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Comparison of Geosynthetic Rolled Erosion Control Product (RECP) Properties between Laboratories

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ABSTRACT

Geosynthetic rolled erosion control products (RECPs) are used extensively to minimize soil erosion and enhance the growth of vegetation on slopes and in channels. RECPs suitable for these applications come in a variety of different fiber and structure types, ranging from coir erosion control blankets (ECBs), jute open weave textiles (OWTs), to polyolefin turf reinforcement mats (TRMs). Although there is a wide variety of products available, engineers are often given little guidance on the selection of RECPs beyond maximum allowable slope, velocity, and shear stress. RECPs can vary significantly in basic index properties and overall field performance. More than a decade ago, the Erosion Control Technology Council (ECTC), in conjunction with TRI/Environmental, Inc. (TRI), developed several index tests in an effort to compare and standardize RECPs. Although these tests are used extensively to characterize different RECPs, no studies have been conducted that evaluate the repeatability, reproducibility, or usefulness of these tests beyond those conducted at TRI. This paper presents the results of a comparative study of two index tests (light penetration and water absorption) for several different RECPs between Syracuse University and ECTC. These tests were selected for evaluation because the properties these tests measure have been identified by several researchers as being important to the performance of RECPs. Based on the results of the evaluation, a new test for evaluating the water absorptive behavior of RECPs is proposed.

INTRODUCTION

Soil erosion is the detachment and transport of soil particles from the ground surface by raindrops, water, or wind. Of these, the detachment of soil by raindrop impact has been identified as being the most important and most damaging (Ellison 1944). In the raindrop erosion process, soil particles are detached from the ground surface by raindrops; entrained in the sediment load; transported by thin films of water; and deposited (Toy et al. 2002.)

Soil particle movement is initiated when the kinetic energy of the rainfall is transferred to individual soil particles, breaking the bonds between soil particles and causing their detachment. One of the most effective ways of reducing the erosivity of raindrops is to provide ground cover than can intercept raindrops, dissipating their energy before they can reach the underlying soil particles (Toy et al. 2002, et al.) A second component is to reduce the transport capacity of the underlying overland flow, which can be achieved through intimate contact of the ground cover with the underlying soil surface. This contact provides resistance against overland flow by providing tortuous flow paths that reduce the velocity and erosive potential of the flow.

RECPs provide immediate ground cover to protect against raindrop impact. Many researchers have noted the importance of RECP surface coverage to rainsplash erosion performance in bench-scale tests (e.g. Ziegler et al. 1997, Ziegler and Sutherland 1998, Ogobe et al. 1998, Rickson 2002). Similarly, these researchers have also documented the importance of high water absorbency of RECP fibers to improve their contact with the underlying soil.

The two index tests that were developed by ECTC to provide information on ground cover percentage and water absorption capacity of RECPs are the light penetration test and the water absorption test, respectively. Smith et al. (2005) related light penetration and water absorption index test results to the performance of six different RECPs installed in a drainage channel in central New York in terms of both soil erosion and vegetative growth. It was found that percentage area cover and water holding capacity/percentage wet weight play a direct role in initial soil erosion protection and long-term vegetation establishment.

This paper presents a critical review of two ECTC index tests (light penetration and water absorption) based on a comparison of laboratory test results for several different RECPs between Syracuse University and ECTC. The tests are evaluated for their repeatability, reproducibility, and usefulness in characterizing and comparing different RECPs. Based on the results of the evaluation, a new test for evaluating the water absorptive behavior of RECPs is proposed.

MATERIALS

Twelve different RECPs from four different manufacturers were selected for the study. The RECPs were selected based on fiber type and manufacturing process. Eight of the RECPs are erosion control blankets (ECBs): temporary degradable RECPs composed of processed natural or polymer fibers mechanically, structurally, or chemically bound to form a continuous matrix (ECTC 2001) (see Figure 1a). Two of the ECBs are composed of curled wood excelsior fibers (W1 and W2); one is composed of blended wood and synthetic polypropylene (PP) fibers (WS1); one is composed of straw fiber (S1); two are composed of 70% straw and 30% coconut blended fibers (SC1 and SC2); and two are composed of coconut fibers (C1 and C2).

