SOFT DIKE DEMONSTRATION PROJECT ON THE MISSISSIPPI RIVER

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ABSTRACT

This paper presents the design, construction, and results of a demonstration project consisting of contraction dikes built of geotextile containers filled with sand. Dikes will contract the channel to a width where the river will maintain its velocity through the crossing. This will prevent the sediment from dropping out of suspension and reduce, or eliminate the need to dredge. Project design considerations and construction results are discussed.

INTRODUCTION

Red Eye Crossing is a 3.2 km (2 mile) reach between bends in the Mississippi River below the city of Baton Rouge, Louisiana where the navigation channel crosses from the left bank to the right bank as the river flows downstream to the Gulf of Mexico. The river widens to about 1220 m (4000 ft) just above the sharp downstream bend and drops its sediment load at various river stages, causing major shoaling to occur throughout the year. Because of these conditions, the crossing fills and requires dredging to maintain the ship channel. Red Eye Crossing was chosen for the demonstration project because it has the highest concentration of fill material dredged of the four crossings in Figure 1, or of any crossing in the New Orleans District, Corps of Engineers.

In 1988, the ship channel from the Gulf of Mexico to Donaldsonville, a town 32 km (20 miles) downstream of Red Eye Crossing, was deepened from 12.2 m (40 ft) to 13.7 m (45 ft) to accommodate Deep Draft vessels. During the design phase to deepen the channel between Donaldsonville and Baton Rouge to 13.7 m (45 ft) , it

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became apparent that it would be more economical to build contraction dikes that would reduce the need to dredge, than to maintain current dredging practices. This paper discusses the contraction dike demonstration project that was constructed at Red Eye Crossing between July 1993 and July 1994. The ship channel depth was 12.2 m (40 ft) during dike construction. After the project was constructed, the depth of channel between Donaldsonville and Baton Rouge was increased to 13.7 m (45 ft).

Figure 1. Mississippi River Crossings Between Baton Rouge and Donaldsonville.

DREDGING ACTIVITIES

Red Eye Crossing is a high traffic area where the Corps keeps the channel crossing open with a dustpan dredge that discharges the material in the river current to be carried downstream. The Corps of Engineers dredge Jadwin has to remove sediments from the Red Eye Crossing several times a year to keep the channel open. During the past five years, an average of 3,820,000 cubic meters (5 million cubic yards) of sediment were dredged per year from Red Eye Crossing. The dredge spent approximately 80 days a year at the crossing removing sediment to maintain the 152.5 m (500 ft) wide by 12.2 m (40 ft) deep channel. When river stages fall rapidly, even dredging cannot provide users with a 152.5 m (500 ft) wide channel. It is anticipated that dredging requirements will double at Red Eye for the Deep Draft channel. At an approximate cost of $.65 a cubic meter ($.50 a cubic yard), dredging costs become significant, especially since dredging has to be done on a routine basis.

ALTERNATIVE TO DREDGING

Model studies have shown that contraction dikes will eliminate or significantly reduce the need for maintenance dredging. A contraction dike is an underwater structure that is placed perpendicular to the river bank to reduce the width of the channel. Refer to Figures 2 and 3 for a plan view and a cross section view of the dike plan. At high river stages a significant amount of flow will go over the dikes, but as the river drops, the dikes will have more influence in restricting the width of the channel. Restricting the width of the channel causes the water to maintain its velocity and keep the soil particles in suspension through the crossing. The most economical method to construct the dikes is with stone, but representatives of the navigation industry expressed concern about stone barriers in the river next to the navigation channel. They feared collisions or major spills from any ship that ran aground. River pilots were concerned that towboat traffic will be thrust into the main channel, increasing congestion and the chances for collisions.

Contraction dikes will save the government approximately $7 million a year in dredging costs for the Deep Draft channel. Removing the dredge Jadwin from the channel will improve navigation by removing obstacles that are associated with dredging activities.

