Coir Products for Soil Bioengineering Applications in Highway Construction

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Abstract

Rapidly increasing human population continues to increase the demand for construction of highways and bridges. Clearing more land to meet this need can destroy wildlife habitat. "Do it right the first time" should be the slogan for restoring this habitat. Proper design, selecting the appropriate products and proper installation are critical for success of any such environmental restoration work. Failure of any restoration project entails not only the cost of reconstruction, but can also create irreversible habitat damage, especially to aquatic systems. This, in turn, can lead to extremely expensive problems, such as flooding.

Soil bioengineering plays a big role in protecting and improving areas surrounding highway construction projects. This technique uses strong, natural and biodegradable products to establish sustainable vegetation. Sustainable, mature vegetation is the key to a balanced ecosystem and provides a permanent solution to accelerated erosion problems. Products made of coconut fiber (coir), an abundant natural resource, offer unique features to support establishment of sustainable, mature vegetation. They are strong and biodegrade slowly. Also, they can be made into a variety of quality products to protect soil and support vegetation establishment.

This paper will describe natural products that are available for soil bioengineering applications. Also, it will present important factors to consider when installing these products and it will describe some field applications.

Soil bioengineering, erosion control, sediment control, natural and biodegradable products, coir products

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INTRODUCTION

Soil bioengineering is an interdisciplinary approach to environmental restoration which protects water resources by combining biological systems with engineering principles to restore deteriorated soil masses. These techniques make use of the ability of mature vegetation to resist erosive forces. Strong, durable, natural coir (coconut fiber) products can provide the needed initial soil protection until mature vegetation becomes established. Mature vegetation provides a perpetual living system that absorbs rainfall, reduces runoff water velocity and provides a filter system for runoff water that flows to streams, lakes and rivers. However, the role of vegetation is not well understood and appreciated as many in the engineering community still believe that synthetic materials and rock rip-rap provide the only permanent solution to erosion problems.

Soil bioengineering techniques produce aesthetically-pleasing results. They support a naturally strong, healthy environment in a number of ways: increasing water infiltration, reducing heat reflection, filtering sediment, improving water quality, maintaining quality habitats for wildlife and fish, providing recreational activities and creating an environment where humans can rest and relax. Streams with well-stabilized vegetation on banks generally have better water quality and a healthier wildlife habitat than streams without any vegetation *(1)*. In short, these methods will sustain a balanced ecosystem which conveys peace of mind for all.

Even though these soil bioengineering methods are widely used in streambank restorations, they can also be used in other applications, such as slope and channel restorations, highway cuts and fills, road and pipeline construction and landscaping. In many situations, bioengineering techniques provide economical, even superior solutions to conventional hard armor methods. These techniques have gained popularity in the United States due to their environmental benefits when compared to traditional hard engineering techniques. The most popular soil bioengineering methods involve the soil wrap technique and coir roll installations. A variety of hardy, native plant materials should be included in these systems for successful results.

Coir is the fiber processed from coconut husks that have been cured in water. This abundant natural resource is a by-product of the coconut industry. It offers the highest strength and durability of any readily-available natural fiber. Traditional coir processing begins with curing the coconut husks in freshwater for at least three months. This curing turns the coir fibers to dark brown in color. It also increases the durability, strength and flexibility of the coir. With skilled processing, coir fiber can be separated into different grades, depending on the length of the fiber, for use in making a variety of products (*2*). Many different coir products are available for various soil bioengineering applications. They include coir block systems, densely packed coir logs, lightly packed coir wattles, bristle coir woven fabrics and coir mattresses.

OBJECTIVES

This paper describes commonly available coir products for soil bioengineering applications and installation techniques. Also, it describes how these products can be used to make traditional hard armor methods more environmentally friendly where hard armor methods must be used. The paper includes critical factors to consider when designing and installing these materials.

AVAILABLE PRODUCTS FOR SOIL BIOENGINEERING

Coir Block System

The most popular soil bioengineering technique is the fabric wrapped soil layering method. Typically, synthetic geogrids or woven and non-woven coir fabrics are used to make the soil lifts. This technique was introduced in the U.S. more than 20 years ago. More recently, concerns have been raised about the long-term performance of this approach (*3*). Failures have occurred when the thickness of the fabrics at the lift faces was not sufficient to hold the lift until sustainable vegetation is established, allowing soil to come through the fabrics.