Two of the RECPs are open weave textiles (OWTs): temporary, degradable RECPs composed of processed natural or polymer yarns woven into a matrix (ECTC 2001) (see Figure 1b). One of the OWTs is composed of coconut fibers (C3) and one is composed of jute fibers (J1). Two of the RECPs are turf reinforcement mats (TRMs): long-term, non-degradable RECPs composed of UV-stabilized, non-degradable, synthetic fibers, nettings, and/or filaments processed into 3-D reinforcement matrices (ECTC 2001) (see Figure 1c). One of the TRMs is composed of a coconut matrix (T1) and one is composed of a synthetic PP matrix (T2). A description of the RECPs and their average physical properties, as measured in this study, are presented in Table 1.

The RECPs tested in this study were obtained from the manufacturers in both rolls and in sections taken from entire roll widths. Sampling was conducted across the roll widths in accordance with ASTM D4354. Care was taken during sampling to maintain the structural integrity of the specimens and to ensure that specimens were representative of the provided materials.

(a) ECB (b) OWT (c) TRM

Figure1. Typical RECP structure types (10 cm by 10 cm specimens)

Table 1. RECPs and their average physical properties as measured in this study

RECP	Structure Type	Fiber Type	Mass per Unit Area (g/m^2)[1, 2]	Thickness (mm) [1,3]	Light Penetration (%)[1,4]	Water Absorption (%)[1,5]
W1	ECB	Wood	346 ± 40	10.07 ± 1.84	41.5 ± 9.2	228 ± 7
W2	ECB	Wood	623 ± 135	10.95 ± 2.06	12.4 ± 2.9	243 ± 13
WS1	ECB	Wood/ Synthetic	164 ± 13	3.57 ± 0.28	20.2 ± 3.5	1896 ± 72
S1	ECB	Straw	243 ± 22	8.54 ± 1.48	27.2 ± 4.7	556 ± 49
SC1	ECB	Straw/ Coconut	312 ± 65	5.55 ± 1.30	20.4 ± 7.1	666 ± 197
SC2	ECB	Straw/ Coconut	278 ± 23	8.29 ± 1.70	14.4 ± 5.0	764 ± 186
C1	ECB	Coconut	254 ± 12	4.83 ± 0.77	20.6 ± 10.7	913 ± 179
C2	ECB	Coconut	247 ± 19	4.81 ± 0.65	20.5 ± 5.5	1218 ± 212
C3	OWT	Coconut	741 ± 20	8.68 ± 0.55	22.7 ± 0.6	297 ± 34
J1	OWT	Jute	422 ± 17	4.41 ± 0.43	50.1 ± 4.2	601 ± 54
T1	TRM	Coconut	388 ± 24	13.11 ± 1.13	18.4 ± 3.1	241 ± 58
T2	TRM	Synthetic	580 ± 35	14.24 ± 1.13	24.6 ± 3.7	42 ± 9

[1]Average is given ± 1 standard deviation from the mean (±1SD); [2]ASTM D6475 (ECBs and OWTs) and ASTMD6566 (TRMs); [3]ASTM D5199 (ECBs and OWTs) and ASTM D6525 (TRMs), as modified by ECTC (2001); [4]ASTM D6567, as modified by ECTC (2001); [5]ASTM D1117, as modified by ECTC (2001)

