Results
from a Study of
Earth Saver™ Rice Straw Fiber
Slope Interrupter Devices (SIDs):
Runoff Characteristics and Sediment Retention
Under Simulated Rainfall Conditions

Prepared for

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1.0 THE SAN DIEGO STATE UNIVERSITY
SOIL EROSION RESEARCH LABORATORY (SDSU/SERL)

The San Diego State University Soil Erosion Laboratory (SDSU/SERL) integrates beneficial features from some of the primary soil erosion research facilities in the United States. Funding for the facility was provided by Caltrans, the California State Department of Transportation as part of a 1998-2000 erosion control pilot study, in which design, construction and operation of the SERL was supervised by URS Greiner Woodward Clyde and SDSU faculty. Actual modification of Industrial Technology Building Room #103 and construction of the soil test bed was carried out by the SDSU Physical Plant.

In designing the SDSU laboratory, members of the Caltrans pilot study team studied the physical layout, testing protocols, and past research activities of the following erosion laboratories:

Utah Water Research Laboratory (UWRL) at Utah State University, Logan, Utah;

USDA-Agricultural Research Service National Soil Erosion Research Laboratory (NSERL) at Purdue University, West Lafayette, Indiana; and

Texas DOT/Texas Transportation Institute (TTI) Hydraulics and Erosion Control Laboratory at Texas A & M, College Station, Texas.

Aspects of the SDSU Soil Erosion Laboratory design that resulted from examination of these facilities include the following:

Table 1.1

Design Features of Soil Erosion Laboratories

Design Feature	Erosion Facility
Norton Ladder Rainfall Simulator	NSERL
Hydraulically-lifted soil bed	UWRL
12-inch soil depth placed on porous, open-grid system for drainage	UWRL, NSERL
Suction chamber to speed up drying of soil between runs	UWRL
Procedures for collection of runoff and sediment samples	UWRL, NSERL, TTI
Confirmation of test plot size	UWRL, NSERL
Number of replicates for each test	UWRL, NSERL

These and other important design features of the SDSU Laboratory are described below:

1.1 Norton Ladder Rainfall Simulator

The rainfall simulation device selected for the SDSU Soil Erosion Laboratory is the Norton Ladder Rainfall Simulator, which was developed at the USDA-ARS National Soil Erosion Research Laboratory by Dr. Darrell Norton. This apparatus has been used worldwide, is reasonably inexpensive, and is easily transported and operated. The Norton simulator is reliable and is documented as giving reproducible results.

For testing in the indoor laboratory, multiple simulators (4) have been installed in parallel above the soil test bed to uniformly apply precipitation over the entire test plot area. The pre-fabricated rainfall devices were purchased from Advanced Design & Machine (Clarks Hill, Indiana), an experienced manufacturer specializing in production of the Norton simulator.

<u>Physical Characteristics</u>

The basic unit of the simulator is an aluminum frame 5.3 meters long, 0.32 meters wide, and 0.25 meters deep. Each frame is a self-contained unit that includes nozzles, oscillating mechanism, drive motor, pump, float valve, piping, and sump.

The drop former used for the Norton simulator is the Spraying Systems Veejet 80100 nozzle, and the nozzles are spaced 1.1 meters apart. For uniform intensity across the plot, the center of spray patterns from two laterally adjacent nozzles meet at the plot surface. This gives a 2.25 mm median drop size, a nozzle exit velocity of 6.8 m/s, and a spherical drop.

The impact velocities of almost all drops from the Veejet nozzle are nearly equal to the impact velocities of those from natural rain storms when the nozzle is at least 2.4 meters above the soil surface. For this reason, the rainfall simulators used in the SDSU Soil Erosion Laboratory have been installed such that the nozzles are a minimum of 2.5 meters above the soil surface. Rainfall intensity can be changed instantaneously with the simulator in operation, and the maximum intensity produced is 135 mm/hr.

<u>Design of Simulated Rainfall</u>

Prior to testing, the Norton ladder-type simulators are placed into position above the soil test bed. Calibration is achieved by conducting rainfall tests and measuring rainfall volumes in collection devices placed at precise intervals within the 2 meter x 8 meter test plot. A full range of rainfall intensities can be achieved by adjusting either one, or both of the following parameters:

- The number of sweeps per minute (spm) of the spray nozzles, ranging from 25 to 125 spm
- Adjusting the water pressure within the supply system. Each simulator has a system of valves that allow internal water pressure to be adjusted from a low of 2 psi to a high of 6 psi. Gauges atop each simulator allow for accurate, manual adjustment.

