US Army Corps of Engineers
Mississippi Valley Division
Corps Hurricane Response

Task Force Hope Status Report Newsletter *November 10, 2010*

Armoring: *constructing for resiliency*

Corps conducting research and testing of armoring types for use on the HSDRRS

by Susan Spaht

As the Corps of Engineers drives forward to complete the 100-year level of risk reduction for the Greater New Orleans area, it is simultaneously researching, testing and planning to provide for resiliency: **Armoring**

Armoring is a natural or artificial material placed on earthen levees and hardened structures; on protected sides of levees; and on floodwalls or other structures to reduce the risk of breaching as a result of an overtopping wave attack associated with a greater than 100-year storm surge.

The Corps plans to achieve 100-year level risk reduction for the Hurricane and Storm Damage Risk Reduction System (HSDRRS) by June 1, 2011. Armoring of levees will add an additional level of risk reduction known as "resiliency."

"Armoring is one of the major components of resiliency," said Reuben Mabry, a Corps Armoring Team leader and a Senior Program Manager with Task Force Hope. "Resiliency is the ability for a structure to withstand forces greater

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Simulated hurricane waves overtop a grass-covered clay levee during the Corps' wave-overtopping tests at Colorado State University last month. The Corps tested Bermuda and Bahia grasses to determine their erosion and wave-resistance capabilities. *To view the video, click here:* http://www.mvn.usace.army.mil/hps2/csu_big_wave.wmv

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than it was designed for; in the case of the HSDRRS, that could mean up to a 500-year event."

Where to Armor?

The Corps of Engineers will armor critical areas of the HSDRRS including the protected sides of levees, certain floodwalls, transition points between levees and structures, and where pipelines and utilities cross levee alignments.

Reuben Mabry

Armoring solutions will vary with location and with site specific hydraulic, physical and environmental conditions.

The Corps' Armoring Team is using overtopping rates based on the work developed by the Interagency Performance Evaluation Task Force, and other overtopping principles developed and instituted by the Corps of Engineers.

Already, about 420 transition points (where a structure meets a levee) have been or are in the process of being armored as the new features are built.

Armoring Types

There are several ways to armor a levee; the most basic and commonly -used method is grass. Research and development are currently underway to identify performance ranges for several classes of armoring including:

Grass-armored levee

Turf reinforced mattress with grass

- **Grass**
- **Turf reinforcement mattresses with grass**
- **Articulated concrete blocks**
- **Lime-stabilized clay**

The Armoring Team is responsible for research and testing of armoring types and design guidance for areas where armoring will be applied. The armoring team is also evaluating other factors to help determine what armoring method to use; these may include: risk of overtopping, cost, constructability, operations and maintenance, and environmental impact.

"Sound hydraulic engineering and research modeling has enabled us to identify all the relevant factors for determining the appropriate type of armoring for each area of the HSDRRS to resist wave overtopping flows from events greater than a 100 -year event," explained Mabry.

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"Appropriate armoring will be applied to best meet the needs of each area and reach of the system."

Research, Development and Testing

The Armoring Team was formed shortly after Hurricane Katrina. Since its inception, the team has worked closely with academia, industry leaders, vendors, Dutch engineers and Corps experts to explore all possibilities for armoring levees. The team has conducted research, development and testing at Louisiana State University, Texas A&M University, Colorado State University, and the Corps' Engineer Research and Development Center (ERDC).

In August 2007, the Corps' Armoring Team hosted an Industry Day for companies that produce armoring products. In September 2007, the team hosted a Resiliency and Overtopping Workshop with experts from many organizations.

Then in October of that year, the Corps installed three types of turf reinforcement mats and articulated concrete blocks on the levee at the Corps' St. Francisville Mat Facility to test installation, mowing and aesthetics of those products.

In February 2009, the Corps released a "sources sought" inquiry seeking industry feedback on innovative armoring solutions to supply and install armoring on the protected side of levees.

And the research, development and testing continues.

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Placing articulated concrete blocks


Articulated concrete blocks with grass growing through


Lime-stabilized clay staging area


Levee being prepared for Lime-stabilized clay

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Currently, the Corps is wrapping up full scale wave overtopping testing of several armoring classes of materials, including Bermuda and Bahia grasses, at a specially-built facility at Colorado State University. The purpose of the testing is to determine erosion and resistance to increasing overtopping flow rates.

"We discovered that there were no full-scale wave overtopping facilities anywhere in the world that could meet our needs," said Dean Arnold, an Armoring Team Leader and a Program Manager with Task Force Hope. "The testing facilities in the Netherlands, for example, could only handle 6-foot high waves at 1 cfs per foot. We needed to simulate 8-foot waves at as much as 3+ cfs per foot - *more than three times what the Dutch had* - to determine our HSDRRS armoring material capabilities.

"So we contracted with Colorado State to build a facility to meet our needs. They had the flume and an unlimited water supply, and they built the rest based on the design of the Dutch. This is now the largest wave overtopping facility in the world."