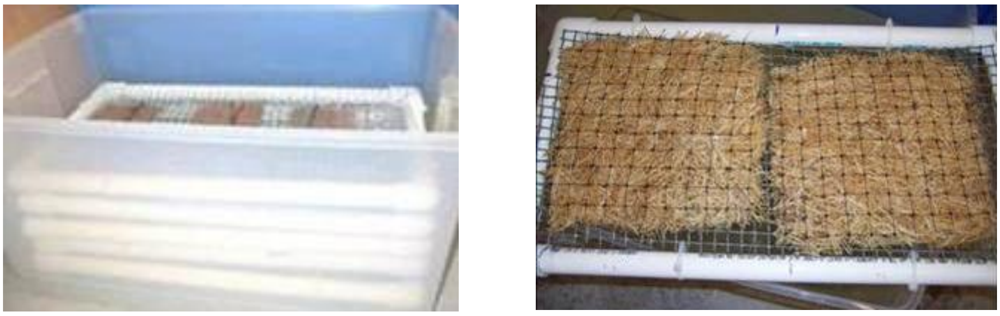
TEST METHODS

Light penetration testing was performed in accordance with ECTC (2001), which is based on ASTM D6567. In the test, light is projected through frosted glass to dissipate the light, and then through a 20.3 cm x 25.4 cm RECP specimen in a closed container (see Figure 2). The amount of light that passes through the RECP is measured using a light meter in terms of foot candles. The percentage light penetration is calculated as the ratio of the amount of light that passes through a RECP specimen to the amount of light that passes without a RECP specimen. Five specimens were tested for each RECP.

(a) (b)

Figure 2. Light penetration (a) apparatus and (b) specimen in the testing frame

Water absorption testing was performed in accordance with ASTM D1117, which was modified by ECTC (2001.) In the test, 20.3 cm x 20.3 cm RECP specimens are placed on a screen and submerged in water for 24 hours (see Figure 3). The RECP specimens are then removed, allowed to drain for 10 minutes, and weighed. The water absorptive capacity is calculated as the ratio of the water held by a RECP specimen to the original dry weight of the sample. Five specimens were tested for each RECP.



(a) (b)

Figure 3. Water absorption (a) reservoir and (b) testing frame

RESULTS

Light penetration

Light penetration testing was conducted to provide information on the amount of ground cover a RECP would provide to an underlying soil surface. Light penetration is inversely related to ground cover. A comparison of the range of light penetration results obtained for each group of RECPs tested (ECBs, OWTs, and TRMs) is presented on Figure 4.

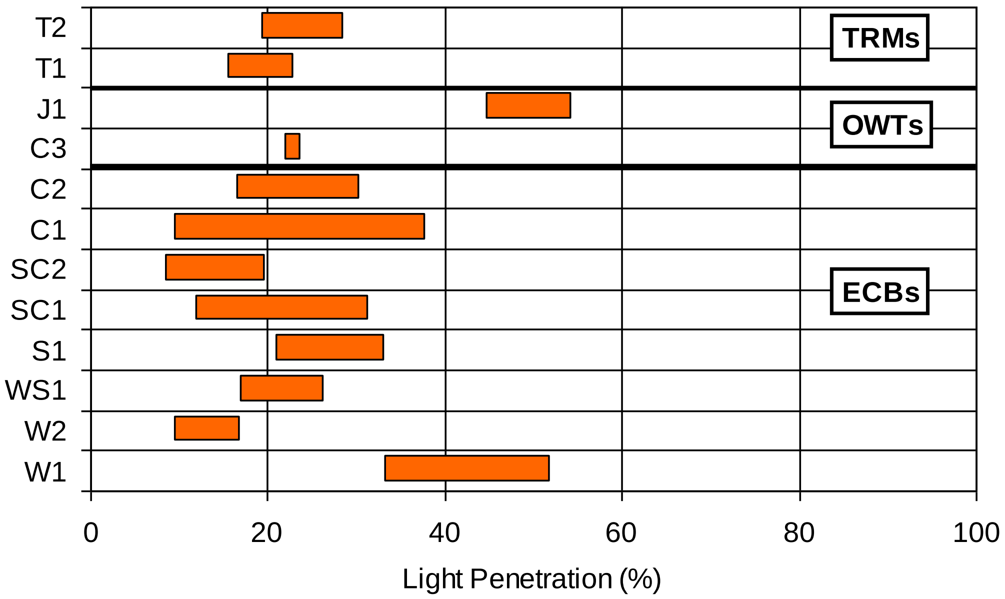


Figure 4. Range of light penetration results

As shown on Figure 4, there was some degree of variability in light penetration results for the RECPs tested. In terms of variability, the ECBs fell within three groups. The first group (W2, WS1, S1, SC2) showed relatively little scatter in results, with results varying less than ±5% (±1SD.) The second group (W1, SC1, C2) showed moderate scatter in results, with results varying between

