SLOPE CONSTRUCTION AND MAINTENANCE PRACTICES

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Abstract
There have been numerous slope related failures. Most simply costing lot of money but some also involving loss of life. Every time there is failure, particularly that involving lot of media coverage, there is considerable awareness, numerous experts expressing numerous opinions and explanations. Issue of slopes has achieved status where it has gone beyond easy understanding of most people.

The paper looks at designs, construction and maintenance of slopes and slope related development from end user point of view. Importance of design and construction methods and their relation on slope safety, environment and issue of educating end user with respect to "intelligent" maintenance of slopes.

Keywords: Slope failures; Construction; Maintenance

1.0 INTRODUCTION

To date we have experienced numerous slope related failures. Lots of these failures have been simply costly and have attracted little or no media attention and soon forgotten except perhaps by those directly affected by these failures. Then there are failures that have been spectacular failures causing lots of public nuisance or damage and have involved fatalities. Whenever this kind of failure occurs, there is usual immediate kneejerk type of awakening of awareness in problems with slopes. Every time this happens we make sincere promises or statement to effect that such will not happen again:

At every major failure we see numerous experts pop-up expressing numerous opinions, giving expert explanations, providing statistics, diagrams and pushing the issue of slopes to status level so high that slopes seem to have become preview only of "high geotechnical level" engineers or geologists, more complex and complicated the better. Such complexities are out of reach of common souls actually affected by slopes. No one, as far as can be seen, ever asks the basis on which these slopes were designed and how carefully were they actually constructed in the first place.

It is sad to note that even with the excellent level of engineering we have, we have yet not got around to the basics. All one has to do is to please take drive and look around. One will hardly fail to notice open areas subject to rapid erosions, slopes consisting of all form of rubbish from construction material to rubbish and sometimes even soil. Our construction methods, even the lowest basics, like drains have deteriorated to level hard to describe.

In spite of our high level engineering expertise but we are falling short of applying these to even getting basic ground data correct to goings on at the work place, at the construction sites. We allow unsupervised work or work supervised by untrained personnel. When things go bad, our statements put forward are usually varied, imaginative and make very little sense. Some examples (Attachment 1):

- "…he highlighted the fact that geological information was under–utilized by geotechnical engineers"
- "…Landslip in Pusing…happened because of weak slope"

- "Landslides, including rockfalls, are often caused by land mismanagement. Improper land use practices, particularly in mountain and coastal regions, can create and accelerate landslide problems"
- "..the (massive) land slide was caused by heavey rain over last few days…"
- "…wet water and loss of soil suction caused the slip…"
- " …loose soils …..assisted by gravity …causes the slides"
- "…Act of God…."

Meanwhile, as if to smear salt over a wound, we have ultimate insult to good engineering practice in the form of guidelines which are developed in short time as the long term solutions to our problems under assumption, or blind eye to, the fact that such guidelines will mitigate problems created by bad practices, which is not true. And soon, following every juicy slope failure after all the "present slope related" hoo-ha has been made, the slope awareness soon peters off until next juicy failure occurs and we start all over again.

It is time therefore that we re-visit our own practices at the very basic levels, start engineering there and take step to get them right or improve them. We must pay more attention to end results that are usable and safe for our end users and their children i.e. sustainable slopes. We compare in this paper old practices and practices we are adopting now.

2.0 BASICS

Basics are, all civil engineering structures, including all manmade slopes involve three basic steps, design, construction and maintenance. We, as the engineering designers must pay attention to all these steps. This is regardless of whether the problem is remedial or new.

3.0 DESIGNS/REMEDIAL DESIGNS

The design is the first step in any civil engineering project where we start to create into our work the sustainability or disaster.

All hill/slope related designs have to take into consideration their surrounds. However, most of our slope related designs, at least in private practice, tend to be isolated designs confining attention mainly to within boundaries of the project area. Effects of our designs, particularly during and after construction on our surrounds or of surrounds on us is rarely considered. This issue is getting more and more prominence now due to various failures during and after construction leading to considerable public outcry.

