Surficial Slope Instability and the Potential Contribution of Erosion Control Practice

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ABSTRACT
Civil and Geotechnical Engineering design practice primarily considers general slope stability, with surficial slope stability addressed with less design rigour. Long term surficial slope stability is commonly accomplished with vegetation in the form of grass lined slopes, where detailing of same is accomplished by the slope stability engineer, a vegetation specialist or an erosion control practitioner.

This paper examines surficial slope instability where design detailing may be a contributing factor to long term surficial slope instability; where instability is found within days, months, years or even decades. Further, this paper will expand on the potential contribution of the erosion control industry where commonly delivered 'Best Management Practices' may contribute to surficial slope instability.

The paper discusses the merits of less topsoil and greater diligence in design detailing to cause long-term sustainable root establishment in the civil grade for more robust grass liner protection of engineered infrastructure.

RÉSUMÉ
La pratique de la conception des génies civils et géotechniques compte principalement

La pratique de la conception des génies civils et géotechniques compte principalement de la stabilité des pentes, pendant que la stabilité de la pente superficielle est traitée avec moins de rigueur de conception. La stabilité superficielle, à long terme de la pente est généralement accompli par la végétation sous forme de pistes bordées d'herbe, où le détail de même est accompli par un génie de stabilité des pentes, un ingénieur spécialiste de la végétation ou un praticien de contrôle de l'érosion.

Cet article examine l'instabilité de la pente de surface où les détails de conception peut être un facteur contribuant à l'instabilité de la pente de surface à long terme ; où l'instabilité est trouvé dans les jours, mois, années ou même des décennies. De plus, cette étude s'étendra sur la contribution potentielle de l'industrie de contrôle de l'érosion où généralement livrés "Meilleures pratiques de gestion" peut contribuer à l'instabilité de la pente de surface.

Le présent document examine les mérites de l'utilisation de moins de couche arable et d'une plus grande diligence dans la conception détaillant à cause racine durable à long terme dans la mise en place de grade civil á creér un protecteur de liner d'herbe plus robust, avec l'ingénierie de l'infrastructure.

1 INTRODUCTION

Surficial slope instability manifests over time, ranging from days to decades and most constructed slopes treated by common design and construction practices are susceptible to failure mechanisms of soil erosion, poor vegetation establishment, surficial soil sloughing and nutrient leaching.

This paper broadly surveys all natural and imposed factors required to perform together to achieve surficial soil and vegetation stability. Historical context of surficial soil building and vegetation succession, civil engineering design and detailing, standard construction practices, as well as the contribution of erosion control practice are examined.

This paper focuses on civil grades and slopes. Shallow surface failures, deeper geotechnical instability and erosion control in hydraulic conveyance are not be covered.

This paper aims to set context for greater communication across designs disciplines in addressing the poor performance of structures delivered under the current framework of infrastructure design and construction.

2 PRECEDENTS IN NATURE

Nature provides precedent and guidance in vegetation establishment. Considering a post-glaciation context, significant soil building and vegetation succession has occurred. The ongoing dynamic natural process supports increase in soil depth over time as well as a constantly changing vegetation regime.

Early pioneering plant species addressed inorganic compacted soils with capacity to initiate nutrient cycling and ability to set root in compacted soils.

Throughout the vegetation succession and soil building cycle, plant roots performed surficial stabilization by mechanically adhering surface soils to subsoils.

Highly elastic and strong vegetation roots evolved on site and over time to be able to mechanically hold rootbound soils in place, even in periods of high soil moisture concentrations when soils become heavy for moisture held in place by the very rootzone holding the soil to the surface.

Civil construction on greenfield sites typically occurs when the construction site ecosystem is in a vegetative climax condition: where plants and soil biology have reached an ecological equilibrium. Having evaluated and documented the ecosystem prior to construction, simplistic ‘remove, store and replace’ has proven ineffective. Greater attention must be given to design and installation of sub-climax vegetation regimes recognizing the necessity for natural process to reinstate equilibrium.

Figure 1. Root development at depth, mechanically attaching topsoil to subsoil

3 DESIGN AND CONSTRUCTION

Current infrastructure design and construction seeks to reinstate a pre-construction condition, but standard practice hinders success due to:

- Subsoil with significantly altered compaction and moisture regime
- Surface soil strata with mechanical characteristics typically not of their original condition. i.e. soils stripped from flat location being repurposed for sloped applications.
- Surface soil strata not mechanically attached to the compacted subgrade.
- Surface soil strata of varying compaction and interaction based on construction placement convenience.
- Vegetation specification based on climax species.

Great care is taken in the design process to consider mass cut and fill balancing as well as the structural stability of the designed grade. Care in surficial stability is typically limited to specified topsoil depths equal to preconstruction conditions or ill-considered by arbitrarily assigned thicknesses. Care in vegetation establishment is typically limited to specifying a Department of Transportation regional roadside mix of broad spectrum planting regime.