In 2002, learning from the failures of fabric encapsulated soil lifts; a patented coir block system was introduced in the U.S. for soil lift construction *(4*). This system features coir fabric attached to a coir block (Figure 1). It consists of a densely-packed, 23-cm (9-in.) thick, 40-cm (16-in.) high and 3.05-m (10-ft.) long mattress coir fiber block with attached woven coir fabric. The coir fabric is tightly wrapped around the coir block and the fabric is connected to the block on three sides, leaving the other side open for filling with soil. The female and male ends on each block create a strong, easy-to-handle connection. This strong connection provides an excellent face for soil layers and assures no failures though the joint.

Densely Packed Coir Logs

Several years ago, the idea of using densely packed coir logs was introduced in Germany *(5)*. This product has since become popular in the U.S. These densely packed coir rolls can be used to provide a strong steambank toe support (Figure 2). They are manufactured from mattress coir fiber densely packed into a tubular 5 cm (2 in.) x 5 cm (2 in.) outer netting made of machine-spun bristle coir twine. The strength of the outer net is critical for containing the densely packed coir fiber core. Longevity and strength of coir logs depend on the density of the coir logs. The higher the density, the stronger the support coir logs provide. Coir logs are currently available in 30-cm (12-in.), 40-cm (16-in.), 45-cm (18-in.), and 50-cm (20-in.) diameters with densities as high as 144 kg/cu. m. (9 lb./cu. ft).

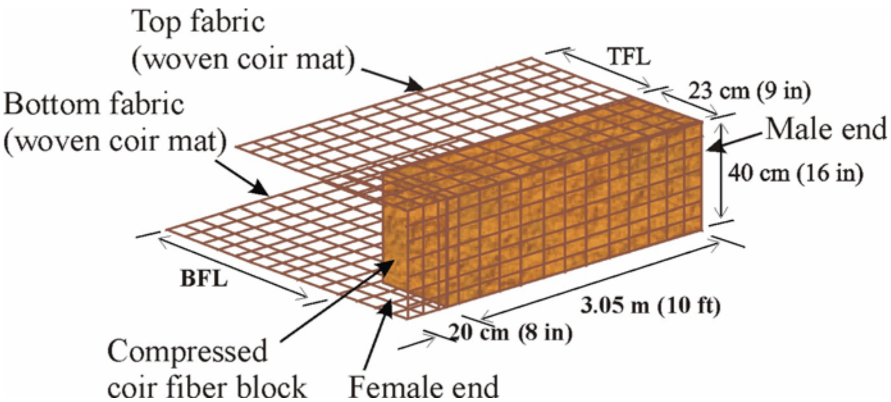


Figure 1 Coir block system.

Figure 2 Densely-packed coir logs placed on a stream.

Lightly Packed Coir Wattles

The idea of using lightly packed coir wattles originated in the construction industry. Coir wattles are made from extra-clean mattress coir fiber lightly packed into a tubular 5 cm (2 in.) x 5 cm (2 in.) outer netting made of machine-spun bristle coir twine. Quite similar in outside appearance to densely packed coir rolls, wattles are used for filtering sediment and as biodegradable check dams in constructing roadside vegetated waterways. They are available in 15-cm (6-in.), 23-cm (9-in.), and 30-cm (12-in.) diameters.

Woven Bristle Coir Mats

Woven coir fabrics (Figure 3) were also introduced to the U.S. from Germany *(5)*. Initially, these woven coir mats were made from mixed coir fiber twines. In 1993 in the U.S., they were further improved *(6)* by introducing a mat woven from machine-spun bristle coir twines (the longer, stronger coir fiber). These 100-percent biodegradable blankets have a higher tensile strength and a four- to six-year functional life *(6)*. They provide higher resistance upon installation, hold moisture and support seed germination and seedling growth. The ability to plant through the mat without having to cut into it is a big advantage in these semi-permanent, open weave blankets. They are excellent for establishing vegetation in channels and slopes *(7)*. Field experiences prove that vegetation comes through these semi-permanent natural blankets better than through the synthetic permanent mats (Figure 4). These blankets are available in three types, depending on unit weight and open area, and made in 1-m (3.3-ft.), 2-m (6.6-ft), 3-m (9.8-ft) and 4-m (13.1-ft.) wide roll sizes.

Coir Mattresses

The idea of using coir mattresses also came to the U.S. from Germany *(5)*. These thicker coir fiber pads are generally used to establish vegetation in areas where soil conditions do not favor establishment of sustainable vegetation. These pads are available in 1.2-cm (0.5-in) thick needle-punched coir liner as well as 3.75 to 10-cm (1.5 to 4-in.) thick mattresses of different sizes. Coir mattresses can also be planted at nurseries and transported to a site for quick re-vegetation.

