LOCAL SEDIMENT SCOUR MODEL TESTS FOR THE WOODROW WILSON BRIDGE PIERS

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Abstract

The Woodrow Wilson Bridge on I-495 over the Potomac River in Prince Georges County, Maryland is being replaced. Physical local scour model studies for the proposed piers for the new bridge were performed in order to help establish design scour depths. Tests were conducted in two different flumes, one in the USGS-BRD Conte Research Center in Turners Falls, Massachusetts and one in the FHWA Turner Fairbanks Laboratory in McLean, Virginia. Due to space limitations in this publication only the tests conducted in the USGS flume are presented in this paper. Two different pier designs were tested. One of the piers was also tested with two different diameter dolphin systems.

Introduction

The Woodrow Wilson Bridge at the I-95 and I-495 crossing of the Potomac River in Prince Georges County, Maryland is being replaced. Large dolphins, for protecting the proposed main channel piers (M1 piers), are being considered as part of the design. The combination of piers and dolphins constitute a large, complex structure from the standpoint of flow resistance and sediment scour. Predicting local scour at these structures is difficult if, not impossible due to their complexity. The purpose of the physical model studies reported here is to help in the establishment of design scour depths for these piers. Tests were conducted in two different flumes, one in the USGS-BRD Conte Research Center in Turners Falls, Massachusetts and one in the FHWA Turner Fairbanks Laboratory in McLean, Virginia. The USGS flume is 6.1 m wide, 6.4 m deep and 38.4 m long and has 1.83 m of sediment. The FHWA flume is 1.83 m wide, 0.61 m deep and 21.3 m long with varying depths of sediment depending on the test. The model pier sizes were made as large as possible for the width of the flumes to minimize scale effects. One reason for testing in two sizes of flumes was to establish the effects of scale on the results so that additional tests on other pier designs could be tested in the smaller flume. Two pier designs were tested in the USGS flume, the main channel pier referred to as the M1 pier and the M9 pier. Two different diameter dolphin systems were also tested with the M1 pier. The dolphin system consisted of 3 cylindrical dolphins on each end and a fender structure along one side of the pier as shown in Figures 2 and 4. Drawings with primary dimensions of the prototype piers are shown in Figures 1 and 2. The test procedures and results are presented below along with estimates of prototype local scour depths for several flow velocities. Two different methods were used to compute prototype scour depths from the measured model results. For a more detailed discussion of these methods the reader is referred to another paper in these proceeding by Sheppard et al. entitled, "Method for Obtaining Prototype Local Scour Depths From Physical Model Tests". For more information on the USGS flume and the instrumentation used in these tests the reader is referred to another paper in these proceedings by Sheppard et al. entitled "Clearwater Local Scour Experiments in a Large Flume".

Experimental Procedure
The procedures discussed below pertain to the physical model tests conducted in the USGS Laboratory. The flume contained a 1.83 m layer of cohesionless sediment. To minimize the amount of near uniform diameter sediment needed for the tests, a 1.52 m layer of filler material (pea gravel) was used outside of the test area. The 6.1 m wide and 9.8 m long test area was located about two-thirds the length of the flume from the entrance. A filter cloth was placed over the filler material and topped with a 0.3 m layer of test sediment. Local scour tests are normally performed in near uniform diameter sediment since the greatest scour depths occur under these conditions. The sediment used for these tests was quartz sand with a median grain size, D_{50} of 0.8 mm and a size distribution, $\boldsymbol{\sigma} \equiv \sqrt{\mathbf{D_{84}} / \mathbf{D}_{16}} = 1.3$.
The sediment in the entire flume was leveled (using a transit) and compacted. An acoustic scour depth-measuring instrument on a traversing mechanism was installed adjacent to the pier (for tests 2-4) along with an underwater video camera. Two electromagnetic current meters were installed upstream and on either side of the model to measure upstream velocity.

Water for the flume comes from a power plant reservoir on the Connecticut River adjacent to the Laboratory. The water is discharged from the flume into the river downstream of control structures where the water level is approximately 10 m below the reservoir elevation.
The scour depth was monitored throughout each test to insure that the duration of the test was sufficient to achieve equilibrium scour depths. Four pier configurations were tested. The tasks performed are outlined below:

Task 1. Scale models of the proposed M1 and M9 Piers and the 13.7 m and 9.1 m dolphins were constructed. Two different geometric scales were used for the M1 Pier, 1:28 and 1:50 and one for the M9 pier and dolphins, 1:50. The M9 Pier was tested first, followed by the M1 without Dolphins, then the M1 with the 13.7 m diameter dolphins and finally the M1 Pier with the 9.1 m dolphins.