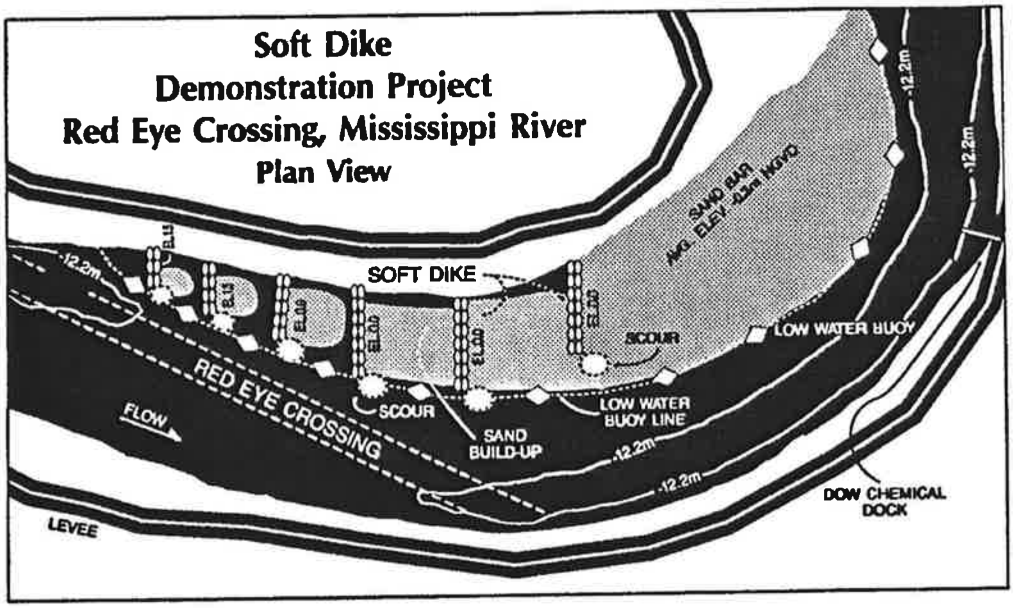

Figure 2. Plan View of Contraction Dikes and Crossing Lane.

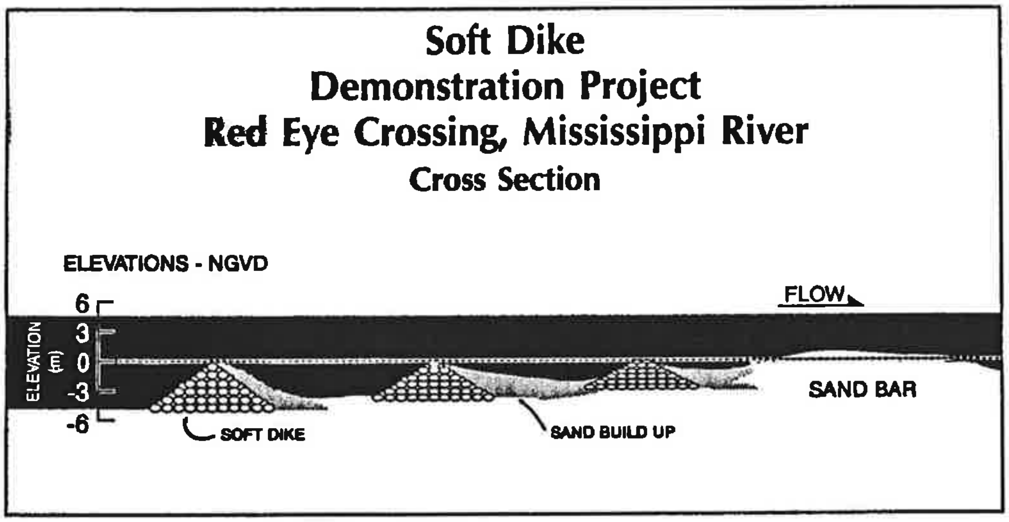

Figure 3. Cross Section View of Typical Dike Sections.

BENEFITS OF SOFT DIKES

Soft dikes made of geotextile containers filled with sand were introduced to eliminate the concerns that were expressed by representatives of the navigation industry. Soft dikes will cushion collisions better than stone dikes. If a vessel hits a soft dike, the worst scenario is that it will be the same as when it hits a sand bar or earthen river bank. In most cases it should fare much better. The collision should dislodge some of the geobags on the top portion of the dike and soften the impact. At high river stages shallow draft vessels, such as towboats, can cross over the dike field without hitting the dikes. During construction several boats used this route in spite of objections from the contractor.