Figure 1: Effects of our construction operations on surrounds

All man made slopes, isolated or otherwise, are designed taking into account the properties of soils that go into the construction of the slope. Such designs also take into account what is or will be at the top or the bottom of the slopes. Almost all these designed slopes provide for stable slope angle and proper drainage. Also, in every slope design, the greatest attention is always paid to the control of water.

However, all designs of our man made slopes assume that all our design information to be used in our designs are reliable and construction will be carried out as per specification, codes of practice some similar controlling/guiding document. In practice is not quite the case and we must revisit at least some of our practices

Firstly, we must re-examine the way we obtain our basic subsoil parameters on which all our slope designs are based. Methods we presently use for obtaining our subsoil parameter, the sampling and testing involving boring into hill slopes or grounds, is usually not acceptable and does not provide either representative or reliable samples or tests.

Figure 2: First two photographs on left show boring rigs used almost every where. These rigs use are not acceptable as "water jetting" method is used to advance the hole. Acceptable sample of a light rotary boring rig is shown on far left. Actions of both these rigs are described in Figure 3.

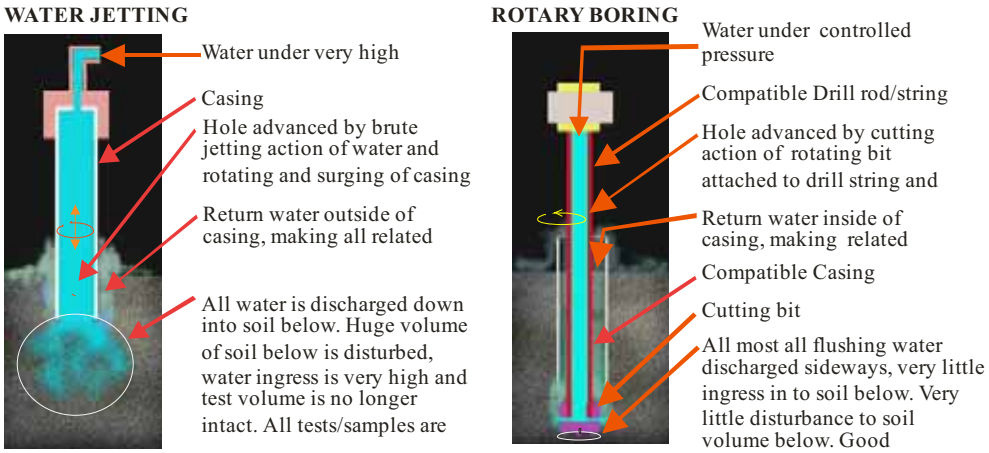

Figure 3: Difference between Waterjetting (Washboring) and Rotary Boring (MS2058:2007)

The method we use, referred to as Rotary Wash Boring, involves advancing boreholes using surging and rotating of casing only with water under very high pressures. Borehole, therefore, is advanced mainly by brute force of water going downwards into sub-soils below. All samples and tests we carry out in such boreholes are in badly altered or disturbed soils affected by high pressure water and thus no longer representative. (Ref. 1 & 2). It is important to ensure the subsoil directly below our bore depth is not disturbed or altered before we test or sample. Weather we bore into soils using foam, chemical or clean water, we above conditions must be met. This means we must select proper equipment, ancillaries, drilling medium, and trained operators. And we must supervise these works ourselves or by trained supervisors under care.

Our designs must also incorporate constructability and maintenance requirements this include discarding of water and waste out of our site safely and environmentally correctly.

Figure 4: Slopes seen from close up and from distance. Illustrating problems of safety for maintenance crew. Narrow berm widths and lack of measures against falling over makes sites like these impossible to maintain. Designs have to address such issues.

Where cross-checked by accredited checkers, such checker must not limit himself only to checking of calculations but must examine all factors described above, unless this is done checking is meaningless. Hence checker should also share responsibility.

