CHAPTER 118

DUNE STABILIZATION WITH A SAND/GEL COMPOSITE SYSTEM

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ABSTRACT

The effectiveness of a novel sand/gel composite system for the temporary stabilization of coastal dunes was demonstrated in wavetank and field testing. The composite consists of 97% beach sand and water, with a few percent of a biodegradable aqueous polymeric gel made from non-toxic ingredients. The gel binds the sand into a firm but resilient composite that is natural in appearance and resists erosion from waves and tides. The composite is applied by pneumatic gun to the front face of a dune to a few feet below the berm level for toe protection.

This paper describes the initial development and performance of the composite system in wavetank tests at the Oregon State University Wave Research Facility and field trials at Anastasia State Park, St. Augustine, Florida; Chuck's Steak House, Melbourne Beach, Florida; and Ocean Dunes Condominiums, Fort Fisher, North Carolina.

INTRODUCTION

Storm and tidal erosion threatens thousands of miles of shoreline and associated coastal property in the US and throughout the world. Current stabilization methods include permanent armoring, such as concrete seawalls, rock revetments, groins and jetties, and temporary measures such as sand-filled bags and replenishment with dredged sand. Several states in the US have prohibited hard erosion control structures. The cost-effectiveness and environmental consequences of these approaches remain uncertain.

The Chemical Division of Pfizer Inc. has produced water-soluble polysaccharide thickeners and gelants for numerous applications in the oilfield and other industries

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for over ten years. The adaptation of this technology for coastal erosion control was investigated.

EXPERIMENTAL PROGRAM

Laboratory Testing

A wide range of gel/sand compositions was evaluated in the laboratory using a water impact test device. Successful compositions, based on a weight loss/hour limit under continual water impact, had unconfined compression strength values of 3000 - 30,000 lb/ft^2.

Environmental Exposure

The leading composition candidates were prepared in a small cement mixer, cast in 1 ft^3 wooden pans and anchored in the sand at a 45^o angle on the eastern bank of the mouth of the Thames River in Groton, Connecticut. Although not subject to appreciable wave impact at this Long Island Sound location, the pans were totally submerged twice a day at high tide. Successful compositions endured intact for over seven months with only minor gouges from driftwood impacts, until the pans were uprooted in a storm.

Emplacement Testing

Pilot sand drum tests showed that ungelled polymer solution sprayed onto the sand surface did not penetrate significantly. Shank-injected ungelled polymer solution did not permeate the sand but left gel-filled voids. Large batch mixing of sand with ungelled polymer solution in a cement mixer and shoveling onto a dune was not possible because of rapid polymer gelation kinetics. Accordingly, the pneumatic gun approach, where sand and polymer gel component solutions are comixed with large amounts of air and sprayed onto the dune, was attempted.

Gun Trials

Five trials were conducted from 1985-87 with commercial gunite equipment at sand feed rates of 120-200 lb/min (1.6-2.7 ft^3/min composite) to test various spray nozzle designs, equipment configurations, and component combinations. Numerous beach pans were sprayed full and evaluated for pregel slump and drying rate. Several of these composite panels were placed on the Groton beach for confirmation of environmental endurance. These panels also remained intact without erosion for the several month exposure period.

OSU WAVETANK TRIALS

To evaluate the full-scale strength and erosion resistance of the composites under controlled conditions, tests were conducted at Oregon State University's Wave Research Facility in May, 1986. The 12-ft wide x 18-ft deep x 350-ft long tank has a computer-controlled hydraulically-driven wave generator.

Dune Preparation

A 1:12 sloping berm was prepared with movable concrete slabs covered with sand in the bottom of the tank. The berm was seasoned with gentle waves and three 8-ft dunes were constructed about 20 feet apart with a 1:1 sloping surface at the end of the tank with local sand. A thin non-woven geotextile was placed over the front surface of each dune to keep the sand base from blowing away during spraying and from washing out if the composite should crack during wave testing. The composites were emplaced with a pneumatic gun onto this filter fabric at a rate of 2.0-2.7 ft^3/min.

Each composite was about 2-ft thick at the bottom, 1-ft thick at the top, and 7 feet high (Figure 1). Different compositions and feed configurations were used for each dune. As the weather in Corvallis in May was cool and damp, a wooden frame and plastic tent were erected over the dune end of the wavetank and kerosene heaters were placed inside to speed composite drying. Colored horizontal stripes were painted on the composite surfaces to measure runup, and a swash gauge was built in the tank to measure wave velocity.