4 SOIL HANDLING

Confounding ill-considered surficial treatment topsoil placement, is the handling of the topsoil, even when re-purposing onsite soils. The concept of re-using site soils is borne of decreasing haul distances by segregating stripped soils for recompacting structural soils for grade material and placing other soils as ‘topsoil’ growth media.

Handled correctly, nutrient rich ‘LFH’ (leaf litter) and ‘A’ horizon (organic rich top soil) soils can be stripped, segregated, stored properly and replaced for adequate, if not excellent revegetation harnessing in-situ seedbank, rhizomes and suckering root masses. With close attention to subgrade preparation for easy root penetration and appropriate compaction, soil re-use can be a very effective method of vegetation establishment and subsequent surficial stability.

More commonly, however, LFH and A horizon soil stripping are contaminated with B horizon soils that may be less desirable for structural purposes. The soil is then stock-piled on as small an area as the pile can stand steep, thereby creating anaerobic conditions within the pile and altering / severely depleting the viability of the soil to be replaced toward the end of the construction sequence.

Soil placement is then executed either by bucket placement loosely compacted by bucket pressure or by more compactive measures such as with loaders or dozers. Loosely compacted soils are prone to mechanical sloughing and highly compacted soils limit root establishment within the compacted soil. Both placement techniques result in a veneer of topsoil that contributes to surficial instability. At best, a thin layer of dozer-placed nutrient rich organic soil can be mechanically incorporated into the subsoil to aid in initial mechanical stability and increasing root penetration into the civil grade subsoil.

Exacerbating all these issues is the practice of mass-stripping the entire construction site, causing topsoil strippings to be stock-piled inappropriately, resulting in low-efficacy planting soils.

5 CONTRIBUTION OF EROSION CONTROL PRACTICE

Mass stripping also results in vast areas of exposed soils prone to erosion and contributing to terrestrial and aquatic sediment pollution. Erosion and Sediment Control (ESC) measures are deployed to arrest as much erosion as possible in an effort to suspend sediment transport.

Common practice suggests vegetation equals erosion control, which guides a highly reactive discipline combining erosion control and vegetation establishment with the belief that the faster vegetation stability, the better. Further, already limited construction budgets are typically exhausted and surficial site stability must be achieved for as low a budget as possible.

Moving quickly to erosion protection and vegetation establishment has resulted in industry norms focused on short term erosion protection and immediate vegetation establishment for construction sign-off, and has resulted in short term vegetative site protection.

5.1 Surficial Erosion Control

Structural, mechanical, chemical and vegetative measures, and combinations thereof, are all employed in attempting to control surface erosion.

5.1.1 Site Grading and Soil Preparation

Current, but not widely adopted site grading and soil preparation erosion control measures provide the highest value, where the practitioner is working from a point of understanding site-specific soil characteristics and how to keep soil in place. The most highly effective ESC designs will have the fewest products detailed.

Shallow, short slopes, properly installed transverse-gradient water bars, as well as soil texturing are examples of good erosion control measures.

Figure 2. Cross-gradient water bar and soil texturing

5.1.2 Rapid Vegetation Establishment of Topsoil

Rapid vegetation establishment in placed topsoil, when executed considering as many determinants as possible, can result in stable sites. Determinants include, but are not limited to, ability of subsoil to sustain vegetation, quality of topsoil, rooting characteristics of vegetation, vegetative cover characteristics, anticipated vegetation timeframe, regional hydrology, near-site hydrology, climate, climate moisture cycle and time of year.

These determinants are best considered as a multi-disciplinary task in evaluation, specification and ongoing maintenance.

More commonly, with a less diligent “one size fits all” specification mindset, placed topsoil is a liability, susceptible to mechanical sloughing and nutrient leaching.

5.1.2.1 Mechanical Sloughing of Rootbound Soils and Rootbound Saturated Soils

Where in-situ soils built over thousands of years, have developed soil strength to site-specific conditions which may have resulted in 100mm of topsoil, removing, storing and replacing 100mm of that topsoil does not result in pre-construction soil stability characteristics.

Current practice sees placed topsoil designed to usually stand on a steeper gradient than in the original condition and the subsoil and the subsoil upon which it sits is typically more compacted than the pre-construction subgrade.

Chronology of sloughing is as follows:

- There is a slip-plane where the topsoil meets the compacted civil grade soil.
- The specified climax species vegetation is not adept at breaking into the compacted grade and topsoil becomes rootbound and heavy.
- The topsoil is prone to slipping as it becomes heavier with roots.
- The rootbound soil holds significant weight in water along the fibrous rootzone.
- The wet, heavy rootbound soil sloughs.

