Building construction in hilly areas — Some important considerations

by
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Introduction :

Building construction activities in the hilly regions have increased manifold in recent times due to developmental activities. It has resulted into instability of slopes and incidence of landslides at many locations. In fact, construction of buildings in hilly areas needs a great amount of attention than that in the plains, due to complex topography, geological features, drainage system and wide range of temperature variations etc. It needs much more care in selection of suitable site for building construction in hilly regions in comparison to the plains which are normally free from most of the parameters mentioned above.

There is always need for site development but in hilly areas it involves operations like deforestation, blasting and slope cutting etc. resulting into disruption of natural drainage system of the area, ecological equilibrium and slope stability. The stability of site and building may also be disturbed due to earthquake tremors especially in earthquake-prone areas.

Site selection is normally done by a committee. In hilly regions the site selected may sometimes be unsuitable from stability considerations or due to very costly measures, otherwise needed to ensure stability of buildings in the future. It is, therefore, imperative that in selection of site in hilly regions, due attention and consideration are given to geological and ecological aspects. Efforts have, therefore, been made to cover the general geological and ecological parameters which need consideration in site selection and maintenance of hill slopes for safety of buildings in hilly areas.

Site selection :

First step in construction of a building is the site selection. Prior to taking decision on site, it is necessary to have detailed observations of the geological, hydrological and topographical features of the area. Any site which appears to be disturbed based on such observations should be rejected outright or avoided except for certain obvious reasons which may restrict the selection.

Experience of persons working in the hilly constructions indicate that, in general, sites with the following conditions are not suitable for building construction and need to be avoided :

(i) *Where slopes of rock structures are unfavourable :* such as, dip of the rock is towards slope or steep and vertical joint planes are dipping towards slope, especially when the amount of dipping of such dipping planes is less than the hill slope at site (Figs. 1 and 2).

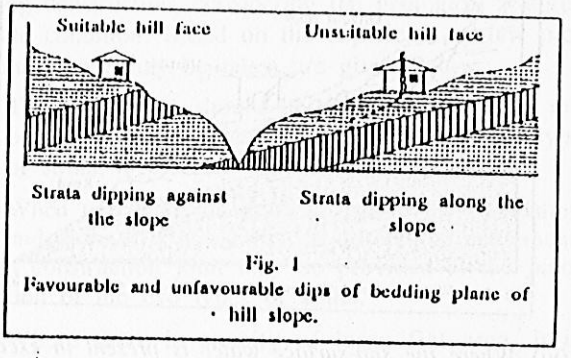

Fig. 1
Favourable and unfavourable dips of bedding plane of hill slope.

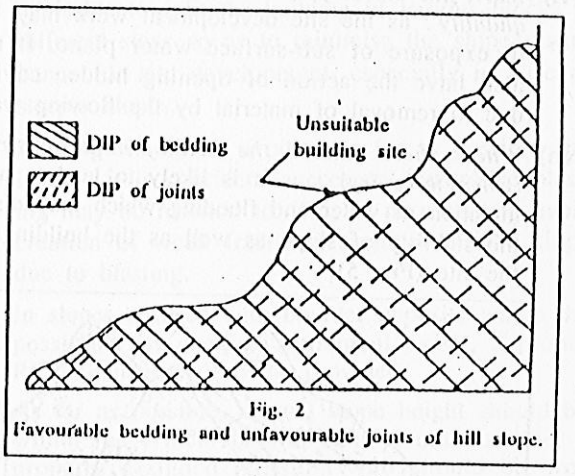

Fig. 2
Favourable bedding and unfavourable joints of hill slope.

(ii) *Where the sequence of rocks is unfavourable :* such as, debris cover is lying over impervious strata and the contact plane dips towards the valley (Fig. 3).

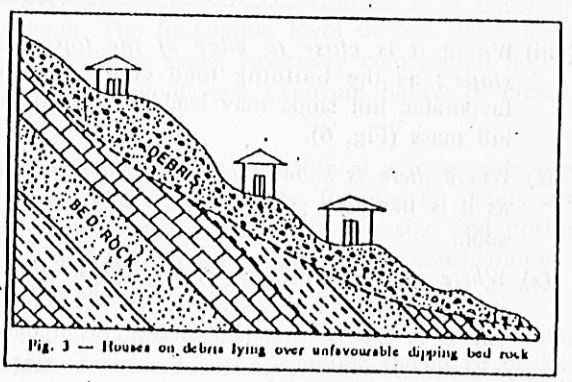

Fig. 3 — Houses on debris lying over unfavourable dipping bed rock

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(iii) *Where stream or river at the toe is cutting the slope :* the extent of cutting is likely to disturb the slope and sliding may start in due course of time.