Wave Testing

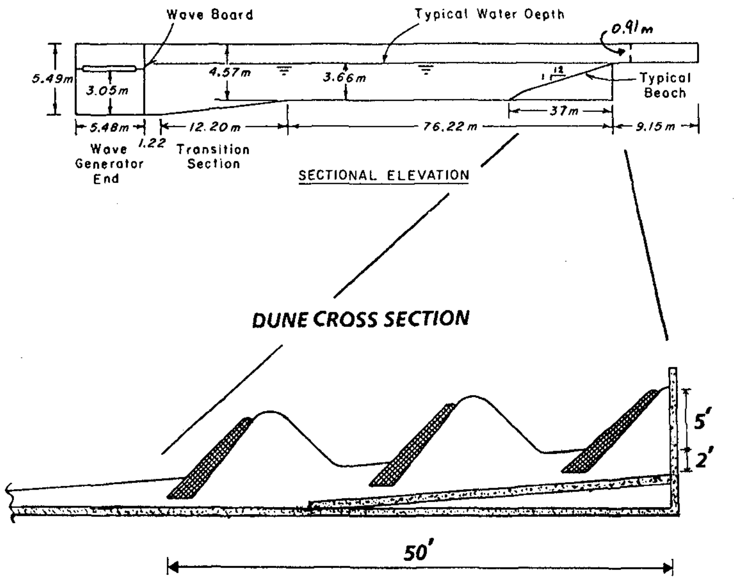

Figure 1. OREGON STATE UNIVERSITY WAVE RESEARCH FACILITY

The tank was filled with water to the base of the front dune. Monochromatic and Bretschneider spectrum random waves were generated with 7-11 ft/sec velocity, 1-11 second period, and 2-5 foot height (Figure 2). Conditions were controllable to allow berm sand to erode away from the dune face or accrete against it. They were chosen so that sand and gravel were thrown against the composite for lengthy periods to exacerbate erosion. The water level was adjusted so that the bores ran up to the top of the composite without constantly overtopping the dunes. In many cases, the waves broke just in front of the dune so that the swash generated was almost entirely dissipated on the dune itself. These conditions simulated average US East Coast annual storms, and likely represented a more severe 2-3 year event.

One dune was tested each day. Each dune was exposed to wave impacts for 4-6.5 hours. Aside from minor sloughing of a crusty skin from one of the composites and loss of a chunk from another because of a gunning defect, there was no appreciable erosion of the composites during testing (Figure 3).

At the end of the first dune test, a 1-ft hole was dug in the center of the composite with a shovel and wave

