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RESEARCH PROGRAMS

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Evaluation of Effectiveness and Cost-Benefits of Woolen Roadside Reclamation Products

http://www.mdt.mt.gov/research/projects/env/wool_test.shtml

Introduction

Wool has been used by humans for millennia for clothing, blankets, and even for housing like the yurts of central Asia. This project took a fresh look at wool and explored its potential for incorporation in erosion control blankets (ECBs) and to increase the establishment of vegetation along Montana roadsides after highway construction or other right-of-way disturbance. The project was sponsored by the Montana Department of Transportation (MDT) and the Center for Environmentally Sustainable Transportation in Cold Climates. A research team from the Western Transportation Institute (WTI) and its partner KC Harvey Environmental, LLC, explored the use of woolen products for roadside reclamation. The project targets the use of low quality wool that is substandard or unmarketable, thus offering both environmental and economic benefits.

Wool has many beneficial attributes (after scouring) including 15-17% nitrogen content, absence of weeds, hypoallergenic, nearly fire proof, and the capablilty to absorb 400% of its weight in water after it has been scoured (cleaned). Due to these excellent properties, other countries have been using wool to develop fertilizer pellets (often mixed with sheep dung), blankets to establish sod roofs, building insulation, weed barrier fabric, and other novel items. This project sought to determine if wool products provided advantages over standard erosion control products, and whether these products were cost effective alternatives.

What We Did

The three-year research project started by reviewing sixteen existing wool products that might be readily adapted for roadside reclamation uses. None of these showed promise due to difficulty in importing them to the U.S., or other performance or availability challenges. In the next stage, the research team developed new roadside reclamation products in three of the most promising areas: 1) erosion control blankets (ECBs), 2) biodegradable silt fence, and 3) small cut wool pieces as an additive to wood-based compost. All three types of products were deployed for field tests along Montana highways and the rolled woolen ECBs were also deployed on a test slope at WTI's research facility outside of Lewistown, Montana.

Typically, ECBs for roadside reclamation and storm water control are fabricated from straw and coir (coconut fiber) that is imported to the U.S. For this project, the research team worked with several Montana wool mills and an ECB manufacturer in Minnesota to develop and construct 1) ECBs of varying wool weights, densities, and composition, 2) three versions of silt fence, and 3) cut pieces of wool to add to compost. Following a preliminary season of field testing, six ECBs were selected for a full field evaluation including:

- two carded (processed to align fibers) pure wool blankets (two different weights);
- two felted (processed to lock fibers together) pure wool blankets (two different densities);
- one rolled ECB composed of 100% wool; and
- one rolled ECB composed of 50% wool/50% straw (Photo 1).

For field experiments testing the wool ECBs and the wool pieces added to compost, the research team selected a west facing roadside cut slope along US Highway 287 near Three Forks, Montana. A randomized block design of one square meter experimental treatments was established. The design included

seven types of treatments: the six ECBs and one wood fiber compost with wool additive. It also included four types of control plots: unseeded, seeded, seeded and covered with a standard 70% straw/30% coir ECB, and seeded and covered with compost. Each treatment had eleven replications at the test site (Photo 2).

To establish vegetation, the research team broadcast seeded all plots (except the unseeded control plots) with a standard MDT native perennial grass seed mix, comprised of four perennial grass species (fescue, wheatgrass, bluegrass and wild rye), which are commonly used by MDT for revegetation projects. The designated ECB or compost was then placed over each plot and covered with a piece of plastic mesh to protect the small treatment plot from strong storm events and wind.

The second field site for testing wool ECBs was at WTI's Transcend experimental station near Lewistown, Montana. This site had a constructed 2:1 experimental test slope where four ratios of wool/straw ECBs, and two controls (seed only, standard straw/coconut ECB) were tested. Each of the six treatments were replicated ten times at the site (Photo 3).