5% to 10% (±1SD.) One ECB (C1) varied more than 10% (±1SD.) In general, it is believed that the variability in results resulted from: (1) variations in mass per unit area across and between specimens (see Figure 5); and (2) difficulties in specimen handling and supporting with some of the ECBs in the specimen apparatus (repeatability). In particular, there were difficulties in securing ECBs that contained loose arrangements of fibers, such as straw fiber ECB S1. In general, as mass per unit area increased, light penetration decreased for the ECBs tested.

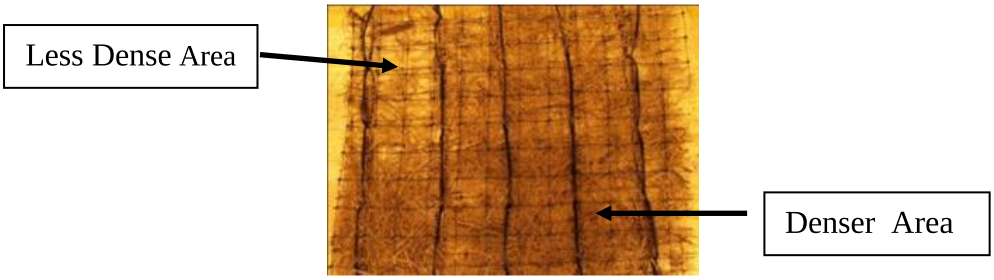
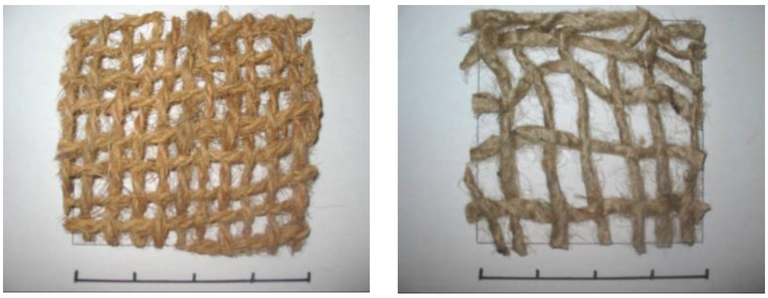


Figure 5. Variability within a RECP light penetration specimen (C1)

The OWTs tested included coconut fiber C3 and jute fiber J1. It is believed that the variability in OWT results is directly related to the rigidness of the structures. C3 consisted of coir fibers that were twisted into yarns, creating a fairly rigid structure, with regular openings. Results for C3 varied relatively little, with results varying only 0.6% (±1SD.) J1 also showed little scatter, with results varying less than 5% (±1SD.) However, there was a greater degree of scatter with J1 in comparison to C3 because of difficulties installing J1 in the apparatus because of the flexible nature of the fibers that made up its structure (see Figure 6.) The fibers were easily distorted during specimen preparation and during installation. Similarly, there was little scatter in results for the TRMs T1 and T2, with results varying less than 5% (±1SD.) It is believed that the rigidness of the three-dimensional structure held fibers in place during testing.



(a) C3 (coconut)   (b) J1 (jute)

Figure 6. Comparison between the two OWTs tested

To evaluate reproducibility, light penetration results obtained by Syracuse University are compared to those obtained by ECTC (AASHTO 2005) for ten RECPs on Figure 7. As shown, light penetration results obtained by Syracuse University were slightly different for half of the RECPs tested (W1, S1, C2, T1, T2) and generally higher than those obtained by ECTC.