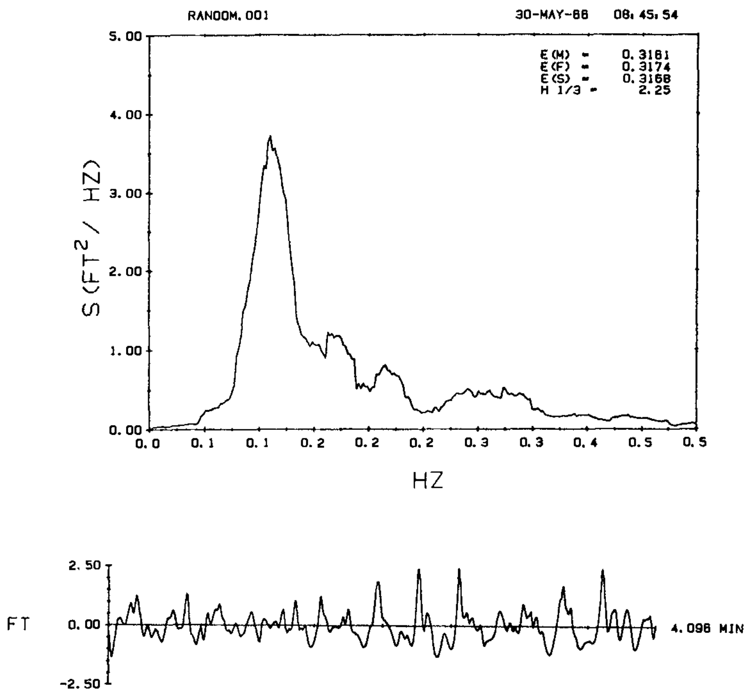

Figure 2. OSU BRETSCHNEIDER WAVE SPECTRUM

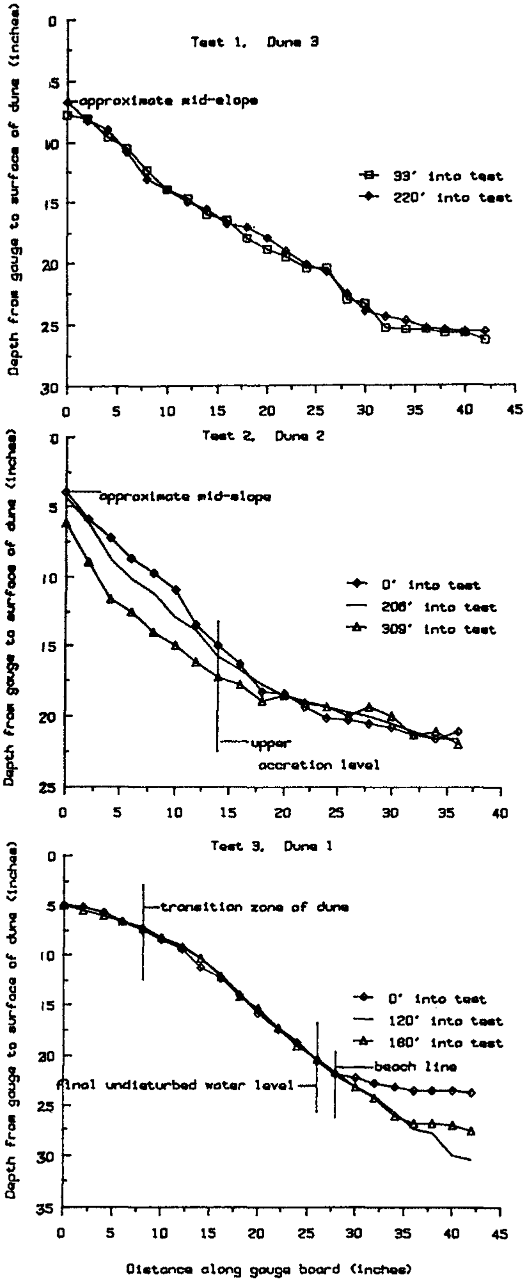

Figure 3. OSU Wavetank Tests
Surface Profiles of Test Dunes
Measured 2-ft from Right Side of Dune

uprush pumped water into the hole. With the exposed geotextile intact, no sand was lost from the dune base and the composite hole was not widened by additional wave impacts. After wave tests on the second dune were completed, a hole was dug in the composite and the geotextile was cut open. Additional waves for a half hour created a 2-ft diameter cavity in the dune base underneath without breaking the composite.

After each day's testing was completed, the intact dune was removed from the tank with a clamshell and the berm repaired for the next test. After all three composites were tested and removed, a fourth dune was built in the tank with untreated sand as a control. Full amplitude 8-second waves (~ 3-ft height) obliterated 80% of this dune within seven minutes, leaving a vertical escarpment.

SHORELINE FIELD TRIALS

Three field tests of the sand/gel composite system have been initiated to date. These are summarized in Table 1 and described below.

Florida Field Trial I - Anastasia

Permitting: Permission was granted by the Florida Department of Natural Resources, Division of Recreation and Parks, in November, 1986, for a field test at the south end of Anastasia State Recreation Area in St. Augustine. As the east coast of Florida is a prime nesting area for endangered marine turtles, the US Department of Interior Fish and Wildlife Service was also consulted about the test. No turtle nests had been observed at the south end of the park in several years, so no turtle monitoring was required. The USDI FWS also advised that the Anastasia Island beach mouse (*Peromyscus polionotus phasma*) was not listed as an endangered species but was a candidate for listing. *P. p. phasma*, a subspecies of the common beach mouse and closely related to the Santa Rosa Island, Perdido Key, Choctawhatchee, and Alabama beach mice, lives among vegetation behind the dune face (USDI FWS, 1986) and would not be affected by the test.