The primary measure for success for ECBs and wool additive to the compost was the amount of seeded or desired vegetation they established after two growing seasons. During the first and second growing season, the research team evaluated the performance of the woolen and standard products by measuring the percentage of canopy cover of each plant species present in each treatment plot. Canopy cover measures the percentage of ground that is covered by a vertical projection of a plant's foliage. To conduct the comparative analysis, researchers calculated an average percent canopy cover for each functional group: seeded native grasses, desired non-seeded (volunteer) grasses and forbs, and weeds.

Since the rolled woolen ECBs were the most promising of the new materials, samples of woolen ECB were sent to a laboratory for materials specifications testing.
Lastly, cost-benefit analyses were conducted for the most promising woolen reclamation products.

What We Found

Silt Fence

Three generations of wool silt fence were developed for the project, yet, even more versions need to be developed to arrive at a commercially viable product. There were some field performance challenges that occurred, including: the fence was too restrictive to water flow which led to the eventual failure of the fence; the appropriate density of wool was difficult to ascertain; a strengthener needed to be added to fence fabric for durability; and, it was difficult to determine the appropriate low cost biodegradable products that worked well with wool. The three versions of wool silt fence were not very promising and much more development would need to be made before a commercially viable product is identified.

Cut Wool Pieces as an Additive to Compost

There was no statistical difference in the mean canopy cover of seeded grass species of the compost treatment (control) compared to the cut wool with compost treatment, 6.4% and 10.2%, respectively. Similarly, no statistically significant differences were found for mean canopy cover of weeds or desired non-seeded species between the two treatments. This indicates that the project could not determine that cut wool pieces provided a benefit to plant establishment and growth when it is added to compost material. Since only one ratio of wool to compost was field tested by the project and it did have 59% greater desired plant canopy cover, further experimentation to determine the ideal ratio of wool pieces to add to compost is warranted.

Wool Erosion Control Blankets

The woolen ECBs developed for this project demonstrated notable results at the US Highway 287 test site: all six types of wool erosion control blankets outperformed the control products by having higher mean canopy cover of broadcast seeded native grasses after the second growing season. In particular, two types of rolled woolen ECBs had statistically significant higher desired species canopy cover. The ECB composed of 100% wool produced a mean canopy cover of broadcast seeded native perennial grasses of nearly 21%, and the ECB composed of 50% wool/50% straw produced a mean canopy cover of nearly 25%, compared to less than 5% for the standard straw/coir ECB. In addition, the two rolled wool/straw ECBs had less mean canopy cover of weedy species, approximately 11% and 14%, respectively, than the standard straw/coir ECB, which had nearly 18 percent canopy cover for

Photo 1: Manufacturing the rolled wool-straw ECBs using standard equipment.

Photo 2: Experimental plots using a random block design along US Highway 287 near Three Forks, MT.

Photo 3: One replication of each of the four wool ECBs, a standard straw-coconut ECB, and the control (no ECB) at the Transcend experimental test slope, 2015.

weeds. However, the difference in weed canopy cover was not statistically significant.

At the Transcend test site, in the second growing season (2017), the mean seeded grass canopy cover of the 100% wool ECB (32.8%) and the 55%wool/45% straw ECB (32.2%) were higher than the standard coconut/ straw ECB (28.0%). However, the statistical analysis showed no significant difference in these canopy cover amounts. Mean canopy cover of weed species were either 5 or 6 percent among the same three treatments, but these were all low due to what appeared to be inadvertent herbicide treatment.

Laboratory Tests of Wool ECB

The laboratory tests for tensile strength, C-factor (soil loss) and shear stress gave some indication of the wool/ straw ECB's performance. These results should be viewed with some caution since only one replication of each test was performed due to the costs of such testing. The 50% wool / 50% straw ECB:

- Met MDT tensile strength standards for a short term (Type II B, C) or long term (Type III A) ECB,
- Exceeded the minimum shear stress specified in the MDT standard specifications for short term ECB (Type II B) for low level events, but not for high level events, and was lower than the updated minimum shear stress level for short term ECB, and
- The C-factor was representative of a short- term ECB (Type II C).