4.0 CONSTRUCTION/REMEADIAL WORKS

Construction is where our designs are put into practice and the owner starts paying. This is also the area where stage is set for sustainable slopes or suspicious slopes. No matter how good the design it is, it is only as good as what the construction stage of the processes makes it. To achieve the targets set by the design, it is essential that construction is supervised under the control of the designer. Designer in turn must ensure that all aspects of the construction/remedial works are properly carried out. This includes proper earthworks (cut/fill), drainage to careful disposal of unwanted construction material or waste.

What is said here is nothing startling, every textbook, specification or Codes of practice says this. What is startling is in practice we rarely follow all above. We therefore must revisit our construction shortcomings.

Construction of slopes therefore plays a very large role in behaviors of slope during the service. Badly constructed slopes which pay very little attention to good construction practices will require lot more maintenance since they are very easily affected by the action of water leading to endless problems from erosions, settlements, seepages and slips to landslides.

Figure 5: Well executed slope construction with down up construction. Neat, well compacted and trimmed slope faces. (East-West Highway)

Figure 6: Messy construction sites, heavy erosions due to bad earthworks (Selangor, Cameron Highlands)

Almost all development in hilly areas consist of some cutting and some fillings and some disposal of construction material/waste. In every case how this is to be done is specified by Engineers and should lead to trouble free slope where care is taken to observe the requirements of the engineer during the construction.

This involves all cut and exposed areas to be protected during and after construction against water and all fill areas to be well packed and similarly protected.

Filling operations require particular care as fills are most susceptible to ingress of water. Loosely filled ground can soak up water and also erode at rapid rate causing instabilities and ugly erosion scars. All filling operations should involve proper preparation and filling in small thickness of spread soil layers with each layer well compacted/packed using rollers or tampers. Well compacted ground does not soak up water easily and it does not easily erode. Erosion from such sites can affect surrounding areas for miles.

These are some of the simple basics. Slopes construction, which pretend but do not incorporate proper practices will always be in some form of trouble during construction and service. In service such slopes will require very much more maintenance and repairs. This is very sad as the final user who usually has no control over the design or construction has to suffer and even pay for bad construction, possibly for ever.

Mehod of building up slope by dumping is fast, but very bad. Where a slope is constructed by simply dumping soil without compaction, soil inside the slope is loose and regardless of vegetation cover and drainage provided, water will still get into the slope face and into slope, loosening soils, washing away fine particles in the soils and causing piping and rapid erosion and in time, slips. On badly filled areas, therefore any thing built will have all sorts of annoying problems like cracks, erosions, sinkholes, settlements or collapses. Utilities placed in such fills will soon experience distress causing yet more problems. The final user of the slope related property has no control over construction, this is the responsibility of the engineer.

Figure 6: Building up slope by dumping soils and waste down slope. Discarding rock-fall debris down the slope on the other side

Though all slopes are provided routinely with adequate drainage structures to control water, in badly constructed slopes these seem to make very little sense as drainage structures are also affected by bad construction and break down even before slope is finished.
Numerous drains are either badly constructed or are damaged as slopes start getting into distress due to localized settlements, small slips, erosions and so on. Such small distresses, particularly that affecting

Figure 7: Cast in place drains are already experiencing settlement while this slope is still under construction

water control like drains will set the stage for bigger slope failures or land slides in time. In numerous cases, particularly where drains are repaired or replaced as part of maintenance, these are rarely supervised and become unserviceable within very short time.

Figure 8: Good ground preparation, alignment and construction of drains (East West Highway 1991)

Figure 9: Unsupervised drainage work on extremely loose dumped soils. Where drains are replaced, old drain are broken up and used as fill. (Gasing hill entrance 2008, July)