Simulated rainstorm events utilized for most of the current testing at the SDSU/SERL have an initial period (Part 1) of low intensity rainfall, followed by a period (Part 2) of relatively high intensity rainfall, and ending with a period (Part 3) of relatively low intensity rainfall.

1.2 Soil Test Bed

The soil test bed is a 3-meter wide by 10-meter long (323 square feet) metal frame which rests on a series of pivots located at the lower end of the bed, and is supported by two hydraulic cylinders near the upper end of the bed. These telescopic cylinders extend to tilt the test bed from its horizontal position to a maximum 1V:2H slope gradient.

The test bed is designed to support a 30.5-cm (1-foot) depth of soil. The depth of 30.5 cm is sufficient to allow placement and compaction of soil and the application of the various surface erosion control practices to evaluate their effect on erosion rates.

The sides and ends of the soil test bed are constructed of steel frame-supported 1.0-cm thick Plexiglas which allows ambient light onto the soil surface, and facilitates viewing of the effects of rainfall impact and runoff. The total usable surface area of the soil bed is 3 meters wide by 10 meters long, but during testing only a portion of the treated bed, 2 meters wide by 8 meters long, is generally delineated for evaluation by the use of plastic edging. Runoff and sediment are collected at the toe of the slope by a flume.

Drainage grates have been installed in the floor underneath and at the front of the soil bed, and all runoff not collected is directed to a sanitary sewer. As a safety precaution, stationary steel support posts are placed beneath the bed when it is raised for rainfall simulations.

1.3 Hydraulic System

The soil test bed has been designed to be lifted hydraulically to the desired slope inclination for testing. Two 5-stage, single-acting, telescopic cylinders are positioned approximately 3.0 meters (10 feet) from the top of test bed. The cylinders, which weigh 505 lbs a piece, have a 20.3-cm (8-inch) diameter as the largest moving stage.

The complete hydraulic system consists of the cylinders, a 60 gallon hydraulic fluid reservoir, a 30 gallon per minute hydraulic pump, and a 50 horsepower electric motor with motor starter. Also included are a suction strainer, return oil filter, pressure relief valve, and a directional control valve.

1.4 Sediment Collection System

Water and soil runoff from the test bed is collected by plastic edging, flume, and collection containers. The components of the sediment collection system on the test bed are installed prior to each rainfall simulation. For most erosion control treatment evaluations, the plastic edging is installed prior to application of the erosion control treatment.

1.5 Water Treatment and Storage

In order to obtain accurate results from the rainfall simulation/erosion rate evaluations, the municipal water supply is treated by reverse osmosis and softened to remove minerals. This treatment process produces "softer" water that is more similar in quality to natural rainfall. Using municipal water without treatment would cause a decrease in sediment load, because minerals in the water serve to decrease erosion.

<u>Water Treatment System</u>

The water treatment system consists of a reverse osmosis unit, preceded by one activated carbon vessel and two softening vessels arranged in series (i.e. carbon/softener/softener). The system, which is capable of producing 300-600 gallons per day (1,140-2,270 liters per day), also includes a pre-filter to remove particulates greater than 5 microns in size that may escape the service vessels. The system is serviced monthly by U.S. Filter.

Delivery of water to the rainfall simulators positioned above the soil test bed is by a pump attached to hard plumbing and flexible hoses. A key aspect of the Norton design is that unused water from within the simulators is returned to the holding tank and available for reuse. Flexible plumbing is installed to accommodate this return flow.

<u>Treated Water Storage</u>

Treated water is stored in a 1,000 gallon (3,785 liter) polyethylene storage tank for use in the laboratory simulations. For outdoor test plots, two 200 gallon (757 liter) tanks are truck or trailer-mounted to deliver treated water to the field for rainfall simulations.