Figure 3. Well-vegetated slope sloughing within six months

Figure 4. Well-vegetated slope sloughing after thirty years

5.1.2.2 Nutrient Leaching

In common practice slope applications, free nutrients in organic soil run downhill resulting in good vegetation establishment at the toe of a slope, mediocre vegetation establishment mid-slope and poor vegetation establishment at the crest of a slope. It is often at the crest of the slope where erosion control vegetation is most required, as in the shoulder of a highway.

5.1.3 Slope Interruption Products

Where site grading is not appropriate / achievable, slope interruption products, such as straw filled wattles serve temporary service to shorten slope lengths or to divert water.

In dry cycle years, water collected upstream of slope interruption products typically has a chance to percolate and leave the slope grade dry and at full shear capacity to carry the forces of the next rain event.

In wet cycle years, the civil grade in the vicinity of the device remains saturated and subsoil supporting the topsoil is at limited saturated shear capacity and results in saturated subgrade sloughing in addition to surficial topsoil sloughing.

Given commoditization of ESC products and installation, it is prudent to consider that this ESC measure will not be installed properly. Improperly installed ESC measures confound failure by causing water to quickly concentrate, resulting in expedited surface erosion.

Figure 5. Slope interruption device contributing to surficial soil instability by moisture retention

5.1.4 Rolled Erosion Control Blankets

Rolled Erosion Control Blankets (RECB) are a decades-old product category offering good erosion protection if installed properly. RECBs need to be installed with enough fasteners of sufficient style and length to hold the blanket against the soil surface causing intimate contact of the RECB to the ground. Intimate contact mitigates erosion below the erosion control blankets and associated seed migration.

Given commoditization of ESC products and installation, it is prudent to consider that this ESC measure will not be installed properly. Improper installation will result in erosion below the RECB.

Figure 6. Erosion below Rolled Erosion Control Blankets not conformed to soil surface

5.1.5 Hydraulically Applied Erosion Control Products

With the commoditization of RECBs products and installation, manufacturers of Hydraulically Applied Erosion Control Products (HECP) have been increasing the erosion control technical proficiency of these products, once limited to products for hydroseeding. High performance erosion control HECPs are quick and cost-effective to install and the higher performing erosion control matrices enjoy greater than one order of magnitude higher erosion control performance than RECBs.

Caution needs to be exercised in design and specification of this relatively new product category with attention placed on ability of the product attributes to best support vegetation establishment while controlling erosion. Attributes to consider include, but are not limited to, ability to hold moisture in the soil for germination, ability to install with intimate seed to soil contact and the ability of the matrix to interact within the soil for interim erosion protection until vegetation is established.

Figure 7. Highly conforming Hydraulically Applied Erosion Control Product high wind performance

6 VEGETATION ESTABLISHMENT

The above practices and products focus on erosion control and not necessarily on vegetation establishment. In the absence of a dedicated, comprehensive Surficial Stability Practice design discipline, each independent discipline is attempting to address site stability along discipline expertise.

The erosion control industry has recognized the necessity for greater diligence in vegetation establishment. Further, this industry has recognized the general lack of expertise in the field and has been working to develop a "one and done" approach to increasing vegetation establishment success across a broad spectrum of conditions; as is currently being delivered under Civil Earthworks Practice.

The Erosion Control Technology Council industry group specifies a new product category Hydraulic Biotic Soil Amendments (HBSA) as being (ECTC 2016) "designed to be used as topsoil or compost alternatives when topsoil is not present, soil is lacking in organic matter, or there is little to no biological activity."

For reasons of topsoil liability as discussed above, HBSAs are likely best employed with limited topsoil and in conjunction with careful consideration of the civil grade subsoil's ability to support sustainable vegetation.

Caution needs to be exercised in design and specification of this new product category with attention placed on ability of the product attributes to best support sustainable vegetation establishment.

Erosion control is required on top of HBSAs.

Figure 8. Hydraulically Applied Biotic Soil Amendment

7 CLOSING

While the erosion control industry is advancing diligence in sustainable vegetation establishment recognizing site, design, contracting and construction limitations, it is the greater design and construction community that must also embrace the concepts and practices discussed herein.

Thoroughly considered symbiotic soil and vegetation relationships will realize the power of vegetative covers for long term surficial soil stability.

Moreover, thorough understanding of all parameters surveyed in this paper will further the predictable, designable nature of

- Vegetative cover for erosion protection.
- Mechanical strength of rootzone interface connection of soil strata.
- Increased soil shear strength by plants transpiring soil moisture.

Long term surficial slope stability is achieved when vegetation establishment design considers the value of natural process in developing sustainable landscapes and when vegetation is regarded as an engineering material.

In considering the concepts and practices discussed herein, we set the context for greater communication across design disciplines in developing stable, sustainable structures.

8 REFERENCES

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