Breakthrough Innovations

Project Title:
Bioengineering for Stabilization of Critical Slopes

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Introduction:
One of the problems with maintaining Minnesota's highway back slopes is dealing with unstable situations caused by water bearing seams. This project was designed to demonstrate the use of bioengineering for stabilizing these critical slopes. Bioengineering is a method of erosion control using vegetation in combination with other natural or structural materials to stabilize areas that are susceptible to erosion. This project used wattling, and brush layering as the chosen bioengineering methods. These were chosen to demonstrate their effectiveness as an environmentally compatible and cost effective method of slope stabilizing. Plant cuttings were selected that are known for high water consumption and the ability to establish on wet sites. Using strongly transpiring plants that absorb high amounts of water helps drain water from the soil. In theory, trenched in vegetation works similarly to a terraced slope, slowing surface runoff while the establishing roots hold the soil in place.

Materials and Methods:
Two slopes were selected on T. H. 169 between Mankato and St. Peter, at milepost (M.P.) 56.750 and M.P. 56.859. Both sites are located on the west side of the highway. Site 1, the slope located furthest south at M.P. 56.750, is 60-70 feet high and 320 feet wide. The second site located at M.P. 56.859 is 50-60 feet high and 100 feet wide. Both sites have a 1:1 - 1.5:1 slope. The vegetation originally present consisted of brome grass and crownvetch with scattered deciduous trees; popular, elm, willow, sumac,(as shown in the original site photos). The soils were sandy and platy clay. The clay soils had pH around 7.7 and the sandy soils were more alkaline around 8.2. Both sites were low in Phosphorous. Soluble Salts were at an acceptable low level. (Details can be found on the soil sample sheets taken on 4 October 1995). Both sites have seeps caused by subsoil layers of clay and sand, which cause the layers of sand to become saturated and lose their stability. Both sites have had stability problems since original highway construction in the mid 1960's.

The sites were sprayed with transline R , (a product of Dow Elanco Co.), to eliminate the crown vetch in the fall of 1995, 4 weeks before the start of the project. The vegetation used for the wattles and brush layering consisted of locally located sandbar willows (Salix exigua). The willows varied in size; 8'-15' tall, 3/4" or less diameter.

The bioengineering work began on November 20, 1995 with nine workers. They began digging trenches for site 2 with hand shovels around 8 AM and finished digging the trenches around 3 PM. They dug trenches from the top down, trenching the northern half of the slope for willow wattle placement and the southern half for brushlayering. The trenches for brushlayering were dug 20 inches deep at a 10% angle. The trench spacing, beginning at the toe of slope has two, 3 foot spaced rows; four, eight foot spaced rows; and four, twelve-foot spaced rows. Each of the two sites had a vertical drain; wattles placed vertically, verses on the slope contour, placed in a seep section of the slope. The trenches were being dug during an intermittent snowfall. This, along with the cool temperature (23 F), prevented the trenches from drying out. Once the workers finished trenching site 2, the workers cut the willows. Some willows were bundled into wattles and others were used for brushlayering. The willows for brushlayering were placed criss-cross in the trench, and then the trench was filled in by hand with shovels. The wattles were placed over lapping the ends in the trench and then were covered with soil. Site 1 was done in the same manner, the next day. Site 1 had a substitute of 15 lineal feet of 4 foot long Sumac (Rhus glabra) placed as brushlayering in a trench at the toe of slope.

Placing wattles in the vertical drain trenches

Wednesday the 22nd of November 1995 at around 11:00 AM all 2,844 linear feet of trenched plantings were finished. The trenching and plant installation was video taped and this videotape is available.

On November 24, 1995 the slopes were hydro seeded with Mn/DOT seed mix 500 and 10-10-10 fertilizer. The process took 45 minutes.

Results:

On April 24, 1996 the sites were reviewed. Site 1 had a 24' wide slump in the middle of the slope that deposited soil from the middle of the slope down into the ditch. Steve Kortuem and his crew installed 50 live willow stakes in the slumped soil. Site 2 had slight soil deposition on the slope from the seeps at the upper portion of the slope. The hydroseeded grass seed had an approximate 5% germination, which was mainly in the wet areas. Site 1 had an average grass growth length of 5/8" and site 2 had an average growth length of 1". The willow wattles sprouted on the ends of the wattles that extended out of the soil. The wattles appeared to be covered with too much soil. Some wattles were covered with 5-6" of soil. The longest growth length of the willow wattles for site 1 was 1-7/4" and site 2 was at 2-15/8". The brush layering on site 1 had 90% visible budding.

Willow wattles placed in trenches

Site 2 was farther along with the longest length of new growth at 1". Roots were developing well, with brushlayering being slightly longer in length.