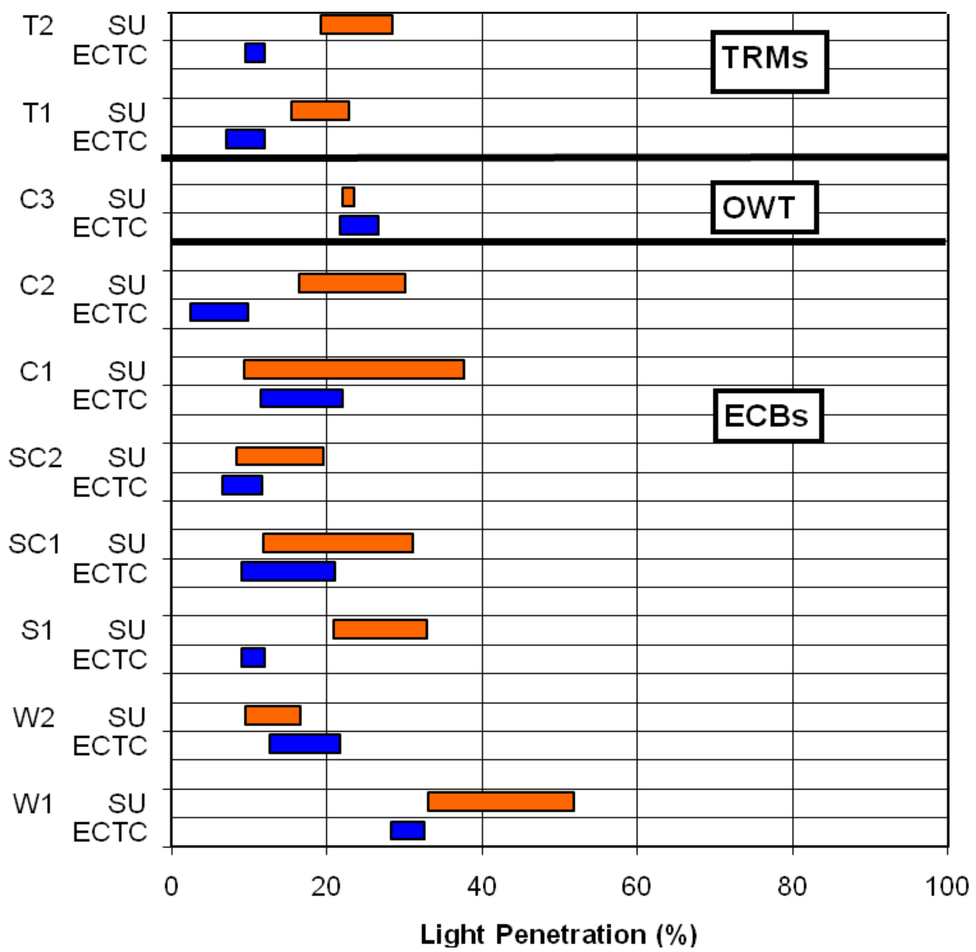


Figure 7. Comparison of the range of light penetration results with ECTC

As shown on Figure 7, in terms of the ECBs, it is, again, believed that variations in mass per unit area across and between specimens lead to variations in results between laboratories. Specimen handling could have also played a role in variations in results. In terms of the OWTs, results were available for coconut fiber C3 for both laboratories. As expected, there was very little scatter in results for both laboratories, with good reproducibility. In terms of the TRMs, it is interesting that light penetration results obtained by Syracuse University were higher for both T1 (coconut matrix) and T2 (synthetic matrix) than by ECTC. Again, this could be due to specimen variability.

In summary, light penetration is a useful property for distinguishing and comparing different RECPs. The method was able to distinguish between the wood ECBs (W1, W2), coconut (C3) and jute (J1) OWTs, and coconut (T1) and synthetic (T2) TRMs, although was limited in distinguishing between the straw (S1), straw/coconut (SC1, SC2), and coconut (C1, C2) ECBs.

Water absorption

Water absorption testing was conducted to provide information on the absorptive capacity of the RECPs. A comparison of the range of water absorption results obtained for each group of RECPs tested (ECBs, OWTs, and TRMs) is presented on Figure 8.