DEMONSTRATION PROJECT

New Orleans District was given authority to design and construct a demonstration project at Red Eye Crossing to evaluate the construction and performance of the soft dike alternative.

Waterways Experiment Station (WES) personnel ran a two dimensional mathematical model and a movable bed model to simulate the effect of contraction dikes and to determine the required dike configuration. Six dikes are required perpendicular to the river bank with a top elevation at -0.6 m, or -2.2 m (-2 or -7 ft) National Geodetic Vertical Datum (NGVD). Dikes have a 3 m (10 ft) crown width, and side slopes of 1V to 2H. Dike lengths varied from 152 m to 549 m (500 to 1800 ft) with a maximum height of 9.2 m (30 ft). To evaluate which type of container would work best, dikes 1, 3, and 6 were built with geobags and dikes 2, 4, and 5 were built with geocontainers topped off with geobags. Geobags were placed on top of geocontainer dikes where placement of another geocontainer would bring the dike above design elevation. Figure 4 shows typical geocontainer and geobag dike sections.

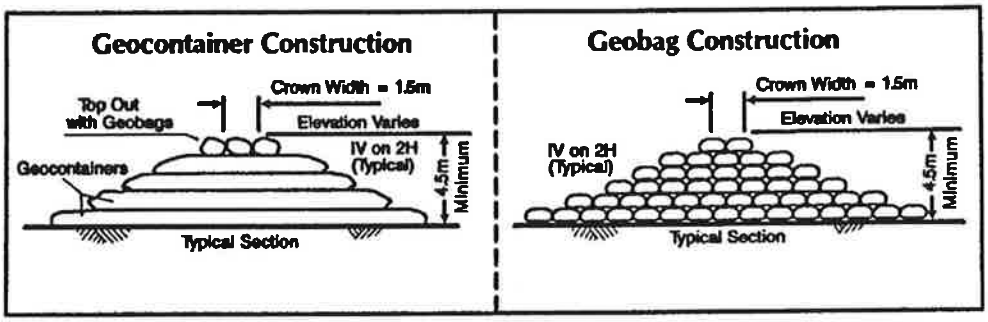

Figure 4. Geocontainer and Geobag Dike Sections.

The objective of the demonstration project was to answer the following questions:

1. Are there technically qualified construction contractors in the continental United States that have the necessary equipment and ability to construct such a project?
2. Can we find a manufacturer for the geocontainers and geobags in the U.S., or will these items have to be imported.
3. Can the contractor place containers accurately in the turbulent waters of the Mississippi River?
4. Will the containers remain in place, or will they slide off the side slopes.
5. Will the dikes perform as the models predicted?

GEOTEXTILE DESIGN

There is not much published information on design methods for geobags or geocontainers. Many challenges have to be overcome during design and construction. Most of the problem is due to the lack of information regarding the effect of water velocity, container drift, and impact forces on the containers as they are filled, dropped, and make contact with the channel bottom or other containers. Geocontainers were used at two documented projects in Europe. The first project was in Weekeborg, Germany where geocontainers were used to construct a breakwater with a maximum depth of drop of approximately 6 m (20 ft). Engineers from the Public Works Department of the Netherlands used information from the construction of that job to fill a scour hole with geocontainers at Old Meuse (Jagt, H.J. 1988) with a maximum depth of drop of approximately 20 m (65 ft). The design of the Red Eye Project is based on the Dutch Report. Changes were made to account for site and construction conditions, and to avoid some of the problems that were encountered by the Dutch.

Most of the geobags and geocontainers were going to be dropped in 9.2 m to 12.2 m (30 to 40 ft) of water, while others were going to be dropped in as much as 21.4 m (70 ft). River velocity data, collected near the site between 1975 and 1983, indicated that the mean velocity would be about 1.5 m/s (5 ft/sec), similar to the velocity at Old Meuse. Data from the Dutch report was used to perform rough calculations of the impact momentum between the geocontainer and river bed. Using a geocontainer drop velocity of 5 m/s (16.4 ft/sec), a geocontainer length of 26 m (85 ft), and a geocontainer submerged weight of 157 metric tons (346,185 lbs) yields a momentum of 80 metric tons (176,318 lbs). Dividing the momentum by the 26 m (85 ft) length results in a demand on the longitudinal seam of approximately 29.8 kN/m (170 lbs/in). Applying a seam strength efficiency of 45%, results in a geotextile strength of approximately 70 kN/m (400 lbs/in). Geobags would have lower stresses during the drop, but since the method of construction was not specified, we decided to use the same geotextile strength for the geobags.