Emplacement: The composite was designed to extend several feet below the berm to provide toe protection and prevent it from being undercut during a storm that might lower beach elevation by several feet. A trench 3 feet deep was excavated in front of 90 feet of eroded dune just south of the beach access ramp. The dune surface was dressed to a 1:1 slope to the bottom of the trench and geotextile was unrolled along the dune face. Beach-compatible sand was imported from a local pit to build a 200-ft control dune south of the test section (sieve analyses in Table 2). The 90-ft test dune was gunned with composite in two configurations (Figure 4) using beach sand from the toe trench. After spraying was completed, a heated tent was erected over the composite to expedite

Table 1: SAND/GEL COMPOSITE FIELD TRIALS

Site	Anastasia State Park	Chuck's Steak House	Ocean Dunes Condos
Location	St. Augustine, FL	Melbourne Beach, FL	Fort Fisher, NC
Empl. Date	December 1986	April 1988	May 1988
Elevation			
Crest	+ 12.0 NGVD*	+ 17.0 NGVD	+ 17.0 NGVD
Toe	+ 5.0 NGVD	+ 8.0 NGVD	+ 8.0 NGVD
Height	7 feet	9 feet	9 feet
Length	90 feet	170 feet	100 ft 100 ft
Slope	1:1	1:1	1:1 1:1.5
Thickness			
Crest	12 inches	15 inches	16" 12"
Toe	24 inches	18 inches	22" 18"
Ft^3/lin-ft	15.0	18.0	20.5 21.0
Spray Rate	1.8-2.4 ft^3/min	1.7-4.5 ft^3/min	2.6-5.4 ft^3/min
Profile Monitoring (Number Profiles - Total Feet)			
N Control	5 - 75	5 - 180	4 - 300
Composite	6 - 90	5 - 170	6 - 200
S Control	5 - 75	6 - 250	8 - 700
Other Monitoring	Storms	Storms Vegetation Sea Turtles Waves/Tides	Storms Vegetation