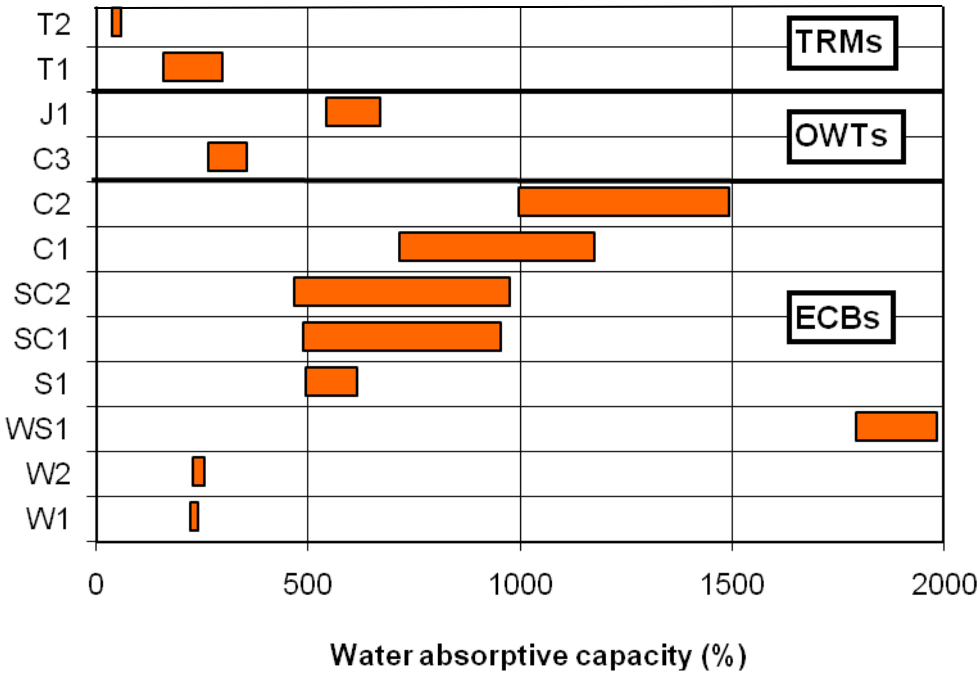


Figure 8. Range of water absorption results

As shown on Figure 8, scatter in water absorption results ranged from very little (W1, W2), to moderate (WS1, S1), to excessive (SC1, SC2, C1, C2) in the ECBs. The little scatter in results for the wood ECBs (W1 and W2) can be attributed to the ability of the wood fibers to hold water once it is absorbed. There was very little dripping or loss of water due to specimen handling during weighing. This was not the case for the straw/coconut (SC1, SC2) and coconut (C1, C2) ECBs. Any tilting of the testing frame from horizontal resulted in loss of water from the specimen fibers. The similar results for W1 (346 g/m^2) and W2 (623 g/m^2) were surprising because it was expected that the denser W2 would have held more water than W1. It is also interesting that the coconut OWT (C3) held less water than the coconut ECBs (C1 and C2). It is believed that higher water pressure is needed for water to penetrate the tight, twisted yarns of C3. The relatively little scatter and low water absorptive capacity of the TRMs (T1, T2) are not surprising because synthetic structures do not absorb appreciable amounts of water.

To evaluate reproducibility, water absorption results obtained by Syracuse University are compared to those obtained by ECTC (AASHTO 2005) for ten RECPs on Figure 9. In terms of the ECBs, water absorption results were generally similar between laboratories for the wood ECBs (W1, W2). However, results varied for the straw (S1), straw/coconut (SC1, SC2), and coconut (C1, C2) ECBs. The wide range in results in comparison with ECTC results is surprising. However, these ECBs are difficult to test in that any tilting of the testing frame from horizontal would result in the loss of water. For example, if the testing frames were not level during drip-drying, significant loss of water could have resulted. Similar to water absorption results at Syracuse University, ECTC's results for the coconut OWT (C3) were also in a relatively narrow range. This is attributed to the twist of the coconut fibers in C3 that held onto absorbed water.