2.0 EARTH SAVER™ STRAW FIBER SLOPE INTERRUPTER DEVICES (SIDs) STUDY

2.1 Introduction

Slope interruption devices (SIDs) are typically constructed of vegetable fibers surrounded by netting, such that a “tube” configuration results. SIDs are normally installed along the contour or at the base of slopes to reduce runoff velocities and to retain sediment reducing the offsite impacts of soil erosion and sedimentation. SIDs are typically used in concert with one or more surface soil stabilization treatments, such as temporary/permanent seeding, hydraulic mulching/seeding and/or rolled erosion control product (RECP) installations. Although the qualitative value of these devices has been demonstrated in numerous field applications throughout California and the western United States, the purpose of the SDSU Soil Erosion Research Laboratory study was to quantify the benefits SIDs provide reducing soil loss and runoff under rigorous, replicate scientific testing.

For the purposes of this study, a standard-configured slope interrupter device composed of straw fiber was placed at the toe of the soil test bed at the SDSU Soil Erosion Research Laboratory (SERL). The surface of the soil immediately upslope from the SIDs was subjected to the erosive forces of a standard 10-year storm event for the Los Angeles, CA basin. Runoff and sediment discharge was collected below the straw fiber SIDs and compared against values obtained for an untreated bare soil, or “control” condition. By comparing the differences in runoff and sediment production between the two test conditions, differential performance and/or effectiveness of the slope interrupter device in reducing off-site sediment impacts can be quantified.

2.2 Study Objectives

There were three (3) main objectives for the SIDs study:

1) To provide scientific, reproducible and defensible data on the effectiveness of slope interrupter devices to reduce runoff and control erosion.
2) To relate these tests to previous evaluations of erosion control materials and methods under similar test conditions.
3) To present the results of the testing in a format useful to field engineers in the design and specification of slope interrupter practices on steep slopes.

2.3 Test Procedures

The test procedures followed for the slope interrupter device (SIDs) study were adapted from portions of the testing protocols developed for the Slope Stabilization for Temporary Slopes study (Caltrans, October 1999) and the Caltrans Erosion Control Pilot Study (June 2000).

Test Conditions

- The soil used was classified as a clayey sand (SC)
- The test area was 2 meters wide x 8 meter in length
- The storm event was a 10-year storm as predicted for the Los Angeles Basin (5 mm for 30 minutes/40 mm for 40 minutes/5 mm for 30 minutes)
- The slope was 1V:3H
- Three replications for the bare soil (control) and three replications for the straw SID treated condition were performed, yielding a total of six (6) tests.

Bed Preparation

- Prior to each test, soil in the bed was removed to a depth of 3-4" and replaced with new, untested soil.
- The new soil was moisturized, tilled and hand-compacted to uniform consistency.
- Sand cone tests were conducted over random portions of the prepared bed to determine relative compaction and moisture content of the soil
- Edging and flumes were installed to differentiate a 2m x 8m plot.
- Prior to all testing, the surface of the compacted soil was loosely raked.
- Prior to the testing of the slope interrupter device, one of the devices was installed (following manufacturer's recommendation) in a trench excavated at the lip of the collection flume.
- The test bed was raised to a 1V:3H slope prior to rainfall.

Rainfall event

- Rainfall consisted of a 10-year storm event as modeled from Los Angeles Basin hydrologic data, consistent with those values of the Caltrans SSTS Study (October 1999) and the Caltrans ECPS Study (June 2000).
- The intensity and duration of the storm were as follows:
    - Period 1: 5 millimeters per hour of rain for 30 minutes
    - Period 2: 40 millimeters per hour of rain for 40 minutes
    - Period 3: 5 millimeters per hour of rain for 30 minutes
- Settings on the rainfall simulators to achieve these intensities were based on previous calibrations conducted at the laboratory.

Sample Collection and Analysis

- Water and sediment were collected at the downstream (toe) end of the flume in polyethylene lined, 35 gallon containers.

- At the end of each rainfall event, 500 grams of gypsum was added to each collection barrel to aid in settling out the fine sediments.
- The samples were allowed to settle overnight (24 hours)
- The supernatant, or clear water, was siphoned from each container, and its weight and volume recorded.
- The weight of the remaining wet sediment was recorded.
- A sample of the remaining wet sediment was taken and placed in an oven overnight to determine moisture content of the wet sediment.
- The moisture content of the wet sediment sample was used to determine the total dry sediment weight of the collected sediment.