Figure 3 Woven coir fabric roll.

Figure 4 Vegetation is coming through a woven coir mat better than a synthetic permanent mat.

SOIL BIOENGINEERING APPLICATIONS IN HIGHWAY CONSTRUCTION

A balanced ecosystem is important not only for wildlife, but also for human health. Proper planning and implementing construction activities to minimize the damage to the ecosystem and educating designers and contractors about the role of natural systems and protecting and restoring areas surrounding road construction activities are critical to preserving the environment. In some cases, soil bioengineering techniques replace traditional hard armor practices. In others, they make hard armor projects more environmentally friendly.

In addition to the added cost of reconstruction, failure of an environmental restoration project can also produce irreversible damage to aquatic systems, leading to more problems. For a successful roadside re-vegetation project, the designer must be open-minded and knowledgeable and should communicate properly with contractors. Each unique situation must be studied thoroughly and should specify the suitable product types and methods of anchoring products and plant types for that particular site. Manufacturers cannot possibly provide installation instructions for each unique field situation. Because contractors are trying to complete their work in minimum time, including all installation details in the project design is vital to a restoration success. When the design is done properly and failures occur due to poor construction, then the contractor must bear full responsibility for it. Thus, it is very important to “do it right the first time”.

Coir Block System

Combining a coir block system with suitable native woody and non-woody vegetation to construct soil lifts is an excellent way to stabilize cut and fill slopes as well as streambanks in highway construction. Building soil lifts with a coir block system is much easier than using fabrics alone. The 40-cm (16-in.) tall coir block provides a uniform height for each soil layer and greatly reduces the time and effort required to make uniform soil layers. The 23-cm (9-in.) thick coir block provides better support and protection at the face protecting the soil mass behind it. Meanwhile, the male-female ends of the block produce, strong continuous sections to maintain structural integrity. The end result is a safer and more stable structure. The coir blocks should not be installed one over the other and coir block lift layers should be at least 23 cm (9 in) apart. The number of lifts needed depends on the length of the slope. The coir block system is available in three different fabric lengths (Figure 5). The coir block system with longer fabric provides safer slope stability than the coir block system with shorter fabric. Initial slope safety can be further increased by adding more anchors. Selecting suitable plant types will assure the long-term stability and safety of the slope.

During construction, the bottom fabric of the coir block system should be anchored properly to the base with wooden wedges and /or metal staples. Then, soil is filled in behind the block up to the 40-cm (16-in). height of the block. This fill soil is compacted well and covered with the top fabric, which should be anchored properly. This lift can then be planted or seeded with suitable vegetation. Two adjacent blocks are joined by inserting the male end of one into the female end of the other (Figure 5). A combination of metal staples and wooden wedges can be used to anchor the coir block system. The length and number of anchors depend on the soil type and also on water flow velocity when used on a streambank. Depending on the application, this procedure can be repeated as many times as needed (Figure 6).

On a highway cut and fill slope, woody plants can be planted in each lift. A mixture of non-woody plants should be included for good ground cover. This mixture should include some with strong root system, some with strong aerial parts, those that provide good ground cover and that are drought resistant, summer and winter plants. It is essential to consult a local plant specialist in the selection of suitable native plant mixture. In the case of streambanks, woody native plants should not be planted on the toe, as they can block the water flow during a storm event. Non-woody, drought- and flood-tolerant riparian vegetation (grasses or sedges) should be used at the base of a streambank (Figure 7).

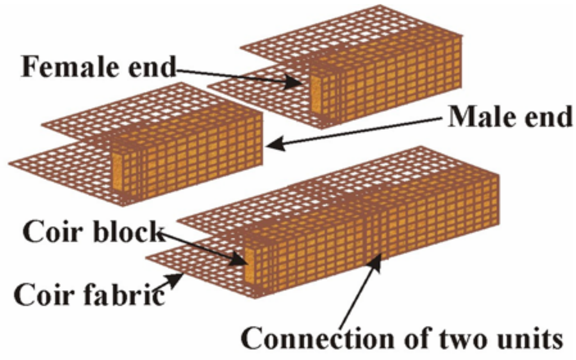
Densely Packed Coir Logs

Densely packed coir logs are generally used to provide initial structural stability to the toe of a streambank by resisting wave action and flow velocity. Proper installation requires anchoring these coir logs securely to the ground. The length and number of anchors needed depends on the diameter of the coir logs, type of soil, method of installation and water flow velocity. In most cases, a wooden wedge with a nail at the top can be used to fasten the coir log to the ground firmly (Figure 8). For additional support, the coir logs can be tied to these wedges with coir twine. In extremely high flow conditions, metal wire anchors may be needed. After installing the coir rolls, drought- and flood-resistant native riparian plants should be planted at the toe near the coir logs where sufficient water is available. With time, sediment will be deposited near the coir logs, encouraging establishment of a blanket of riparian vegetation that will provide the permanent erosion control.