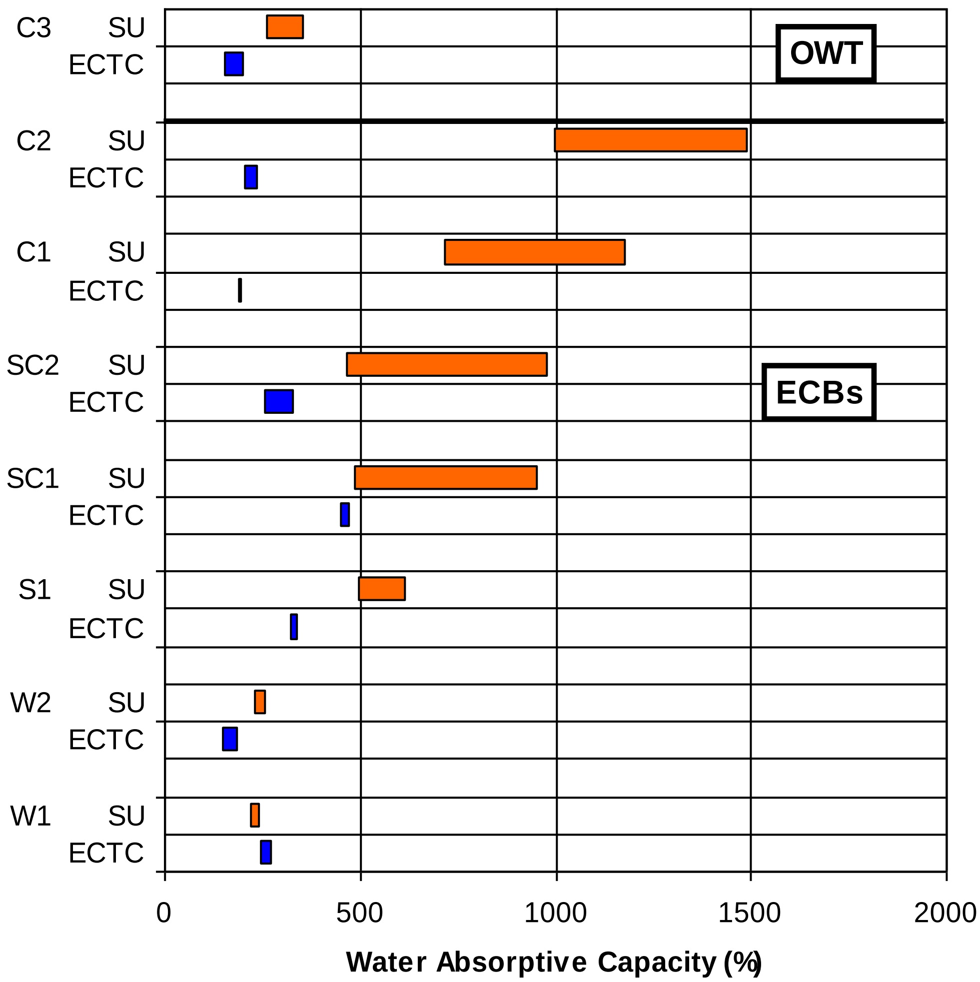


Figure 9. Comparison of the range of water absorption results with ECTC

Water uptake (New test)

Because of difficulties associated with the water absorption test, water uptake testing was conducted on the natural-fiber RECPs to evaluate their water absorption properties. Water uptake testing is commonly used to characterize building materials, but is not used to characterize RECPs.

Water uptake tests were conducted in accordance with ASTM D5802. In the test, 12.7cm by 12.7cm RECP specimens are weighed and placed in air-dried specimen Plexiglas containers with fine-mesh metal screens on the bases (see Figure 10.) The weighed containers are then placed in a reservoir that is filled with water to a height where it would just be in contact with the bottom of the RECP. The containers with RECP specimens are then weighed at time intervals that coincide with a square root of time scale for a period ranging from one hour to several hours, depending on the RECP being tested, to measure the amount of water absorbed by the material over time. This measurement provides information on the amount of "free" water or water that is loosely held within and between the RECP/fibers and easily drains from the RECP/fibers. To go one step further, RECP specimens were also weighed after being held vertically for 10 seconds to measure "held" water, the water that is physically "held" by the RECP/fibers and does not readily drain.