In general, the wool/straw ECB was comparable to a short-term (Type II B or C) standard ECB commercially produced and used along MDT roadways. Future product development of the wool/straw ECB should focus on improving the shear strength at high flows so it meets all required Type III specifications and thus, withstands higher rainfall or storm events.

Analytical tests, conducted in the laboratory, of the geo-chemical properties of a sample of the 100% wool ECBs used in the field tests indicated it was comprised of 15% nitrogen (N), while the 70% straw/ 30% coconut ECB contained 0.1% N and the wood-based compost was comprised of 0.5% nitrogen. So as the wool decomposes, a significant amount of N could be released to support plant growth, with the amount of N available for plant growth dependent on the quantity of wool used.

Cost Benefit Analysis of Wool Erosion Control Blankets

The projected scaled (projected commercial production) cost for the 50% wool/50% straw ECB was estimated to be $1.18 per square meter; approximately double the cost of standard 70% straw/30% coconut ECB. However, after two growing seasons at the U.S. Highway 287 field site, the 50% wool/50% straw ECB averaged five times more seeded grass canopy cover than the standard 70% straw/30% coconut ECB after two years, 24.99% cover versus 4.7% cover, respectively. This suggests the added cost for wool ECB may be a benefit due to greater seeded grass cover.

The cost to generate each percent of seeded grass canopy cover per square meter of material at the U.S. Hwy 287 site, where there were statistically significant differences in canopy cover, for both the 50% wool/50% straw ECB and the 70% straw/30% coir ECB was as follows:

- 50% wool/50% straw ECB: 25.0% canopy cover/$1.18/ m^2 = $0.05/ percent cover/$m^2$
- 70% straw/ 0% coir ECB: 4.7% canopy cover/$0.62/ m^2 = $0.13/ percent cover/$m^2$

Restated, the calculations above indicate that it cost five cents to establish each percent of seeded grass canopy cover per square meter using the 50% wool/50% straw ECB and it cost thirteen cents to establish each percent of seeded grass canopy cover per square meter using the 70% straw/30% coir ECB. This makes it nearly three times more cost effective to use the wool ECB material than standard ECB if the goal is maximizing vegetative cover at this site. Precaution must be made to extrapolate these results to other environments or treatments.

What the Researchers Recommend

Silt Fence

Future development of the use of wool in biodegradable silt fence should focus on a more even distribution of the fiber, improvement of fencing strength, and the allowance for the proper amount of water flow thru the material (permeability) .

Wool as an Additive to Compost

Due to the total nitrogen level in wool and its water holding capacity, cut wool pieces as an additive to compost may improve plant establishment. Further research will be necessary to more fully understand the ideal mix of wool as an additive to compost.

Rolled Erosion Control Blankets

The project made the following recommendations regarding wool-straw ECBs:

- It appears the ratio of wool to straw in the filler would not have to exceed 30 - 50% wool - straw to take advantage of the benefits of wool while keeping the woolen ECBs more cost effective.
- The wool - straw ECBs should be used on slopes steeper than 3 horizontal : 1 vertical (18.4 degrees slope).
- It is recommended wool - straw ECBs be used on roadsides with poor soils, particularly if nitrogen is limited, and/or soils are rocky or clayey.
- It is recommended that wool - straw ECBs be used in arid areas or windy locations in Montana where water stress may challenge vegetation establishment and growth.
- Currently, the 50% wool-50% straw (the only product that was tested in a commercial laboratory by the project) met most Type II and Type III material standards required by MDT. It is recommended that future adjustments to a stronger netting might allow the woolen ECBs to meet all MDT material standards for these two ECB types.

For More Details . . .

The research is documented in Report FHWA/MT-017-009/8223-001, http://www.mdt.mt.gov/research/projects/env/wool_test.shtml.

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To obtain copies of this report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.

MDT Implementation Status: November 2017

The implementation recommendations documented above were made to MDT. These recommendations, along with MDT's response, are documented in the implementation report, which can be found at the above URL.