Figure 10: Effect of loose fills, some bad design and lots of water

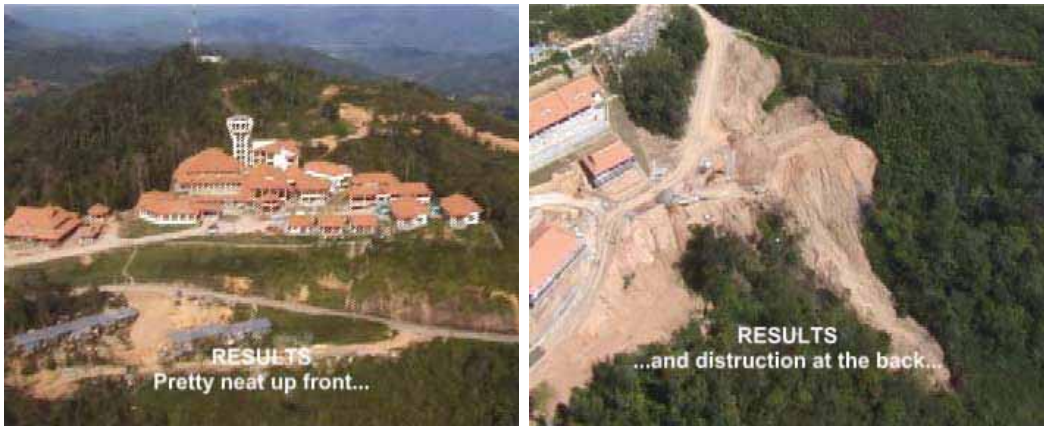

Figure 11: Discarding construction waste into surrounds

5.0 MAINTENANCE

All hillside developments are assumed to have been constructed according to required local and professional standards. Since property owner usually has very little say after completion of the home-site, institution or the development, only concern he now has, has to be directed towards maintaining the slopes, drainage and similar facilities so that they will perform as designed, working of which most hardly understand.`

Figure 12: Well maintained slopes (East-West Highway, Cameron Highland) and difficult to maintain slope (Kuala Lumpur)

In practice, both the single property owner, or institutional development (schools, public facilities) are maintained by owners or maintenance staff, usually the gardeners. These are not trained people and they have very little idea with respect to maintenance requirements.

In about 1997, about 215 institutions were inspected for slope related problems in Wilayah, Selangor and Pahang. The management at every one of these institutions genuinely cared about the facilities under their care. All these institutions were well kept and pleasant to visit. Yet almost all of these institutions experienced slope related problems to various degree of seriousness as direct results of inadequate maintenance. Numerous examples were found of clogged drains, some have completely silted over, sumps filled with rubbish, cascade drains spilling over slopes to highly eroded areas below.

DISTRESS CATEGORY	WILAYAH	SELANGOR	PAHANG	TOTAL
Slopes which have failed and further may damage life or property OR slopes which are not stable from geotechnical perspective and may fail at any time resulting in loss of life/damage to property	5	1	2	8
Slopes which are not stable from geotechnical perspective and may fail at any time but do not endanger lives/property because of remote location	6	4	3	13
Slopes expected to fail in future but sufficient time is available for monitoring and further investigation to determine cause and provide remedial measures	22	5	33	60
Slopes requiring improved maintenance of all drainage structures	61	9	64	134
TOTAL	94	19	102	215

Table 1: Institutions experiencing various degree of distresses directly related to maintenance and some suspected of inadequate designs.

All these problems related to one simple fact that the people responsible for the welfare and maintenance of facilities under their care had no clear idea why these drains and sumps had to be kept clean, why uncontrolled streams of water should not be allowed, what does it mean when walls start cracking and so on. In short there were no guidelines, nothing to explain what a simple blocked drain with water spilling all over steep slope can do?

In practice, as far as the slopes are concerned, items that cause most damage are also simplest to maintain, provided one is briefed on what to maintain and why it must be maintained. Very little literature is locally available addressing this issue without flying of into maintenance organization charts, responsibilities and so on. Can we not consider that there is such an entity as the gardener and that properly briefed he can prevent disaster ?

Some examples of maintenance management/construction issues at various Institutions and other places:

Figure 13: Damaged drains deteriorated to ditches, drains clogged up, drains used as rubbish dump. This one is just above a steep slope.

Figure 14 : Institutional slopes in various stages of distresses from ground movement to toe drains silted over or blocked

Figure 15 : Spot turfing going bad, erosion gullies as deep as 5 meters and cutoff drain above slope with number of "sinkholes" developing

Figure 16 : Covering slope against rain, only the slope on far left is an example of proper cover, rest just pretending**.**