* National Geodetic Vertical Datum

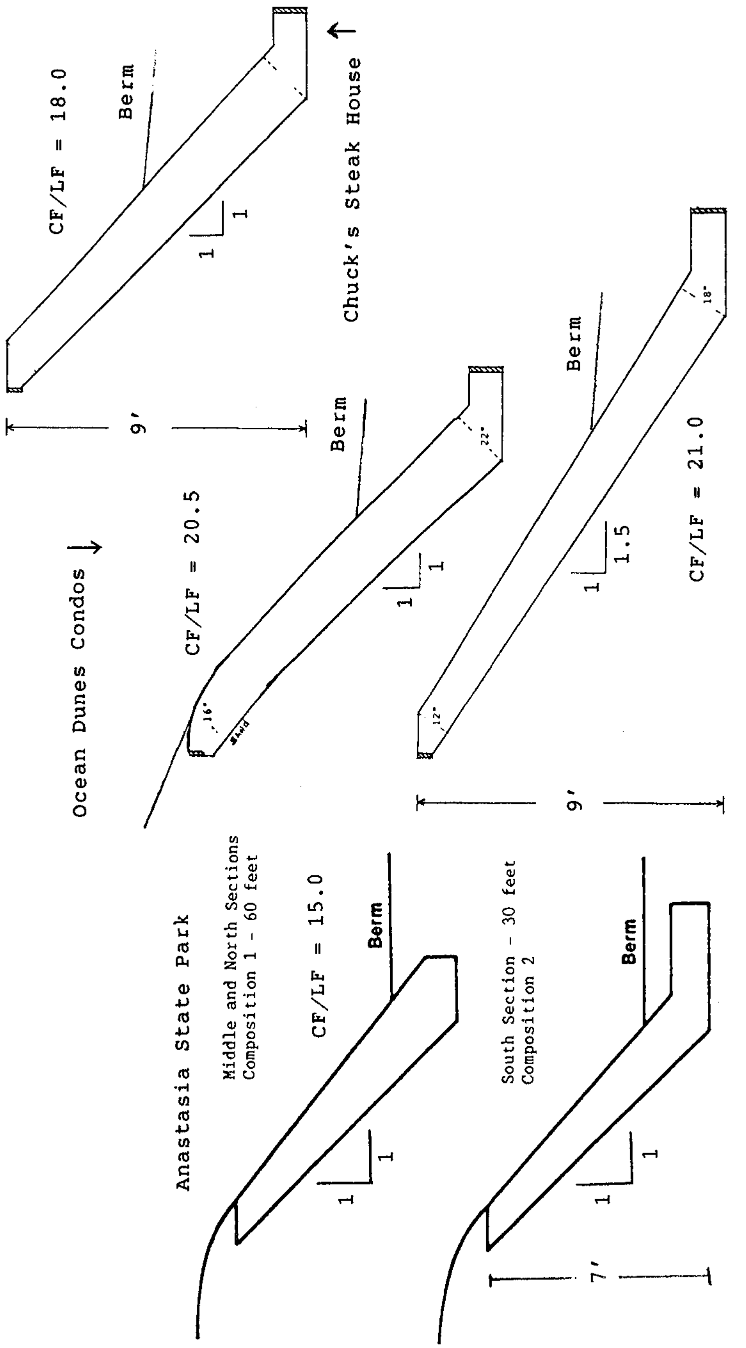

Figure 4. Sand/Gel Composite Cross-Sections

drying, a precaution taken because of the cool, damp weather and possibility of storms in northeast Florida in December. The tent was removed after a week of drying and the side flanks were covered with sand and the berm in front of the composite was replaced.

Table 2: Anastasia Sand Analyses

Sand	% H_2O	% Retained on - Mesh 40	60	80	100	200	Pass 200
Beach	9.4	0.0	5.0	61.6	24.4	8.8	0.24
Imported	9.6	0.0	5.5	53.6	29.6	11.0	0.30

Monitoring: The test area was videotaped before, during, and after the emplacement. Survey monuments were installed atop the test and control dunes and 16 profile measurements were made from the dune top to mean sea level at monthly intervals at the positions shown in Figure 5. Analysis of the data from the first 15 months of profile measurements indicate there was no significant difference in sand erosion or accretion rate in front of the composite vs. in front of the adjacent control dunes (Table 3).

Storm Exposure: A major northeaster hit the test area on January 5, 1987, two weeks after the emplacement was completed. The storm surge was not recorded at the Mayport tide gauge 60 miles north, but wave uprush was observed running up to the top of the composite by Park Rangers. This was confirmed by a storm hindcast performed by the Institute for Storm Research, Houston, TX. Beach elevation was lowered 1.5-2 feet and 2-5 foot escarpments were created in the adjacent control dunes, while the composite remained intact. No other storms have impacted the composite. The escarpments on both sides have since filled in with accreted sand. Selected dune profiles are shown in Figure 6.

Vegetation: In April, 1987, 600 sea oat seedlings (*Uniola paniculata*) were planted above and alongside the compoite by children volunteers from the St. Johns County 4-H Club with guidance from the US Department of Agriculture Soil Conservation Service. The plants were watered several times by the St. Augustine Beach Volunteer Fire Department. The seedlings atop the composite were trampled later by park patrons (see below), while those on the adjacent control dunes with less traffic are lush and vigorous. Voluntary railroad vine (beach morningglory, *Ipomoea pes-caprae*) from behind the dune have grown over the top of the composite down to the berm, with new roots penetrating the composite in several places. New plants also appeared in the rebuilt control dunes and in the berm in front of the composite. Ghost crab burrows were occasionally seen in the base of the composite.

Foot Traffic/Vandalism: The only noticeable damage to the composite has been the result of frequent foot traffic and occasional vandalism by park patrons. Some shovel