3.0 RESULTS

Tables 3.1 and 3.2 show the results of the laboratory analysis of sediment weight and runoff volumes for each of two test conditions:

- Table 3.1 presents the sediment and runoff yield on the bare soil (control)
- Table 3.2 presents the sediment and runoff yield on the straw slope interrupter device

The data illustrate that the use of the SIDs at the toe of the test slope somewhat reduced runoff when compared to the untreated soil condition, but dramatically reduced downslope sediment delivery: The straw SID reduced runoff by an average of 11% over the bare soil control, while sediment yield was reduced by 58%.

Table 3.1
Sediment and Runoff Yield on Bare Soil (Control)

Bare soil	Rep#1		Rep#2		Rep #3		Ave.	
Period	Sed.(Kg) Wt.	Runoff(L)	Sed. Wt.	Runoff(L)	Sed. Wt.	Runoff(L)	Sed. Wt.	Runoff(L)
1	3.95	33.12	1.83	30.83	1.20	29.16	2.33	31.04
2	36.38	368.32	45.12	372.79	37.45	401.30	39.65	380.80
3	2.47	69.45	3.67	71.85	3.13	71.97	3.09	71.09
total	42.8	470.89	50.62	475.47	41.78	502.43	**45.07**	**482.93**

Table 3.2
Sediment and Runoff Yield on Straw SID Test

Straw-SID	Rep#1		Rep#2		Rep #3		Ave.	
Period	Sed.(Kg) Wt.	Runoff(L)	Sed. Wt.	Runoff(L)	Sed. Wt.	Runoff(L)	Sed. Wt.	Runoff(L)
1	0.13	19.60	0	5.68	0.13	15.14	0.09	13.47
2	30.00	383.23	10.27	306.94	17.34	326.65	19.20	338.94
3	1.12	76.90	0.53	70.71	1.18	64.92	0.94	70.84
total	31.25	479.73	10.8	383.33	18.65	406.71	**20.23**	**423.26**

Figures 3.1 and Figure 3.2 provide relative comparisons of sediment weights and runoff volumes for each slope condition.

Figure 3.1
Comparison of Relative Sediment Weight

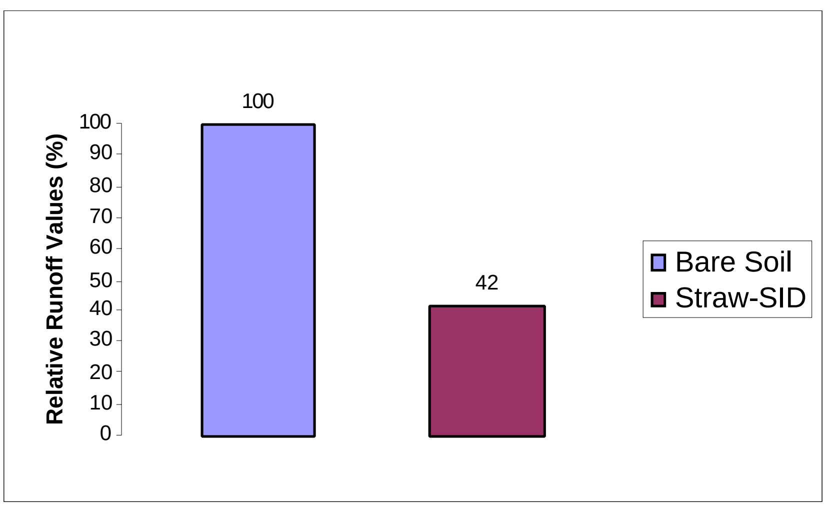


Figure 3.2
Comparison of Relative Runoff Volumes

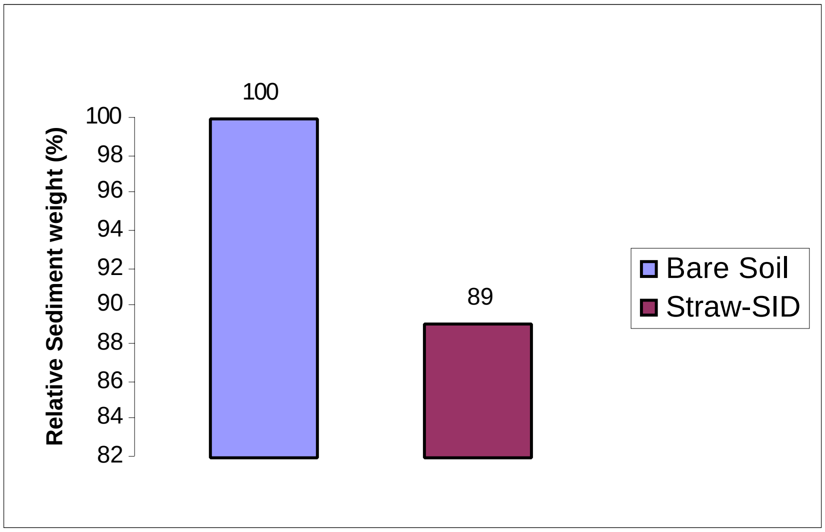


Figure 3.3 and 3.4 illustrate the cumulative runoff volume and sediment weight at 10- minute intervals throughout the testing period.