Woody plants should not be planted along the toe of a streambank. Their leaf canopies will not cover the toe completely, which can leave the soil vulnerable to erosion. Also in high flow situations, the canopies can block the water flow, which could cause flooding during storms. If construction is done in hot, dry weather, the site should be irrigated to provide sufficient moisture for young plants to establish. Even though coir logs are available in different lengths, 3.05-m (10-ft) long logs are more convenient to handle and cheaper to transport than longer ones. These 3.05-m (10-ft) logs can easily be joined to the desired length in the field using coir twine. Always use dry coir rolls. In highway construction, these coir logs can be used with a variety of application methods to suit each situation.

Woven Bristle Coir Blankets and Coir Wattles

During highway construction, water diversion channels should be stabilized immediately after they are graded to protect against erosion. Failure to do so is the biggest threat to water quality in highway construction. Heavy flows of storm water runoff can completely destroy a bare-soil channel and wash large amounts of sediment into nearby water bodies.



	Coir fabric lengths
Type 1	40 cm (16 in) and 71 cm (28 in)
Type 2	71 cm (28 in) and 142 cm (56 in)
Type 3	122 cm (48 in) and 190 cm (75 in)

Figure 5 Joining coir blocks.

Figure 6 Soil lift construction with coir block system.

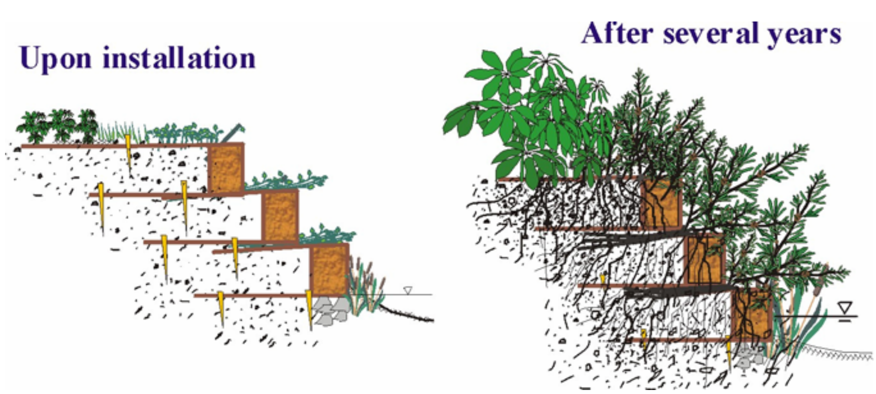


Figure 7 Conceptual diagram of coir block application.

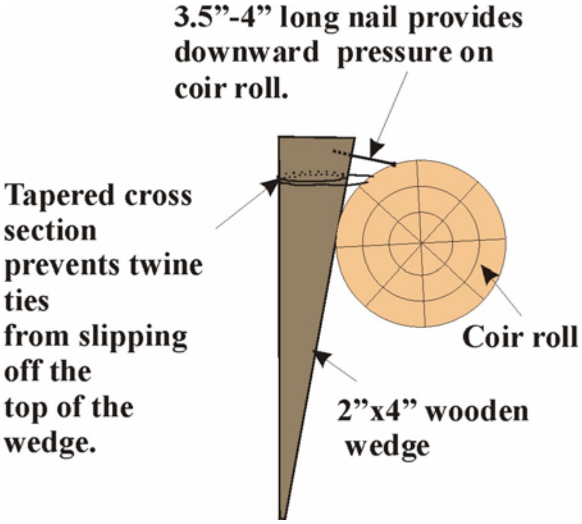


Figure 8 Installing coir logs with wedges.

Figure 9 Vegetated waterway construction with woven coir mats and coir wattles.

