabilization, flood defence, erosion control, retaining walls and tree root protection. Geocells are made of polyethylene, which is lightweight and easily handled.

#### **4.9 Geocomposites**

This type of geosynthetic material is made up of a combination of a geotextile along with a geonet, geogrid, or geomembrane. By combining several materials, a geocomposite is capable of strengthening the soil while allowing for proper drainage. Geocomposites can help address several specific problems within an application. The manufacturing of geosynthetic materials involves the use of thermoplastics. Although some specialized geosynthetics can have steel wire or biodegradable fibres incorporated into them, most are made with raw materials such as Polyamide, Polyester, Polyethylene, Polypropylene, Polyvinylchloride, Ethylene copolymer Bitumen. Geosynthetics have been used successfully in stabilizing steep slopes of residual soil and weathered rock. Geotextiles placed horizontally in layers have helped to prevent landslides, which are generally induced by heavy rainfall. The tensile



**Article Title: Building Design Techniques to Withstand Landslides**

reinforcement and filtration help to stabilize the slopes or embankments. Through slope classification and geotechnical engineering reports, it can be determined what reinforcement type is needed to prevent landslides.

#### **4.10 Shotcrete**

Shotcrete reinforces the strength to the rock face. It includes aggregates, cement and water, and may be complemented by fine materials, chemical additives and reinforcing fibres. Shotcrete figures prominently among several methods for slope stabilization due to its versatility, durability, early resistance and its capacity to adhere to the substrate. Because shotcrete is applied pneumatically, the material is compacted against the surface to fill cracks and fissures and prevent loose material from falling. Shotcrete can therefore act both as a protective coating over the slope's surface, but also as an 'anchoring surface' onto which bolts and other support systems can be fastened. It's important to note that very steep slopes in terrains with poor rock mass quality entail a greater risk of slope failure, and therefore a superficial layer of shotcrete will not suffice. This type of slope will require extra stabilization such as wire, mesh and fibres.



**Figure 3: Shotcrete**

#### **4.11 Multiwood**

Multi wood is a white sheet that is made up of 'U' PVC Polyester resin. This is a type of wood that is completely recyclable and it is also environmentally friendly. This wood is effective and perfect for moisture-prone areas without any worry of getting damaged. This is what is multiwood. There are different types of multi wood such as Multiwood regular, Multiwood matt finishes, Multiwood plus, Multiwood eco board premium, Greenwood. It is resistance to chemical, water proofing features, fire-retardant characteristics, bending feature setc make multiwood area ledge over wood and hence suitable for both. Multi wood provides a natural and elegant look. It is adaptable to many operations such as drilling, screwing, painting, carving, moulding, etc. This is the reason multi wood is considered so versatile. Interior designers love multi wood because you can create so many designs on multi wood. It can be used both indoors and outdoors and it is capable of thermal and noise insulation. This



**Article Title: Building Design Techniques to Withstand Landslides**

product is waterproof and dirt in multi-wood can be easily removed with soaps. Multi Wood is resistant to termites and stains. Multi-wood can be reused by the carpenter. Multiwood can be screwed, drilled, planed, carved, painted and glued also. Owing to its versatility, it has been widely used for interior decoration and for many customized applications.



**Figure 4:** *Multi wood*

#### **4.12 GI Frame (Galvanized Iron Frame)**

Galvanization is the process of applying a protective zinc coating to steel or iron, to prevent rusting. The most common method is hot-dip galvanizing, in which the parts are coated by submerging them in a bath of hot, molten zinc. Galvanized Iron frame is a framing system that utilizes professionally engineered cold-framed galvanized metal section and prefabricated truss elements that suits the roof, walls design of homes, commercial & institutional projects. The zinc coating, when intact, prevents corrosive substances from reaching the underlying iron. Additional electroplating such as a chromate conversion coating may be applied to provide further surface passivation to the substrate material.



**Figure 5:** *GI Frame*

#### **4.13 Bison Panel**

Bison panel is a cement bond particle board made out of 62% cement and 28% wood. Bison Panel is highly fire resistant & has been classified as an incombustible material in many countries around the globe. With cement constituting 62% of its composition, Bison offers excellent resistance to weather. The board has been subjected to many cycles of soaking,



**Article Title: Building Design Techniques to Withstand Landslides**

freezing, & heating without any sign of disintegration. The board should generally be painted or for external applications to provide a weather seal. Bison Panel is manufactured by an irreversible process combining cement & wood particles into a chemically stable building material which maintains its strength with time & exposure to elements. The board is unaffected by many dilute chemicals such as brines, bleaches, detergents, & chlorine solutions. Due to adoption of special manufacturing process, the panel acquires the strength and durability of cement and the work ability of wood. Bison Panel can be drilled, sawn, & sanded with normal wood working tools. For bulk volumes, Bison should be cut with Tungsten Carbide tipped circular saw & drilled with high speed steel drill bits. It can be fixed using screws & nails. Pre-drilling a hole slightly bigger than the shank would be required.

## **5 Construction Details**

Buildings in the areas which are prone to natural disasters like landslides need to be designed and constructed with suitable disaster mitigating features. In addition to that, the sustainability of such structures and their impacts on the environment also demand due consideration. The guidelines which need to be incorporated to ensure sturdy building structures.

### **5.1 Hazard Identification**

Based on the building location and hazards map analysis, the main hazards which can disturb the critical infrastructure needs to be identified. Considering these hazards during the planning and location phase help in mitigating landslides and flood-related dangers.

### **5.2 Hazard Assessment**

Once the hazards are identified after referring to the available hazard maps (for both floods and landslides), they should be further deeply evaluated. Dependent on the type and scale of the maps, added information on the specific hazard sub type and its intensity should be determined for the building location.