(iv) *Where landslides are not active or old landslides are existing :* due to ill-planned excavation the landslide may reactivate.

(v) *Where a road is proposed to be cut and is close to the site :* especially on the lower side, it is expected to disturb the stability of the site (Fig. 4).

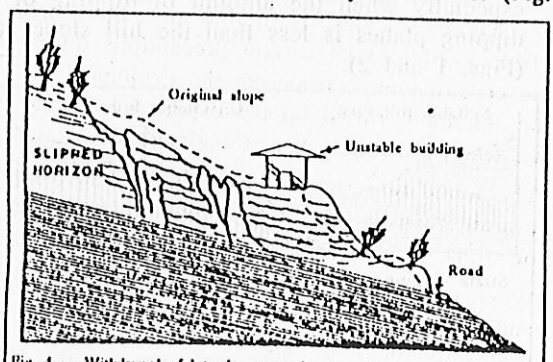

Fig. 4 — Withdrawal of lateral support due to road cut causing instability.

(vi) *Where the sub-surface water is present in excessive quantity :* as the site development work may lead to exposure of sub-surface water plane. It may also have the action of opening hidden cavities due to removal of material by the flowing water.

(vii) *Where there existed the bed of nala or stream (when it is dry) :* as it is likely to lead to accumulation of water and flooding which may disturb the stability of slope as well as the buildings on the site (Fig. 5).

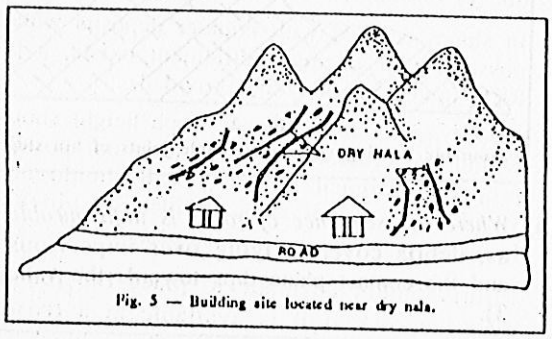

Fig. 5 — Building site located near dry nala.

(viii) *Where it is close to edge of the top of steep slope :* as the building load coupled with unfavourable hill slope may lead to shear failure of hill mass (Fig. 6).

(ix) *Where there is known active fault or thrust zone :* as it is likely to get disturbed easily during monsoon.

(x) *Where there is steep slope, and the height of cut out slope behind the building for development of site is in excess of critical height :* as it may lead

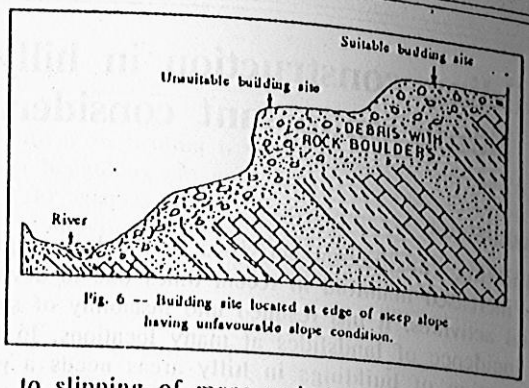

Fig. 6 — Building site located at edge of steep slope having unfavourable slope condition.

to slipping of mass and damaging the building (Fig. 7).

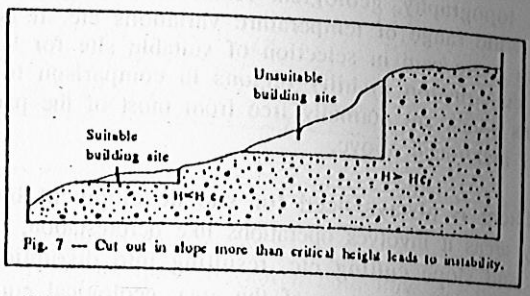

Fig. 7 — Cut out in slope more than critical height leads to instability.

(xi) *Where there are boulders or stone pieces rolling down the hill slope :* the impact of rolling stones/boulders is likely to damage the building (Fig. 8).