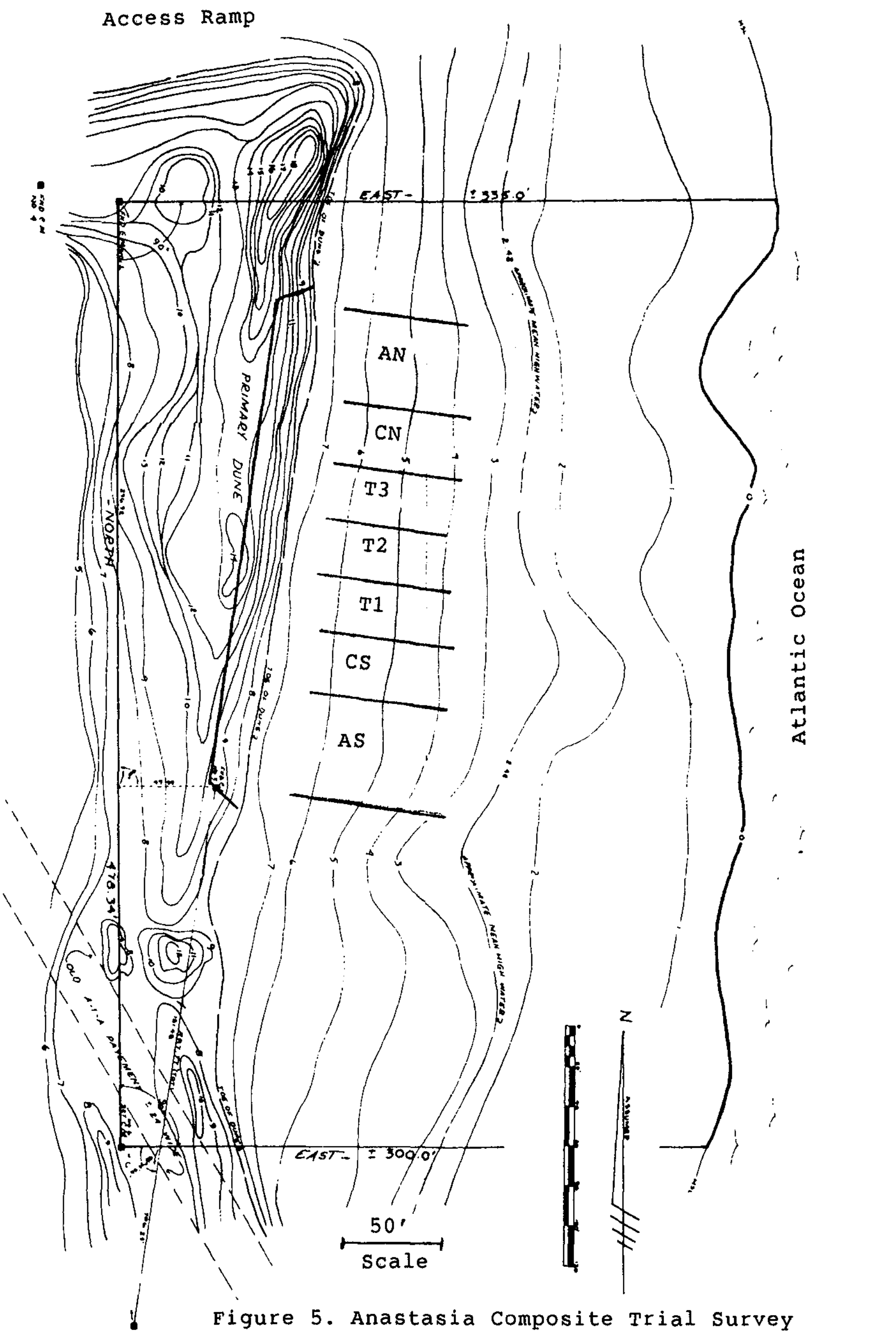

Figure 5. Anastasia Composite Trial Survey

Table 3: Anastasia Trial Beach Profile Analysis

LEGEND

Section (Total 240 ft)	
AS: South Adjacent Dune	45 ft
CS: South Control Dune	30 ft
T1: South Test Section	30 ft
T2: Middle Test Section	30 ft
T3: North Test Section	30 ft
CN: North Control Dune	30 ft
AN: North Adjacent Dune	45 ft

Period (Total 466 days)		
1:	12/29/86 - 1/8/87;	10 days
2:	1/8/87 - 2/23/87;	46 days
3:	2/23/87 - 3/25/87;	30 days
4:	3/25/87 - 6/1/87;	68 days
5:	6/1/87 - 6/29/87;	28 days
6:	6/29/87 - 8/3/87;	35 days
7:	8/3/87 - 8/25/87;	22 days
8:	8/25/87 - 9/16/87;	22 days
9:	9/16/87 - 10/26/87;	40 days
10:	10/26/87 - 12/1/87;	36 days
11:	12/1/87 - 1/27/88;	57 days
12:	1/27/88 - 3/1/88;	34 days
13:	3/1/88 - 4/8/88;	38 days

