Nantasket Beach Revetment Design

A design concept for a stone revetment was developed for the conditions reported in the 20 May 2008 Draft Nantasket Beach Coastal Engineering Appendix. This revetment design is for the approximately 2200 foot long section of beach between the existing Northern Revetment and the Temporary Seawall Fortification revetment (TSF) to the south.

A visit to the beach revealed that the existing seawall is distressed by continued erosion of the beach and loss of material behind the seawall. The TSF is functioning reasonably well. It was designed for a beach slope of 1V: 60 H based on profiles in 1995 and 2000. The most recent data indicates that there has been less erosion than was predicted since the TSF was constructed. This does not mean that the predicted erosion and wave heights are incorrect, but does lend some confidence in the conservatism used in predicting these values. Because wave height in this shallow environment is controlled by depth and erosion is apparently limited, this design will utilize the 1995 and 2000 data. The stone used for the TSF was designed to be stable in storm conditions with a return period of 25 years.

In a design memorandum dated 5/11/2004 for the TSF, the required 10-year armor stone weight was 3450 lbs. This was calculated in accordance with the USACE Engineer Manual 1110-2-1614 and a depth limited wave height of 7.9 feet. The minimum thickness of the revetment armor stone is 5.5 ft. with armor stones weighing between 2,860 lbs and 4,770 lbs. The 2-layer stone bedding should be at least 2.5 feet thick and consist of a uniform stone weighing 350 lbs. A 6-inch thick layer of gabion stone followed by a 6-in thick layer of crushed stone should be placed immediately below the stone bedding to separate layers and serve as a protection layer for the geotextile. A non woven filter fabric layer should be placed immediately below the crushed stone layer and should have an apparent opening size (AOS) of No. 70 sieve.

The above design was for a temporary structure. To upgrade the design for a more permanent structure, the width of the crest is increased to 8.25 feet (approximately 3 diameters of the armor stone), the thickness of the under layer is increased to two layers thick rather than a single layer (2.5 feet), and the toe of the revetment is carried to a depth equal to the height of the design wave impacting the structure (8 feet). The 25-year armor stone weight was determined to be 3,820 lbs. The cost of stone is primarily due to transportation costs which will be essentially the same for all stone weighing less than 3 tons. Increased stone size and associated level of protection are controlled by layer thickness. Two sizes, 3,500 lbs and 4,500 lbs, were priced for comparison.

			Nantasket Beach Calculations				
W=165H^3/2[165/64-1]^3 cot θ							
	10 year	25 year		10 year	25 year		
Calculations working down the columns							
W = weight of D50							
X = 165/64	2.578125	2.578125					
X-1	1.578125	1.578125					
(X-1)^3	3.930286			3.930286	3.930286		
Depth of water	8.3	8.6					
D^3							
Wave Height				7.9	8.17	ft	
H^3				493.039	545.3385	cf	
W= 165(D^3)/ 6[(X-1)^3]				3449.767	3815.704	lbs	
W/165				20.90768	23.12548		
r = 3root (W/165)				2.752085	2.846048	ft	
2nd Layer = W/1650				2.090768	2.312548		
r = 3 root (W/1650)				1.278668	1.322365	ft	
				Minimum	D 50	Maximum	
				2588	3450	4312.5	10 year
				2862	3816	4770	25 year

Emergency Ramps:

Where the emergency ramps cross the revetment, the revetment will abut the concrete ramp. The armor stone size is increased in this zone (within 10 feet of the ramp). Using a design stability number of 1.3 yields a stone size of 4000 lbs to 6625 lbs in this section (D_{50} = 5300 lbs). The thickness of the armor in this area will increase to 6.5 feet. The increased thickness shall be above the design rather than digging the excavation deeper.

Stairwells and Handicapped Ramps:

Openings in the revetment are necessary to allow direct access from the ramps and stairs to the sand. These openings will provide the same access that currently exists but expose small sections of the sea wall and revetment to erosion and possible undermining. A more protective approach is a continuous revetment. An above ground continuous

revetment is not recommended because it requires a walkway on the armor stone or bridging structure over the revetment. A revetment with openings still can be built that is continuous and tapers down to the top of the seawall footing. The example is shown on the attached plan.

Beach Level Access:

The access through the riprap should be a 20-foot wide path that is bounded to either side by a slope of 1V to 3 H. The upper surface of the underlying riprap will be placed one foot below the existing beach elevation. The depressed section of the revetment will begin three feet seaward of the toe of the exposed portion of the revetment to accommodate future erosion without exposing the underlying riprap. The width of the side slopes in the depressed section will increase as the path approaches the seawall.

The riprap slopes to either side of the pathways will act as groins and capture long shore drift. The collected material will help protect the seawall and minimize the need for pathway maintenance. During large storms this material will likely be washed out. However, the underlying riprap will protect the toe of the wall. The existing seawall to the south of this project is protected by a temporary revetment with larger openings than are being proposed here. The lack of damage to the seawall in the area of the temporary revetment suggests that the seawall will not be compromised by the proposed pathways.

CONSTRUCTION

All excavated material including beach material and riprap shall be sorted and stockpiled for reuse on the site. Riprap shall be sorted by size in conformance with ASTM D5519. Materials not suitable for reuse shall be removed from the site and disposed of properly.