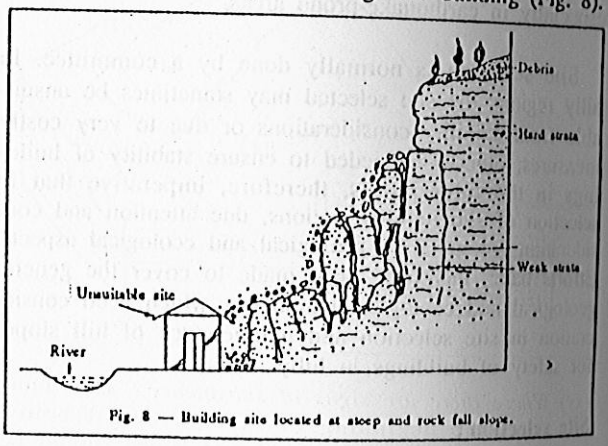

Fig. 8 — Building site located at steep and rock fall slope.

(xii) *Where the slope overlooking the site is susceptible to avalanches or glaciers :* as their movement/occurrence may damage the structure which is normally not designed to take such impacts or loads (Fig. 9).

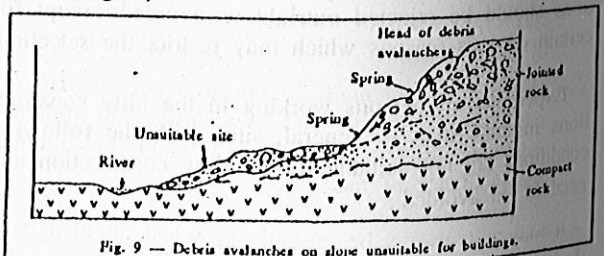

Fig. 9 — Debris avalanches on slope unsuitable for buildings.

(xiii) *Where the site falls below a natural or artificial reservoir and especially when the geological conditions are not favourable :* as the seepage of water at any stage may trigger off movement of mass along the bedding plane (Fig. 10).

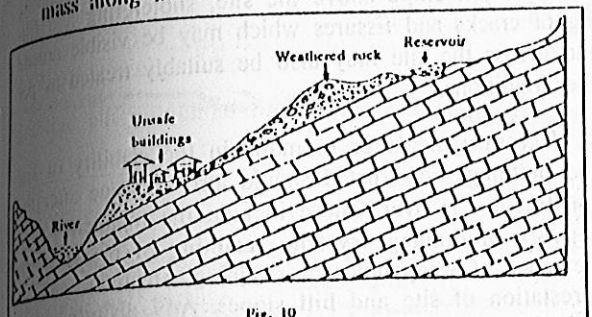

Fig. 10
Buildings falling below a reservoir/lake disturbed by leakage of lake/reservoir water.

(xiv) *Where the hill slope is having sign of surface erosion :* as with time it may develop into deep cuts especially where it is overlain by weathered rock and prove fatal for the building (Fig. 11).

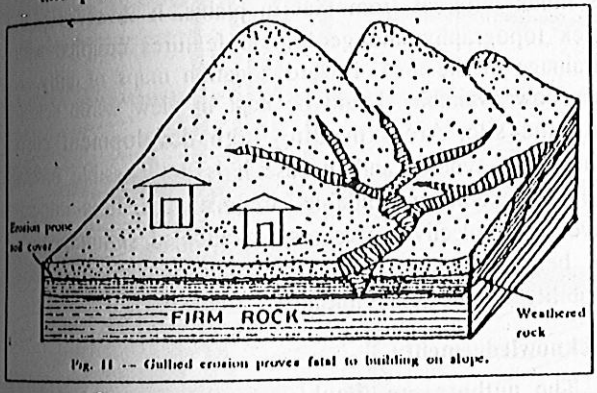

Fig. 11 — Gullied erosion proves fatal to building on slope.

(xv) *Where there are signs of subsidence :* as it indicates the beginning of the movement below ground has already started and hence should be avoided.

(xvi) *As far as possible, the site should be on the sunny face of the hill slope :* as it is considered to be safe due to natural growth of trees and shrubs/grass which normally exists in sunny side of the hill slope.

(xvii) *Hazard zonation maps of the area should also be considered :* as they lead to identify safe and unsafe areas in terms of instability and thus reduce the incidence of landslides.

It may not always be possible to select an ideal site free from all unsuitable conditions mentioned above. At times the site having one or two of the above mentioned features may have to be unavoidably accepted. In such cases suitable precautions and measures must be taken to control the possible likely disturbances in the future. The measures to be adopted will depend upon the nature of unfavourable features in the site selected, the expected nature of disturbance and the types of building etc.