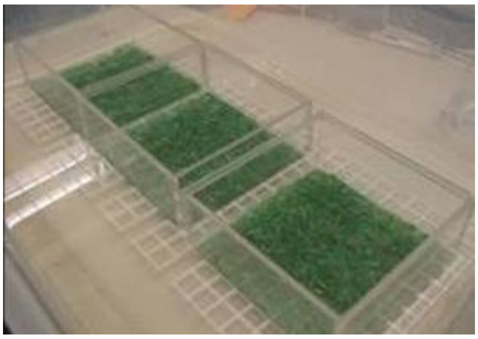


Figure 10. Water uptake (a) reservoir with three specimen containers

Typical water uptake results are shown on Figure 11. As shown, the water uptake test presents very interesting results. For example, the straw (S1), straw/coconut (SC1), and coconut (C1) show different performance in terms of total water uptake, when the products are used in a horizontal orientation. However, this data indicates that the three products would behave similarly in terms of water absorptive behavior when installed in a non-horizontal orientation. This test also demonstrates the differences between coconut ECB (C1) and coconut OWT (C3). Both coconut RECPs absorbed similar amounts of water; however, the coconut ECB (C1) released most of its water when the orientation changed. The OWT (C3), which contained twisted coir fibers, held onto its absorbed water. These differences may have important design implications that are not measured in the water absorption test.

In summary, water absorption is an important property that is distinctive for different fiber types. The ability of natural fibers to absorb water increases their weight and ability to drape, improving the contact between the RECP and the underlying soil. Second, when fibers absorb water, they swell, increasing the amount of ground cover they provide. Third, the ability of a RECP to hold water allows seeds to germinate quickly and vegetation to grow. Because of this, it is important that the water absorptive test be repeatable, reproducible, and useful.

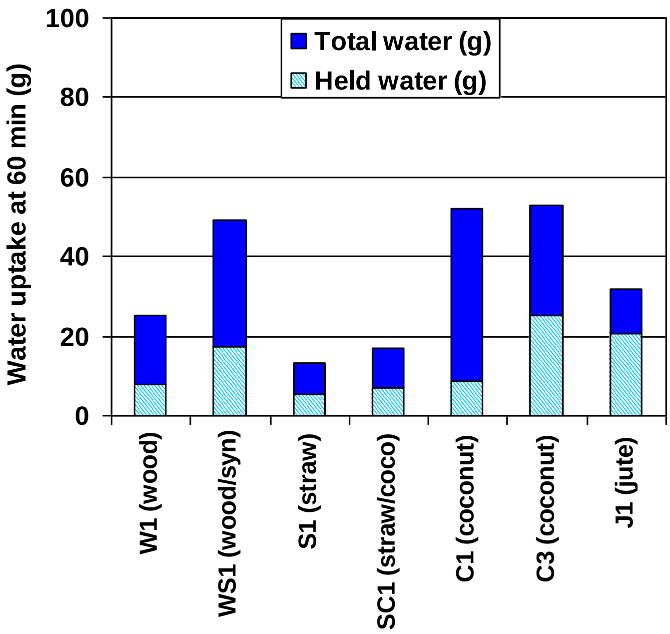


Figure 11. Water uptake results

CONCLUSION

In summary, the index tests provide a straight forward way to characterize and differentiate RECPs, although to varying degrees. The ECTC light penetration test was able to distinguish between the wood ECBs, wood/synthetic ECBs, coconut, and jute OWTs, and coconut and PP TRMs, although was limited in distinguishing between the straw, straw/coconut, and coconut ECBs. The method also showed a relatively slight to moderate range in results.

Water absorption appears to be an important property that is distinctive for different types of fibers. The ECTC water absorption method was able to distinguish between the wood/synthetic ECBs, coconut ECBs, coconut and jute OWTs, and coconut and PP TRMs, although was limited in distinguishing between the straw, straw/coconut, and coconut ECBs. The method also showed significant variability for some products, due to product variability and sensitivity of the test.

The water uptake test in conjunction with the ECTC water absorption test is promising for evaluating RECP performance. Although some field and laboratory studies have shown the usefulness of these tests for performance, more studies are needed to substantiate these studies.

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