Sieve analyses of random samples from the borrow pit were used to determine the proper geotextile Apparent Opening Size (AOS) that is required to keep the sand in the containers. The material from the borrow pit consists of sand with a SP classification according to the Unified Soil Classification System. Average values for all of the grain size curves yield the average grain size curve in Figure 5. Values for the average curve are 0.4 % gravel, 99.3 % sand, 0.3 % silt, no clay, a uniformity coefficient of 1.4, and a curvature coefficient of 0.97.

There are many different design methods to compute the AOS of a geotextile so that it retains the desired soil. For the average gradation curve, European criteria require a geotextile with an AOS between a No. 20 and No. 30 sieve, while current U.S. standards ranged from a No. 30 to a No. 100 sieve. We decided to use a somewhat open geotextile to avoid some of the problems the Dutch had experienced. The design objective was to let as much air or water out of the containers in the shortest amount of time without loosing sand. The geotextile that the manufacturer used to make all of the geocontainers and geobags was stronger than the minimum value of 400 lbs/in that was specified, seam efficiency was also greater than the 45% value that was estimated. The geotextile ultimate strength, seam strength, and AOS mean values are:

Tensile Strength (both directions)	ASTM D 4595	88 kN/m (500 lbs/in)
Seam Strength	ASTM D 4595	61 kN/m (350 lbs/in)
AOS	ASTM D 4751	No. 30 sieve

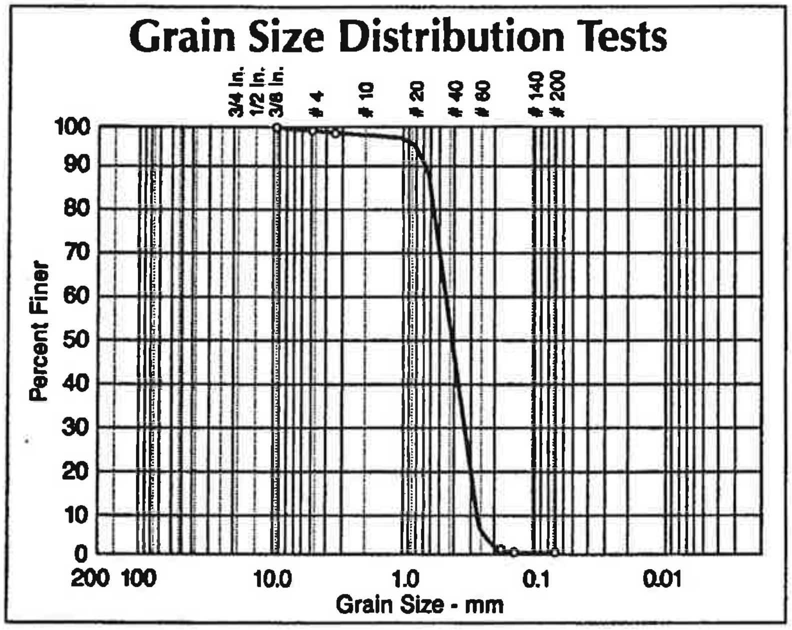

Figure 5. Average Grain Size Distribution Curve.

GEOCONTAINER INFORMATION

Geocontainers were manufactured to fit the modified split barge bin that was approximately rectangular in shape. The perimeter of each geocontainer is 13.7 m (45 ft), measured perpendicular to the length of the barge. Geocontainer lengths varied from 12.2 m to 35 m (40 to 115 ft). Circular areas (vents) were cut out of the ends and top of the geocontainers and replaced with a No. 20 AOS geotextile to ease the escape of trapped air or water, and reduce the chances of rupture during impact.