RESULTS

Sec/	Unit Volume Change Cu-Yd/Lin-ft (+: accretion; -: erosion)										
Per	AS	CS	T1	T2	T3	CN	AN	Avg/ft	Cum Av	Tot Cu-Yd	Cum Cu-Yd
1	-4.4	-4.9	-5.0	-4.7	-4.8	-4.3	-3.4	-4.42	-4.42	-1060	-1060
2	1.5	1.6	1.8	1.9	2.1	1.7	1.5	1.69	-2.73	405	- 656
3	-2.1	-2.2	-2.2	-2.5	-2.8	-2.9	-2.6	-2.45	-5.18	- 589	-1244
4	6.1	6.1	6.1	6.8	7.3	7.2	7.0	6.63	1.45	1592	348
5	6.8	6.9	7.3	7.0	6.4	6.0	5.7	6.56	8.01	1575	1923
6	-2.6	-2.2	-2.0	-1.5	-1.0	-0.4	1.0	-1.18	6.84	- 283	1640
7	0.6	0.8	1.5	1.0	1.7	3.0	2.7	1.61	8.45	387	2027
8	0.3	-0.1	-1.3	-2.3	-2.9	-3.6	-4.5	-2.06	6.38	- 495	1532
9	-3.1	-3.8	-4.0	-3.5	-3.7	-3.3	-2.7	-3.36	3.03	- 805	727
10	-8.4	-8.2	-8.1	-8.4	-8.3	-8.7	-9.1	-8.48	-5.45	-2034	-1307
11	3.7	3.9	3.8	1.4	1.7	2.2	4.3	3.12	-2.33	748	- 559
12	4.3	3.7	2.9	3.5	4.1	4.9	3.6	3.88	1.55	931	372
13	3.5	1.7	1.2	2.1	1.5	0.6	-0.4	1.47	3.02	352	724
Total	6.4	3.3	1.9	0.8	1.5	2.3	3.0	3.02		724	