Geotextile

Geotextile shall be a woven pervious sheet of polymeric material and shall consist of long-chain synthetic polymers composed of at least 95 percent by weight polyolefins, polyesters, or polyamides. The use of woven slit film geotextiles (i.e. geotextiles made from yarns of a flat, tape-like character) will not be allowed. Stabilizers and/or inhibitors shall be added to the base polymer, as needed, to make the filaments resistant to deterioration by ultraviolet light, oxidation, and heat exposure. Regrind material, which consists of edge trimmings and other scraps that have never reached the consumer, may be used to produce the geotextile. Post-consumer recycled material shall not be used. Geotextile shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including the edges. Geotextiles shall meet the requirements specified. Where applicable, property values represent minimum average roll values (MARV) in the weakest principal direction. Values for AOS represent maximum average roll values.

Property	Test Method	Acceptable Value
Grab Tensile Strength	ASTM-D-4632	370/250 lb
Grab Elongation	ASTM-D-4632	15 %
Mullen Burst Strength	ASTM-D-3786	480 psi
Puncture Strength	ASTM-D-4833	135 lb
Trapezoidal Tear Strength	ASTM-D-4533	100/60 lb
UV Resistance after 500 hrs	ASTM-D-4355	90 %
Apparent Opening Size (AOS)	ASTM-D-4751	70 sieve
Permittivity	ASTM-D-4491	0.28 SEC(-1)
Flow Rate	ASTM-D-4491	18 gal/min/ft

The Manufacturer shall be responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request. Manufacturing quality control sampling and testing shall be performed in accordance with the manufacturer's approved quality control manual. As a minimum, geotextiles shall be randomly sampled for testing in accordance with ASTM D 4354, Procedure A. Acceptance of geotextile shall be in accordance with ASTM D 4759. Tests not meeting the specified requirements shall result in the rejection of applicable rolls.

Crushed Stone

The crushed stone filter layer shall be placed and shaped to a uniform plane as required to receive the gabion stone. The stone should be graded such that 100% passes 2 inch, 75% passes 1.5 inches, 50 % passes 1 inch, and 25% passes 0.5 inch.

Placement of the crushed stone will begin at the toe of the slope and proceed up the slope. The crushed stone shall be placed so as to avoid damage to the geotextile, as approved by the Engineer. Stones shall not be dropped from a height greater than three feet. Lower drop heights may be required, as directed by the Engineer, if damage to the geotextile fabric is evident. Equipment shall be kept off of the crushed stone over geotextile fabric.

Gabion Stone

The gabion sized stone is (4 to 8 inch stone) placed and shaped to a uniform plane as required to receive the under-layer stone. A maximum of 50% shall pass a 6 inch sieve. The Gabion stone shall be placed in a 6-inch thick lift.

Placement of the gabion stone will begin at the toe of the slope and proceed up the slope. The gabion stone shall be placed so as to avoid damage to the crushed stone and geotextile, as approved by the Engineer. Stones shall not be dropped from a height greater than three feet.

Underlayer

The underlayer stone is to be supplied and placed in a 2.5-ft thick layer over the gabion stone prior to placing the armor stone over it. The underlayer stone shall comply with Massachusetts Highway Department Specification M2.02.3 for Stone for Pipe Ends. Underlayer stone shall be the product of the primary crushing of a stone crusher.

The underlayer shall meet the following gradation requirements: Each stone shall weigh not less than 260 lbs nor more than 440 lbs. and at least 75% of the volume shall consist of stones weighing not less than 350 lbs. The remainder of the stones shall be so graded that when placed with the larger stones the entire mass will be compact and without segregation. Placement of the underlayer stone will begin at the toe of the slope and proceed up the slope.

Stones weighing in excess of 100 pounds shall not be allowed to roll down slope. Stones shall not be dropped from a height greater than three feet. Lower drop heights may be required, as directed by the Engineer, if damage to the crushed stone or geotextile is evident.

Armor Stone

The 3,820 lb. armor stone layer is for the typical revetment section. The armor stone layer shall be at least 5.5-ft thick and consist of uniform stone weighting 3,820 pounds with a minimum weight of 2,600 lbs. and a maximum weight of 4,600 lbs. so long as 50% weigh at least 3,820 lbs. The upper surface may vary to allow a local thickness of 5 feet to 6.5 feet as long as the total averages a minimum of 5.5 feet and low spots do not extend in any direction for more than one stone. The stones shall be placed in zones not be more than 6 inches inside or 12 inches outside the slope lines shown on the Plans. The finished surfaces shall be approximately the same as those shown on the Plans and shall be reasonably uniform and free of bulges and depressions. Any gaps that are determined unsafe by the Engineer shall be filled with 350 lb stone as directed by the Engineer. However, the placement of such stone shall not interfere with the contract between and among 3,820 lb stone.

The upper most armor stones in the layer shall have a uniform gradation across the structure surface. All stones shall be placed so that there is continuous contact from the toe of the structure to the concrete of the backing wall. The surface armor 3,820 lb. stones should be firmly supported by other 3,820 lb. stones.

Placement of armor stone shall begin at the toe of the slope and proceed up the slope. Stones shall be individually placed.

During construction, the Contractor shall take all necessary precautions to protect the work from displacement by the sea and from all other causes. The Contractor shall replace any stone displaced by the sea or by other causes during the progress of the work without additional cost to the government.