The May 16, 1996 review of the site looked great, 99% of the vegetation was growing. The wattles on site 1 had an average growth length of 2-5/8". The brushlayering had less growth than the wattles, with an average length of 1-½". Site 2 had slightly smaller growth than did site 1. Site 2's willow wattles had an average length of 2-5/8" and the brushlayering averaged 1-5/8". Germination of the grass seed was highest in the wet areas, near the top of the slope where the seeps were. The rainfall amount for the month was recorded as 2.05 inches, with no major storm occurrences.

Root length of brushlayered willow

On June 17, 1996 Mankato was deluged with 7 inches of rain in 24 hours. Rain amounts up to 9" in 24 hours hit the area near T.H. 169. These rains caused massive mudslides that covered the two southbound lanes of T.H. 169 with 3 feet of mud. The severe storm caused much of the bioengineering project to basically slide the down

the slope onto T.H. 169. Mud washed down over the site from the slope above covering both sites. Approximately four wattles are seen remaining two apart of the vertical wattles.

On September 24, 1996 the site was reviewed. A surprising number of willows were intact and growing after the mudslides that occurred this summer. Slumped areas resulting from the mudslides eliminated sections of the installed willows. On site 1 the far south end and the center slumped. Site 2 had slumps at the top of the slope. The brushlayering had greater growth than the wattles with site 1 having greater growth in both categories. The average growths of site 1 brushlayering at 3’3" and site 2 having 2’7 1/2". The average growth of wattles on site 1 was 2’3 3/4" and site 2 2’2 ½". This could be contributed to variances in installation depth of the wattles between the sites and the amount of mud washed on top of the slope from the June storm. The willow wattles held more soil than the brushlayering, by acting as terraces. Some willows wattles, mainly on site 2, were intact but showed no growth. This is contributed to being covered too deeply with soil. All the vertical drain wattles were growing profusely. One of the two groups of vertical drains installed slumped down the slope. There were gullies between the remaining vertical drains, but the soil was retained under the vertical drains. Average growth of the vertical drains were site 2 in center of the site; 2’5 ½" south of site 2; 2’2" and the vertical drain in site 1; 2’1".

Discussion:

Installing the willow wattles and brushlayers in the fall when the plants were dormant was a viable approach. New growth on the willows was further ahead on site 2. This site seemed to have a higher moisture content that assisted in earlier development of new growth in the spring. The willow wattles budded sooner than the brushlayering on both sites. The toe of the slope was behind in growth compared to the top and middle of the slope due to lower moisture content. The wattles all sprouted under ground and above. The depth of the soil in some areas slowed down the growth of the willows, but in some instances the plant reached the surface before being smothered.. The wattles, dead or alive placed on the slope contour acted as terraces and retained some sediment from washing down the slope, controlling sedimentation.

The wetter areas, where most of the seeps were located in the upper one third of the slopes, had the earliest, therefore the most growth of the willows and grasses. The vertical drain willows were effective in transferring water down the slope. At the end and between the wattles of most of the vertical drain some of the soil washed out. It was important to secure these wattles with long stakes due to the high mobility of the soil on the slope and forces from water flow through the wattles.

Brushlayer and Waddle Growth on Slope

Conclusions:

The methods used in this project are cost effective when using plant material from Mn/DOT rights of way. The costly portion of this project is labor, which could be reduced using Mn/DOT personnel. Being sure the willows are in a dormant stage enhances the success of the willow wattling and brushlayering. Installing the willows immediately after cutting or not allow the cuttings to dry out are essential. Initially the contractor tried to use willows that were cut a week earlier and stock piled, these did not grow they only continued to dry out and die. Installing the wattles so they have soil within them to keep them from drying out is helpful. Crews need to be careful not to cover them over too deep causing them to be smothered. This was one of the reasons some wattles did not grow as profusely as the brushlayering. The wattles on the slope contour, dead or alive assisted in holding some soil back, acting as a terrace. Brushlayering had a higher success rate than the willows the second year. This could be contributed to the deeper trench for brushlayering than prevented mid-summer dry out. The vertical drain wattles grew well. This is attributed to them being placed in seep areas that are continuously moist. Gully erosion occurred between the vertical rows, but seeping water was drained through the wattles. The upper third of the two sites lost almost all the willow wattles and brushlayers. This was attributed to it being steeper than the rest of the slope sloughing of the top portion of the slope. These sites had extreme conditions, including enduring the 100 year storm in the early part of establishment. Bioengineering with willows for slope stability warrants further research.

Willow growth in the vertical drain Site 2 on August 1997

Literature:

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