Building construction :

After having selected a suitable site, there will always be a need to take certain precautions during the building construction, considering the geological features and site condition. Based on the experience, a few precautions which may be taken are given below :

i. The foundation should be designed based on the bearing capacity, which will depend upon the type of strata.

ii. When two types of strata is met in the foundation and there is a possibility of differential settlement, a construction joint may be provided at the junction of the two types of strata.

iii. Where there is paucity of large flat area, it is advisable to split the building in various blocks in different steps so as to minimise the slope disturbance for site development, especially in case of steeper slopes.

iv. Blasting should be avoided as far as possible and in case it is considered necessary, controlled blasting may be resorted to. This is necessary to avoid creation of weak fractured surfaces on the slope due to blasting.

v. In slopes covered with boulder deposits where the possibility of unequal settlement exists, a proper RCC foundation may be provided.

vi. As far as possible, the cut slope height should be within the critical height. If it is not possible, a properly designed retaining wall should be provided, and cut out slope divided by providing a beam in between two cut slopes.

vii. Efforts should be made to place the foundation over the rock if it is available at a reasonable depth. The foundation level of one block should normally be same. Necessary care should be exercised to avoid rock exposure below or close to the site.

viii. Where rock is not available at a reasonable depth and the building is to be founded on debris overlying the rocks, the foundation size and position of building should be decided in consideration of the angle of internal friction (θ) of the debris.

ix. There should be systematic and proper drainage around the building. The drains should be made in such a way that they should finally discharge into road-side drain or nala. Catch water drains should also be provided on the hill slopes above the

building site to avoid damage due to displacement if any and water is diverted to the network of drainage system.

x. The material available out of slope cut due to any developmental activity at site, should not be thrown or disposed on the lower hill slope as it may lead to ecological disturbance. Efforts should be made to use the cut out material in development of parking spaces and lawn by providing retaining walls on the lower side of site.

xi. Retaining walls may be provided to contain the freshly cut slopes and gaps behind the wall properly filled and surface dressed to avoid percolation of water behind the walls.

xii. Any sub-surface drains which may appear on excavation should not be blocked. They should be allowed free flow and diverted to drainage network of the site.

xiii. After site development, the plantation, both deep rooted as well as wide-spreading grass and bushes should be planted, particularly the fast growing ones suited to the climate, as a measure to check the erosional activity.

xiv. Necessary earthquake-resistant measures should also be adopted depending upon the earthquake zone where the building is to be constructed, as a safeguard against any such future eventuality.

Some of the considerations in view of seismic provisions are :

(a) Unsymmetrical loadings in a building should be avoided as it produces torque. Various sources of unsymmetrical loading are, water tank on the roof if placed in a corner, provision of different thicknesses of RCC slab, provision of lift/stair at one corner etc.

(b) Materials used for construction should be relatively ductile such as low grade steel and high grade concrete etc.

(c) Bending of steel bars in beams should be avoided and minimum 8 mm dia stirrups should be provided to combat the shear stresses.

(d) Laps and splices are the areas of weakness in a beam and should never be provided near the column supports.

(e) The compression steel in beams should not be less than 50 per cent of tensile steel in RCC beams.

(f) Column stirrups should pass through the beam column junction in case of RCC structure.

(g) Spacing between different buildings and blocks should be as much as possible.

(h) RCC bands may be provided as per recommendations of the Indian Standard 1893, for the seismic zone of the area.

In addition to the above, measures like deflecting walls on hill slope above the site, shotcreting and filling of cracks and fissures which may be visible around and across the site may also be suitably treated as per site conditions.

Necessary measures to maintain the stability of site and buildings constructed should also continue after the construction is over. These include the maintenance of network of drainage system, retaining of breast walls, clearance of weep holes of retaining structures, and afforestation of site and hill slopes. Any disturbance of hill slope around the site should be immediately attended to before it spreads and becomes unmanageable causing threat to the site and structures there.

Conclusion :

It is an accepted fact that construction in hilly areas is much different from that in plains. It involves complex topography and geological features coupled with drainage of the area. Hazard zonation maps of hilly areas now available should be kept in view while selecting the site. Areas needing high development costs should be avoided and in case it is not possible on account of some unavoidable circumstances, it is imperative that protective measures are adopted simultaneously or before construction and maintained well to ensure stability of site and buildings.

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