SOFT DIKE CONSTRUCTION

Most of the geobags and geocontainers were placed between October 1993 and April 1994, which includes down time due to high river stages. Construction was performed by two crews that worked simultaneously. One crew was responsible for placing geobags, the other for placing the geocontainers. The geobag crew worked on barges that had a hopper where sand was placed to fill the geobags. Three geobags were filled at a time in the customized hopper filling station. Each geobag was filled with 2.3 cubic meters (3 cubic yards) of sand. During the filling operation, each geobag was supported by a cage that was designed for this project. Sand was dumped into the hopper and transferred to the geobag by a conveyer belt. After the desired amount of sand was placed in the geobag, the opening was sewn using two rows of stitches made with a hand held sewing machine. A frontend loader transferred the cage with the geobag to the location where the geobag was dropped into the water. The contract limited the height of drop to 3.7 m (12 ft) above the water surface to avoid large stresses in the geotextile. The actual drop height was 2.3 m (7.5 ft). Geobags were not filled completely to provide room for the sand to move and dissipate some of the impact energy before it reached the seams. The barge where the geobags were filled and dropped was positioned upstream of the dike alignment to compensate for geobag drift. River velocity and geobag drift were checked periodically and cross sections were taken to make sure that the geobags were falling into the dike section. Towards the end of geobag placement operations, after the crew had reached peak performance, an average of 373 geobags were placed a day with a standard deviation of 58 geobags. The maximum number of geobags that were placed during one day was 473. Wooden or foam floats were installed in the first 3500 geobags that were dropped to determine if any of the geobags broke during placement.

Workers placed each geocontainer on the split barge, opened the container, and tied the tension straps to the sides of the barge. A backhoe with a 7 cubic meter (9 cubic yard) capacity was used to fill the geocontainer with moist sand. After the geocontainer was filled to the desired volume, three rows of stitches were sewn with a hand held sewing machine to seal the top flap of the geocontainer. The split barge with the geocontainer was moved and tied to an empty barge that had been positioned to account for geocontainer drift, so that the container would fall to the desired location. Geocontainer dikes were constructed by dropping geocontainers on 6.1 m (20 ft) centers, with the length of the geocontainer perpendicular to the length of the dike. Alternate lifts were offset by 3 m (10 ft) to fill the hump between the geocontainers that were dropped during the previous lift. Geocontainers dropped slowly and evenly out of the barge bin without releasing many air bubbles. The friction between the geocontainer and barge allowed for a slow and even drop. Using two split barges, the geocontainer crew dropped 8 geocontainers a day, on average, with a standard deviation of 2 geocontainers. The maximum number of geocontainers that were dropped during one day was 12. Floats were installed in the first 160 geocontainers. If a float came to the top of the water, the float number indicated which geocontainer had broken.

River velocity near the bank at the time of construction was approximately 0.6 m/s (2 ft/sec). Away from the bank, the velocity was between 1.1 and 1.5 m/s (3.5 and 4.9 f/sec), depending on distance from the bank and river stage. River stages ranged from 3.9 m to 10 m (12.7 to 29.9 ft) NGVD.

The following quantities give an idea of the size of the project. A total of 77,939 metric tons (85,914 tons) of Grade "B" stone was used to construct the bankheads and protect the bank. Approximately 38,000 geobags were used to construct the geobag dikes and to top off the geocontainer dikes. The combined total weight of sand in the geobags is 167,465 metric tons (184,600 tons). Five hundred and fifty six geocontainers were placed. The combined total weight of sand in the geocontainers is 206,474 metric tons (227,600 tons). The largest geocontainers have a volume of 422 cubic meters (552 cubic yards).