### **5.3 Determining Building Characteristics for Landslide Resistance**

The dangers buildings face due to landslides is a combination of the total hazards posed by the location, the vulnerability of the specific site characteristics, and the vulnerability of the building structure characteristics. Some types of building structures are more exposed than the others.

### **5.4 Risk Assessment**

A complete risk assessment of the structure and critical infrastructures need to be evaluated.



**Article Title: Building Design Techniques to Withstand Landslides**

## 5.5 Design and Construction Fundamentals

**Foundations** – Foundation should be designed and built efficiently to carry the building load according to the bearing capacity of the soil.

**Plinth** – Should be free from structural cracks as these indicate weakness of the foundation. RCC Plinth beam should also be incorporated in the design to alleviate the powerful lateral forces of rains, floods, and sea surges.

**Walls** – Should be capable of withstanding strong lateral forces exerted by the flood waters. 8” – 9” thick bricks or blocks load bearing walls are preferred.

**Roofs** – The roofs should be of the required slopes based on the type of roofing material used (Clay tiles or corrugated sheets) to survive heavy winds and rain.

**Drainage System** – Safe drainage system can prevent landslides to a large extent. Water which drains from the roof and other areas like the portico should not be allowed to flow down the slopes but should be drained through proper drain pipes.

**Sanitation systems** – Should be of approved types and of sturdy construction so that it doesn't allow the leeching of effluent (human waste) into the soil. Septic tanks where used should not be rendered by high water table levels or impermeable soil. Here, dry compost toilet system is a great option.

Design professionals would agree that the most successful way to alleviate losses of life, property, and function is to construct buildings that are structurally strong and disaster-resistant. This approach should be incorporated into your project planning, design, and development at the earliest possible stage to ensure your design and material decisions are based on an integrated and all-inclusive approach.

## 6 Working Details

Here we are going to mention a working technique which can be applied in building design using some of the materials mentioned above. This technique protect the building from landslide. For that we have to implement specific equipments in it. These equipments helps the building to rise during landslide. During the time of landslide there should be vibrations within the underground soil strata. These vibrations are detected by accelerometer sensor and it identifies the frequency and intensity of the landslide. Then these data are transmitted towards the microcontroller board. The board is already coded with the frequencies and the height to which the building have to be raised according to the intensity of landslide. The board crosscheck the data from the sensor and operates according to it. The data that obtained from the board are then passed to the solenoidal valve which acts as a connecting link between board and the hydraulics lifting system. According to the input data the hydraulics lifting system uplifts the building to desired height with respect to the intensity of landslide. As the weight of the building is already reduced without any difficult we can raise the building and the debris will flow underneath the raised building. All these processes will be within a minute. Accelerometer sensor are put into the ground at about 10m depth from the



**Article Title: Building Design Techniques to Withstand Landslides**

foundation. The output from the sensor are transmitted in the form of voltages through electric wires to the micro controller board which is placed under the ground near the sensor. Microcontroller board and solenoidal valve are placed inside a box which we named as controlling box. Connections from these devices are provided to the hydraulic system which is in the four corner pillars. Then these system is connected to the pillar in which the hydraulic system is inbuilt. The connection of the controlling box and the sensor to the pillar. On the top of the pillars, the foundation which is made with the reinforcements are laid and above which the superstructure have to be constructed. Up to here the building should acts as a normal building. During the time of landslide or in early, the sensor detects the unfrequent vibrations on the ground. The sensor detecting vibrations. These frequencies are transmitted to the controlling box. The frequencies detected by the sensor are cross checked by the micro-controller board and sends the signals to solenoidal valve, it initiates the hydraulic system. All these processes are happening within seconds. As this mechanism is fully automated, there should not get any destruction even if the landslide is happening on night time or no residents are in the house. Complete protection will get to the inhabitants in the building and no property damage occurs. By using flexible pipes for water pumping and electricity, there should not occurs any hindrances in water and power supply. Within the time period that the debris reaches the structure, the entire structure rises up to the desired value of height in accordance with the intensity of the landslide and the landslide matters will flow through under the building.

## **7 Conclusion**

The present study was aimed to design a landslide resistant building. In recent years we are witnessing tremendous landslides in Kerala and thus huge disasters are causing to human life and properties, out of which a huge lose is to the construction field. The Landslides pose a recurrent hazard to human life and livelihood in most parts of the world, especially in some regions that have experienced rapid population and economic growth. Hazards are mitigated mainly through precautionary means—for instance, by restricting or even removing populations from areas with a history of landslides, by restricting certain types of land use where slope stability is in question, and by installing early warning systems based on the monitoring of ground conditions such as strain in rocks and soils, slope displacement, and groundwater levels. There are also various direct methods of preventing landslides; these include modifying slope geometry, using chemical agents to reinforce slope material, installing structures such as piles and retaining walls, grouting rock joints and fissures, diverting debris pathways, and rerouting surface and underwater drainage. Such direct methods are constrained by cost, landslide magnitude and frequency, and the size of human settlements at risk. The design of building is in such a way that during a landslide it can rises up itself by the action of the mechanical devices which includes a sensor and hydraulic lifting mechanism. For a structure to rises up by itself, the self-weight of the building should be a



**Article Title: Building Design Techniques to Withstand Landslides**

minimum, to obtain that condition the super structure of the building is designed with light weight non-conventional building materials which poses adequate strength to the building and can withstand wind load, live load etc.

Even so it has its own limitations, with further increase in the advancement of technology we can make it as our future residential building in landslide prone areas. The most successful way to mitigate loses of life, property and function is to construct buildings that are strong and disaster resistant.

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