Task 2. Sediment in the test area was excavated and the first model pier was installed. The sediment was compacted at approximately 0.3 m intervals to insure the proper sediment density. An acoustic transponder array on a traversing mechanism was installed (for tests 2-4) near the structure for the purpose of monitoring the scour depth as a function of time. Video cameras in streamlined underwater housings were set up for periodic submersion for reading scour depths at specific piles with length scale markings.

Task 3. The flume was filled with water and allowed to stand for approximately 12 hours. It was then drained slowly and the bed compacted once again. This procedure was used to insure that there were no voids in the sediment near the structure.

Task 4. The test procedure was as follows:

a. Video and still photography were used to document the initial conditions.

b. The flume was filled, being careful not to generate scour during the fill process. Water was allowed to stand at the level of the discharge weir until air trapped in the bed had escaped.

c. The flow and instrumentation was started. Scour depths were monitored at specified intervals throughout the test with an underwater video camera (and in tests 2-4, acoustic transponders).

e. Periodic plots of scour depth versus time were made during the test in order to establish the time when the local scour depth reached equilibrium.

f. The test was stopped and the flume drained.

g. Point gauge measurements of the scour hole and surrounding area were made. Still and video images of the scour hole were also made.

Task 5. The data was reduced and analyzed.

Task 6. Tasks 2 – 5 were repeated for three additional pier configurations as stated in Task 1.

Test Results

The sediment and flow conditions and the measured maximum local scour depths for the four tests are presented in Table 1. Before and after (test) photographs for the four tests are shown in Figures 3 and 4. The tests with the dolphins used a geometric scale of 1/50. The M1-45 test was with a 13.7 m (45 ft) dolphin system and the M1-30 test with the 9.15 m dolphin system. The locations of the dolphin centerlines were the same in both tests.

Table 1. Model sediment and flow conditions and measured maximum scour depths.

Test	Pier	Water Depth, y_0 (m)	Depth Average Velocity, V (m/s)	Critical Velocity, V_c (m/s)	Sediment Diameter, D_{50} (mm)	Test Duration (hr)	Measured Scour Depth, y_s (m)	Corrected Scour Depth $V/V_c=1$ (m)
1	M9	0.16	0.30	0.32	0.8	125.8	0.15	0.17
2	M1	0.50	0.34	0.36	0.8	136.7	0.22	0.24
3	M1-45[1]	0.28	0.32	0.35	0.8	140.0	0.28	0.33
4	M1-30[2]	0.29	0.33	0.35	0.8	140.0	0.29	0.32

[1] M1 Pier with 13.7 m dolphins

[2] M1 Pier with 9.1 m dolphins

The effective diameters of the four pier configurations are given in Table 2 along with prototype critical velocities, V_c, and velocities at the live bed peak, V_{LP} (see paper in these proceedings by Jones and Sheppard entitled "Scour at Wide Bridge Piers**")**. The prototype scour depths for all four pier configurations were computed for four different design velocities spanning the 100 and 500 year return interval velocities for this site.

Table 2. Model and prototype effective diameters and prototype critical velocities and velocities at the live bed peak.

Pier	Model Effective Diameter (m)	Geometric Scale	Prototype Effective Diameter (m)	Prototype Critical Velocity (m/s)	Prototype Live Bed Peak Velocity V_{LP}[3] (m/s)
M-9	0.083	50	4.16	0.351	6.30
M1	0.126	28	3.53	0.368	8.17
M1-45[1]	0.194	50	9.71	0.368	8.17
M1-30[2]	0.187	50	9.35	0.368	8.17

[1] M1 Pier with 13.7 m dolphins
[2] M1 Pier with 9.1 m dolphins
[3] Based on 500 year water depths (14.08 m for M1 and 8.14 m for M9)

Table 3. Prototype local scour depths for a range of design velocities using two different methods.

Pier	Design Water Depth (m)	Design Velocity (m/s)	Prototype Local Scour Depth (m)	
			Geometric Scale Method	Local Scour Scale Method
M-9	7.3	1.43	8.79	3.20
M1	13.3	2.13	8.10	3.02
M1-45[1]	13.3	2.13	16.61	8.22
M1-30[2]	13.3	2.13	16.19	7.92
M-9	7.3	1.83	8.79	3.80
M1	13.3	2.74	8.10	3.59
M1-45[1]	13.3	2.74	16.61	9.78
M1-30[2]	13.3	2.74	16.19	9.43
M-9	8.1	2.44	8.79	4.54
M1	14.1	3.51	8.10	4.23
M1-45[1]	14.1	3.51	16.61	11.53
M1-30[2]	14.1	3.51	16.19	11.12
M-9	8.1	3.05	8.79	5.39
M1	14.1	4.42	8.10	5.06
M1-45[1]	14.1	4.42	16.61	13.80
M1-30[2]	14.1	4.42	16.19	13.30

[1] M1 Pier with 13.7 m dolphins
[2] M1 Pier with 9.1 m dolphins
[3] See Sheppard et al in these proceedings "Method for Obtaining Prototype Local Scour Depths From Physical Model Tests".