INSTRUMENTATION AND RESULTS

Research personnel from the Waterways Experiment Station arranged funding for instrumentation under the Construction Productivity Advancement Research (CPAR) program. Three 35 m (115 ft) long geocontainers were instrumented with strain gages and pressure transducers and dropped in 21.4 m (70 ft) of water. Ten strain gages were placed along the diameter of each geocontainer. Some gages were placed across the seams to determine the strains on the seam during the drop. Pressure transducers were inserted near the gages to measure the pressure inside and outside the geocontainer. Measurements from the transducers were used to calculate the velocity of the container as it dropped to the bottom of the river bed. Gage readings show that the maximum geotextile strain occurred while the geocontainer was sliding out of the split barge bin. Strains between 8% and 12% were recorded. Geotextile strains during geocontainer impact with the river bottom were approximately 3% to 4%. Terminal velocity was reached within 1/2 a second after the geocontainer dropped from the barge, and it took approximately 5 seconds for the geocontainer to hit bottom. Recorded velocities were between 3.5 m/s and 4.5 m/s (12 and 15 ft/sec) for geocontainers and geobags. Three geobags were also instrumented and dropped in shallower water. Maximum strains in the geobags occurred when the geobag hit the water surface, and were between 3% and 8%.

Six geobags broke out of the 3500 that were equipped with floats, approximately 0.2%. Most of the breaks occurred within the first 5 days of geobag placement, and occurred while the geobag was sliding off the cage that transported the geobag. There were no more breaks after the contractor made changes to the cage. Six geocontainers broke out of the first 160 that were equipped with floats, approximately 3.8%. The corners of the geocontainers were difficult to seam in the field. After the contractor made changes to the sewing procedure for the corners, breaks were less frequent, but the field seam is still the weak link in the whole operation.

Drift distances for geocontainers ranged from 1.2 m to 2.4 m (4 to 8 ft), with the smallest geocontainers drifting the most. Geobags drifted downstream on approximately a 1V to 1H slope. Figure 6 presents depth of water versus geobag drift distance.

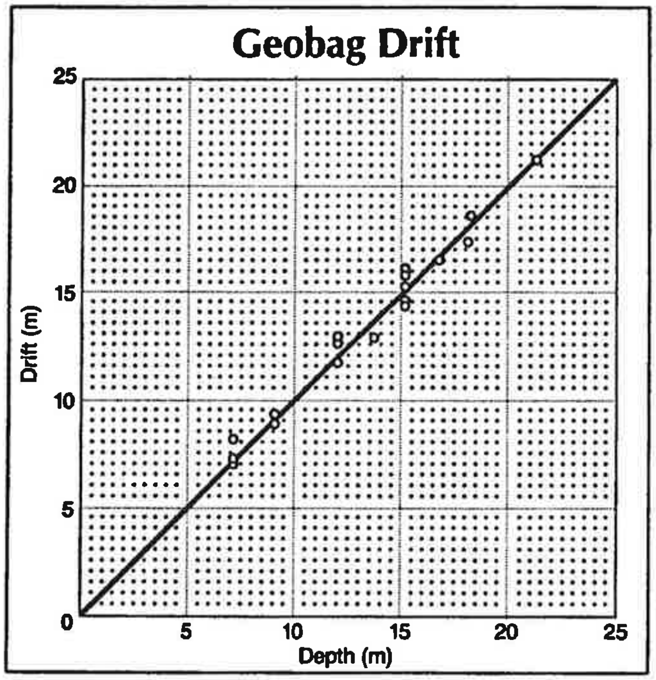

Figure 6. Depth of Drop Below Water Versus Geobag Drift.

CONCLUSIONS

The project revealed that soft dikes made of geotextile containers filled with sand can be successfully constructed in the Mississippi River. There are technically qualified contractors in the U.S. that have the necessary equipment and ability to construct such a project. Higher and longer than normal river conditions did not prevent the contractor from placing the containers accurately in the dike section. There is no evidence of geocontainers or geobags sliding off the dike slopes. Maximum strains in the geocontainer geotextile did not occur during impact with the river bottom or other containers as had been anticipated, but while sliding out of the barge bin. The largest geobag strains occurred during impact with the water surface. Measured strains in the geocontainer geotextile approached the allowable limit, indicating an economical design. Geobag strains were considerably less than the design values, but the geobag ruptures revealed that maximum stresses can occur during transport rather than impacts. Any reduction in geotextile strength for the geobags should be based on the method of construction and other pertinent factors. We are monitoring the site to evaluate whether the hydraulic performance is according to the predictions from the models.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Lynn Broussard for her detailed critique and helpful suggestions. Permission to publish this paper was granted by the Corps of Engineers.

REFERENCES

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