Figure 3.3
Sediment Delivery of Earth Saver SIDs Over Time

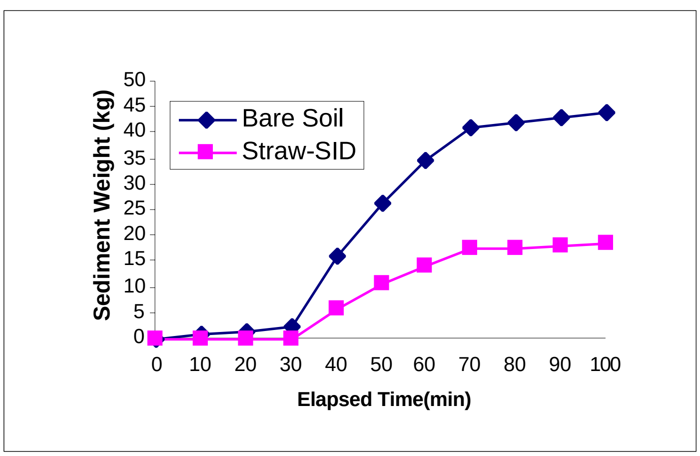
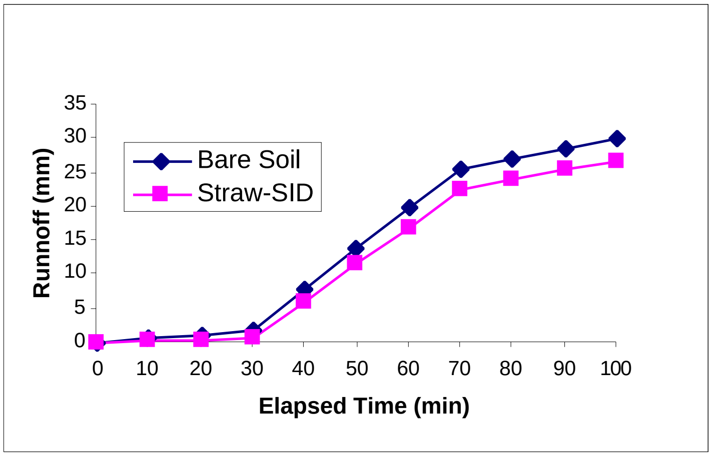


Figure 3.4
Runoff of Earth Saver SIDs Over Time



4.0 CONCLUSIONS

The data from this series of tests appear to support the use of Earth Saver™ Straw fiber slope interrupter devices (SIDs) to reduce runoff and off-site delivery of sediment from steep slopes. A modest reduction in runoff water volumes – 11% - illustrates that one of the beneficial functions of SIDs is to slow runoff water velocities and retain a certain amount of water within their fibrous core. Figures 3.3 and 3.4 seem to support a conclusion that once saturated, the SIDs release water at a steady rate. This is important because with some soils, total absorption of runoff water would not appear to be beneficial for slope stability or establishment of vegetation.

The data also illustrate that the SIDs, as tested, reduced off-site sediment delivery by a significant amount – 58% for the straw SID. Figures 3.3 and 3.4 demonstrate that in the middle and most intense portion of the 10-year storm event, sediment delivery, like runoff water, reached an almost constant rate.

Finally, previous testing at the SDSU Soil Erosion Research Laboratory has demonstrated the effectiveness of various surface treatments – such as hydraulically-applied soil binders, bonded fiber matrices and rolled erosion control products - to control soil erosion. Recent tests have also shown that changes in the surface roughness of a soil – such as trackwalking, sheepsfoot rolling or imprinting - can also have a dramatic impact in reducing soil erosion. It is therefore reasonable to conclude that these temporary surface treatments when used in combination with slope interrupter devices can provide a highly effective means of soil erosion control.