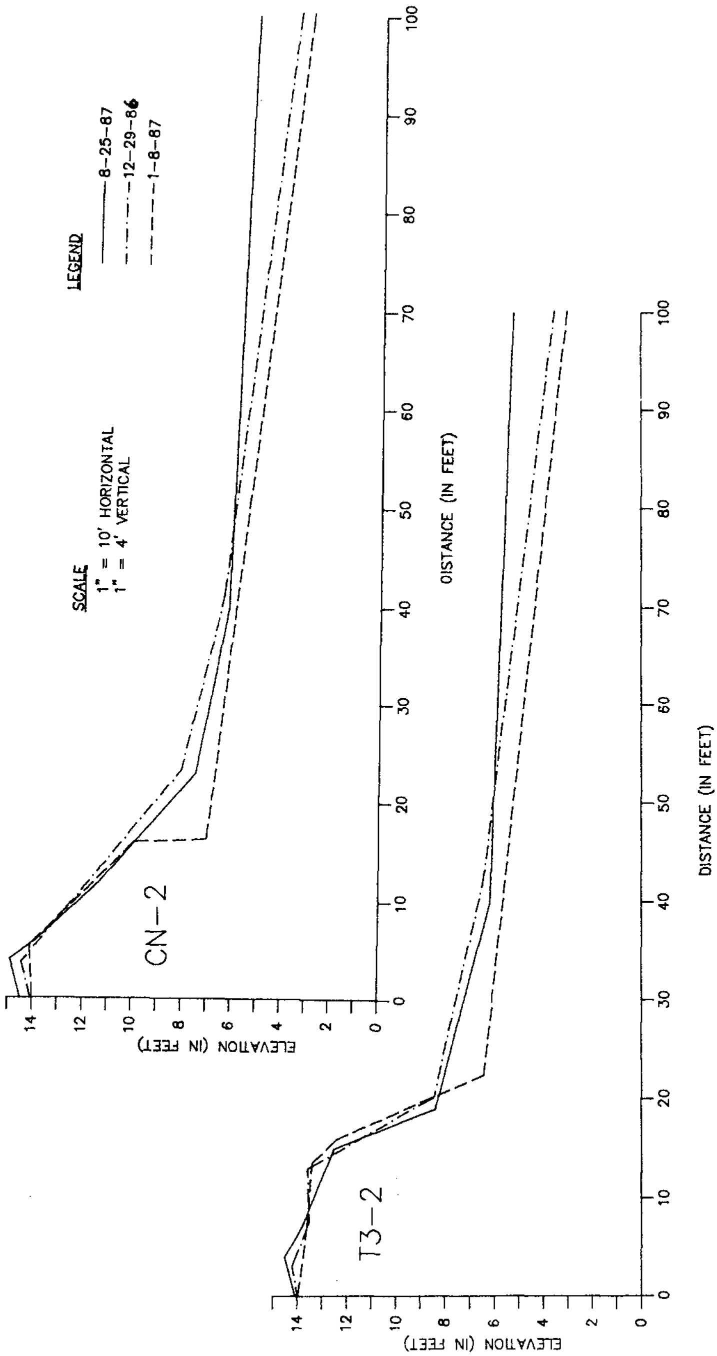

Figure 6. Anastasia Trial Dune Profiles

cuts and graffiti were gouged in the face of the test material and several distinct sets of toeholds were dug in the middle of the composite by climbers. The north control dune was also worn down by heavy foot traffic. The south third of the test section, which was prepared with a somewhat different gel composition, appeared to have softened in the heavy summer 1987 rains, and was broken through to the geotextile by repeated foot traffic.

The damage was repaired in September, 1987, and again in June, 1988. The toeholds and gouges were patched with small batches of fresh composite hand-mixed in a bucket. The patches have remained intact in the composite surface.

Florida Field Trial II - Chuck's

Because of a lack of turtle nesting at Anastasia, a site was chosen for a field trial adjacent to Chuck's Steak House, a restaurant in south Brevard County. This is located in the densest loggerhead and green turtle nesting area of the Western Hemisphere, with plentiful historical data on nesting activity (Ehrhart, 1986a, 1986b, 1987).

Permitting: Permits were applied for and received from the Brevard County Office of Natural Resources Management; the Florida Department of Environmental Regulation; the Florida Department of Natural Resources, Division of Beaches and Shores; and the US Army Corps of Engineers. Comprehensive site surveys, work plans, environmental impact statements, and dune profile, vegetation, and turtle nesting monitoring plans were required for permit approval.

Emplacement: The composite was emplaced in April, 1988, along 170 feet of dune surface in a similar manner to that used at Anastasia. Further details are given in Table 1 and Figure 4. The composite was allowed to air dry for one week and then berm sand was restored such that half of the composite's height was below the berm elevation at + 12.5 ft NGVD.

Monitoring: The emplacement operation was videotaped and dune profile survey markers were set. Arrangements for daily monitoring of marine turtle activity from May - October were made with the Department of Biological Sciences of the University of Central Florida, Orlando. Sea oats and railroad vine seedlings were planted in May, 1988, in the sand above the composite and in the north and south control dunes adjacent to the composite flanks.

Foot Traffic/Vandalism: This site is on private property much more isolated than Anastasia. Accordingly, there is very little beach traffic most of the time. From April to October, however, the restaurant hosts very popular beach parties every Sunday afternoon which draw hundreds of people. A few gouges appeared in the composite in May, 1988; further damage has been prevented by posting a guard during the parties. The damage was repaired with patch composite material in June, 1988.

North Carolina Trial - Ocean Dunes

Because of the lack of significant storm exposure at Anastasia, a site adjacent to the Ocean Dunes Condominiums, Fort Fisher, was chosen for a field trial. This area has endured several severe winter storms that caused property damage in the last few years. A permit for a test was obtained under the North Carolina Coastal Area Management Act from the Department of Natural Resources and Community Development.

Composite was emplaced along 200 feet of eroding dune in two configurations (Figure 4) in May, 1988. The composite was air-dried for one week and the berm was replaced as at Chuck's Steak House. Dune profile monitoring along 1200 feet of beach was initiated to measure longshore sand transport effects. As this is a private development, no significant damage from foot traffic has been observed.

CONCLUSIONS

The sand/gel composite system has been shown to be resistant to erosive forces, natural in appearance and compatible with beach vegetation. As intended, it appears to be resilient and environmentally compatible. Monitoring of the three field trials will continue for several years.

This technology is intended to stabilize threatened dunes against typical tides and storms long enough to allow natural vegetation to take hold, perhaps 3-5 years. In time, the composite should slowly disintegrate back to sand and water. Individual pieces of composite material, if broken free in a severe storm or hurricane, should break up in the surf and not accumulate on the beach. This novel system will hopefully provide a cost-effective, environmentally acceptable alternative to current approaches for coastal protection.

ACKNOWLEDGEMENTS

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APPENDIX - REFERENCES

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