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Short Communication
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Effect of Slope Shape on Soil Erosion

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Introduction

Why do most natural slopes have curvilinear rather than planar profiles? What slope shape is best suited for minimizing erosion losses …. convex, concave, compound (convex-concave), or planar (uniform)? Why are most man-made slopes constructed with planar surfaces and uniform gradients? These are not trivial questions - perhaps no other variable affects the stability of slopes with regard to both surficial erosion and mass wasting as does topography or slope morphology. Topographic parameters normally considered in estimating soil erosion losses include inclination and length of slope. Surprisingly, slope shape is seldom if ever considered. Conceptual and mathematical models, as well as the results of laboratory tests and field observations, can be used to determine the effect of slope shape on both mass stability and resistance to rainfall erosion [1]. These conceptual and mathematical models are normally two-dimensional, i.e., they assume slope profiles are invariant in all vertical planes perpendicular to one of the co-ordinate axes. This assumption of two-dimensional symmetry may appear to be unduly restrictive. However, most engineered or man-made slopes meet this requirement. These slopes are usually planar in form with an unvarying, down-slope gradient and little, if any, plan-form curvature. Benching may be employed on occasion, but planar faces are generally the rule. These man-made slopes include embankments (dams), cut slopes along transportation corridors, cut or fill slopes within hillside developments, and earthen waste stockpiles or landfills. Conventional grading practice does not usually promote nor encourage other slope forms, e.g., concave, convex, or compound slope profiles. The reasons for this grading practice and slope form preference are somewhat puzzling. Natural slopes do not typically exhibit planar slope faces with uniform, unvarying gradients. Instead they manifest a variety of complex slope forms and profiles. Slopes that start out with planar topography also tend to change with time into slopes with curvilinear shapes in both the down-slope and cross-slope direction. In other words, slopes tend to evolve over time into equilibrium shapes that seldom, if ever, are entirely planar. The simplest way to determine the effect of slope shape is to invoke a conceptual model or a mental image of the problem. This provides a way to think rationally about and compare the relative stability of planar vs. curvilinear slope profiles. More rigorous, theoretical analyses can also be undertaken based on physical and/or mathematical models of different slope forms. Finally, the results laboratory tests and field observations of erosion losses from different slope forms can be reviewed. The findings in every case tend to be inescapable, viz., concave or compound slope shapes are superior to planar forms in terms of improving mass stability and limiting erosion. Visual observations of natural slopes provide yet another way of gauging the long-term stability of different slope profiles or shapes. A good place to observe these profiles is in arid or desert climates where the absence [or scarcity] of significant vegetal cover make it easier to determine slope forms. Equilibrium slope forms can be observed readily in the mesa and canyon country of the southwestern United States. A topmost resistant layer of hard sandstone or igneous rock typically results in erosion remnants--mesas and buttes with near vertical rim walls at the top and foot slopes below that characteristically develop a concave, equilibrium profile over time as illustrated in Figure 1.

Concave foot slopes are also well developed and can be readily observed in the Unaweep Canyon a few miles south of Grand Junction, Colorado. This canyon cuts through the Umcompahgre Plateau. At one time the ancestral Gunnison River flowed through the Unaweep Canyon, but the rate of uplift in the surrounding plateau was too high

Figure 1: Photo of Mesa with vertical rim wall at top and concave foot slope below. Hwy 128, Colorado River Canyon, CO.

Figure 2: Photo of Unaweep Canyon with development of broad valley and concave foot slopes. Hwy 141, CO.

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to allow the river to maintain its course through the canyon. As a result the river was forced to change course and flow elsewhere. The present canyon or valley has a saddle or high point with a relatively small stream draining away in opposite directions. These conditions have eliminated stream erosion and down-cutting as a major geomorphic force in the canyon in recent geologic time. Instead more diffuse erosional slope processes and mass wasting dominate topographic development. Over geologic time these slope processes have produced a relatively broad valley with concave foot slopes along canyon margins as illustrated in Figure 2.

Conclusion

The results of field observations and laboratory tests clearly show that concave slope profiles appear to be more stable and generate less sediment than uniform, planar slopes. These findings are consistent with conceptual models and they also accord with results of computer modeling of soil erosion on slopes with irregular shapes and with time evolved digital terrain models.

Reference

1. Gray DH (2013) Influence of slope morphology on the stability of Earthen Slopes. Geo-Congress 1895-1904.