This problem can be solved easily by installing bristle coir woven blankets as channel liners and coir wattles as check dams (Figure 9). After a channel is graded to a desirable shape, it should be smooth and free of rocks. Spread a fresh mixture of suitable native seeds before covering them with the woven coir mat. The width of the blanket should be wide enough to cover the channel completely. Covering only the channel bottom invites failure, while wasting time and labor. In this case, water flowing from the sides of the channel during a rain event can destroy the channel and transport sediment away from the site. Once the blanket is placed in the channel, anchor it securely, starting from the bottom and working up on both sides. This will assure good contact between the blanket and the ground, which is required for proper performance.

Anchoring the blanket from the sides of the channel first and then working down to the bottom of the channel prevents good soil-blanket contact at the bottom of the channel. This will allow water to flow under the blanket, creating erosion and washing away the seed under the blanket. In addition to preventing establishment of vegetation, this problem can be extremely difficult to correct.

Using 23-cm (9-in) or 30-cm (12-in) diameter wattles as check dams at 3.05-m (10-ft) intervals can help keep the close contact between the blanket and the soil and slow the water flow. These wattles must be installed by placing wooden wedges with nails at the top on its downstream side and by inserting metal staples at the bottom on the upstream side of the wattle (Figure 10). This will prevent water from going under the wattle. At least some of the seeds should germinate within a week after planting. Once seedlings appear, a suitable fertilizer should be applied.

The extremely flexible coir wattles can be used in a variety of ways to control sediment during highway construction. These include protecting curbside inlets and reducing slope lengths. Because they can withstand the weight of construction equipment without becoming deformed, coir wattles can be especially effective as a sediment barrier in traffic areas. Also, these 100-percent biodegradable coir wattles can be used in place of standard silt fences and they can be left in place after construction is completed to degrade naturally. The wooden wedges will also biodegrade with time. This reduces removal, waste hauling and waste disposal costs.

Coir Mattresses

Coir mattresses are used mainly to establish vegetation on hard armor materials, such as wire gabions. A suitable coir mattress should be secured to a gabion using coir twine or metal wire. If the construction can be planned properly, these mattresses can be vegetated at nurseries and installed with suitable plants (Figure 11). In this case, irrigation will probably be required to assure successful establishment of these nursery-grown plants. Once the vegetation is properly installed on the mattresses, the plant roots will grow farther into the gabions filled with deposited sediment and will develop to a sustainable state.

Using soil bioengineering methods in highway construction can reduce damages to the environment during highway construction and create an aesthetically-pleasing environment near new highways. These methods also can be used to restore the deteriorated habitats along any highway. Furthermore, soil bioengineering applications in highway constructions not only improve habitat and aesthetics in surrounding areas but also reduce the amount of trash hauled from completed construction projects to landfills. This significantly reduces construction expenses.

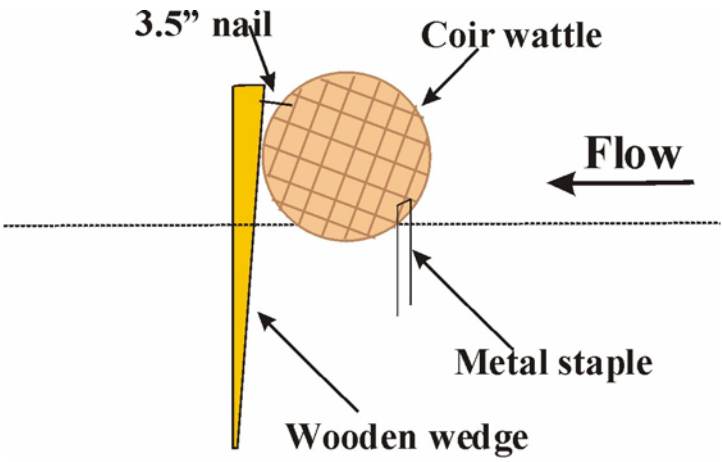


Figure 10 Installing coir wattles with wedges and staples.

Figure 11 Nursery-vegetated coir mattresses.

CONCLUTIONS

1. Soil bioengineering methods are essential for protecting and improving natural areas cleared for highway constructions.

2. A variety of coir products are available for successful soil bioengineered restoration on highway construction projects.

3. "Do it right the first time" is critical for environmental restorations since a failure means additional reconstruction costs and possible irreversible and extremely costly damage to nearby water resources.

4. Successful soil bioengineering projects hinge on a proper design with very specific installation instructions for each site, proper product selection and correct field installation.

5. Soil bioengineering applications in highway constructions not only improve habitat and aesthetics in surrounding areas but also reduce trash to haul from completed construction projects to land fills. This significantly reduces construction expenses.

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