Dean Arnold

The tests included increasing water flows for longer periods of time to simulate waves overtopping a levee during a typical hurricane.

"A typical hurricane has overtopping waves that last for 3-4 hours," explained Arnold. "Our tests were run for 6 hours with over 1,000 waves.

Concrete slope paving

Transition armoring at RR floodgate

"We have been amazed at the performance of the grasses," said Arnold. "The results have been much better than expected. Even after we rutted areas and created bare areas in the grass to model extreme levee conditions, the clay and root systems held."

The Corps is now starting tests on articulated concrete blocks and lime-stabilized clay at the Colorado State facility.

The research and development efforts are expected to be completed by the end of the year.

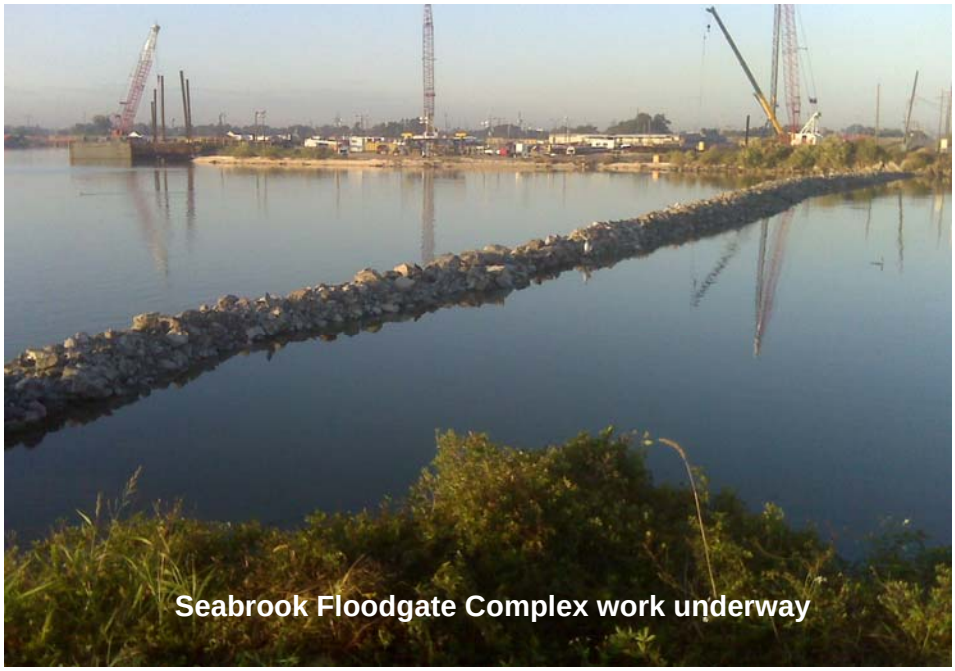
Partnerships

Throughout the armoring research and development process, the Corps of Engineers has included its stakeholders and partners. Members of the Southeast Louisiana Flood Protection Authority-East and West, as well as the State's Coastal Protection and Restoration Authority have been invited to participate in seminars, Industry Days, focus groups and Armoring Team regular meetings to provide comments and input.

"Our testing and modeling of armoring materials and techniques are based on scientific rigor, robust independent external peer review and working closely with academia and our partners and stakeholders," said Karen Durham-Aguilera, Director of Task Force Hope.

"Our partners and stakeholders have a huge vested interest in the armoring phase of the HSDRRS. We value their participation, experience and expertise.

"We are very excited about the armoring effort and what it means to the people of Greater New Orleans."



Seabrook Floodgate Complex work underway

The Corps recently finished construction of a Rock Dike across the Inner Harbor Navigation Canal (Industrial Canal) at Seabrook. The structure will slow down flows across the now-closed channel so that the existing scour hole can be filled and construction of the Seabrook Floodgate Complex can get started. The contractor's next step will be to build the cofferdam and the foundation of the future Seabrook structure.

Corps building big, building fast, *building strong*

West Closure Complex

Construction at the West Closure Complex continues to move along at a rapid pace. The 11 water intake bays are now visible from this aerial view, as is the wall for one of the huge sector gates. USACE Photos

Contact Information

U.S. Army Corps of Engineers

Task Force Hope
(504) 862-1836

New Orleans District
(504) 862-2201

Hurricane Protection Office
(504) 862-1708

The *Status Report Newsletter* supports the information program for Task Force Hope and its stakeholders. It also serves as the primary tool for accurately transmitting the Corps' hurricane risk reduction efforts to stakeholders.

This is an online publication that is open to public distribution.

This issue and past issues can be found at:
http://www.mvn.usace.army.mil/hps

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b2fwdpao@usace.army.mil

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Status Report Newsletter
Task Force Hope
Strategic Communications
7400 Leake Ave., Room #388
New Orleans, LA 70118
(504) 862-1949