Summary

Physical model local scour studies were performed with proposed piers for the Woodrow Wilson Replacement Bridge. Tests were conducted in two different size flumes using different geometric scales for the models. Reasonable agreement was achieved between the tests in the two flumes. Due to space limitations only the procedures and results from the tests performed in the USGS flume are discussed in this paper.

Prototype local scour depths were computed from the measured model results by two different methods, one using the Geometric Scale and one using a Local Scour Scale which is discussed in another paper in these proceedings. The difference in the predictions by these two methods is relatively large at lower design velocities but decreases as the design velocity increases.

Acknowledgements

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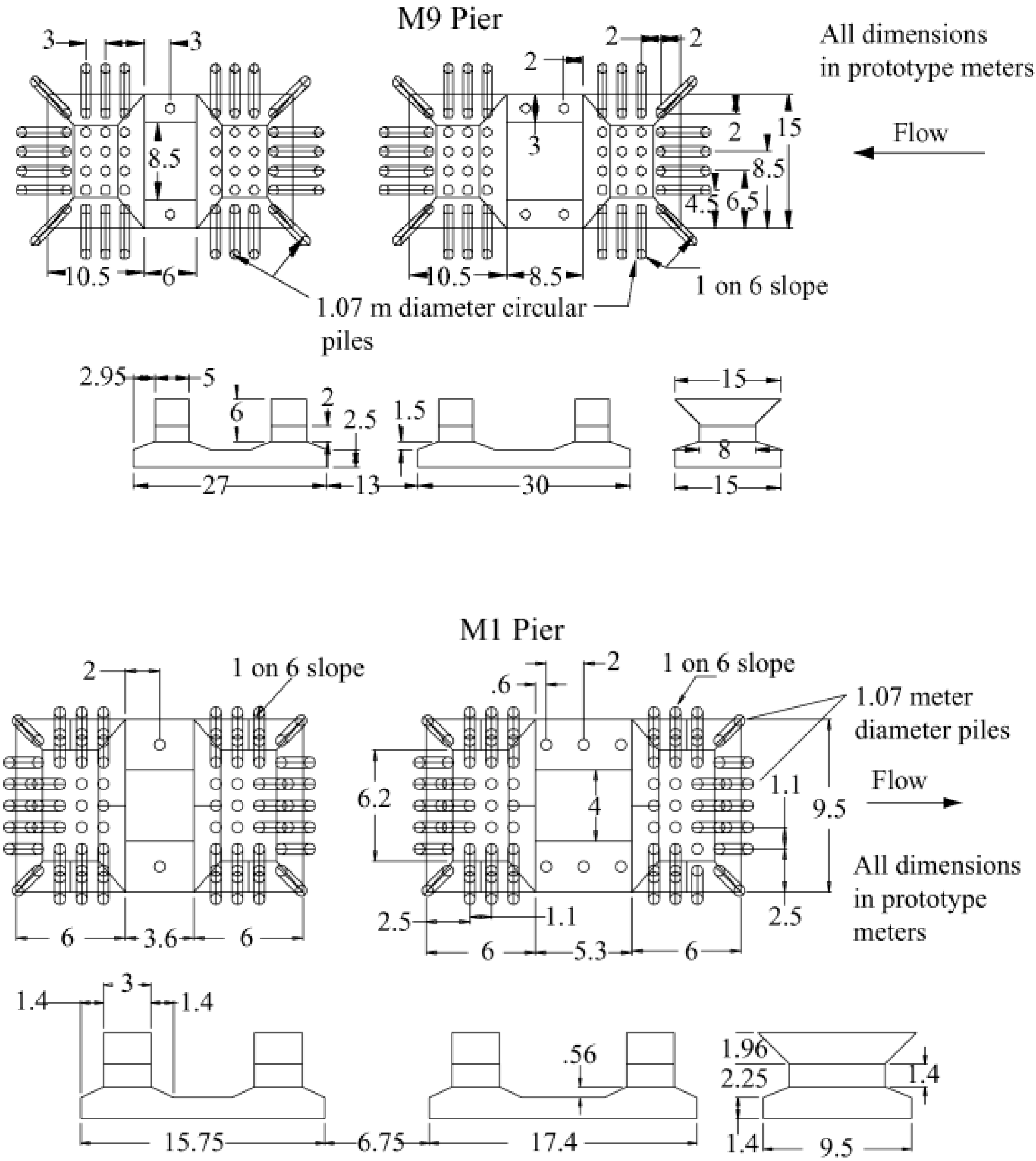

Figure 1. Drawings of two of the proposed piers for the Woodrow Wilson Replacement Bridge. All dimensions are in meters.

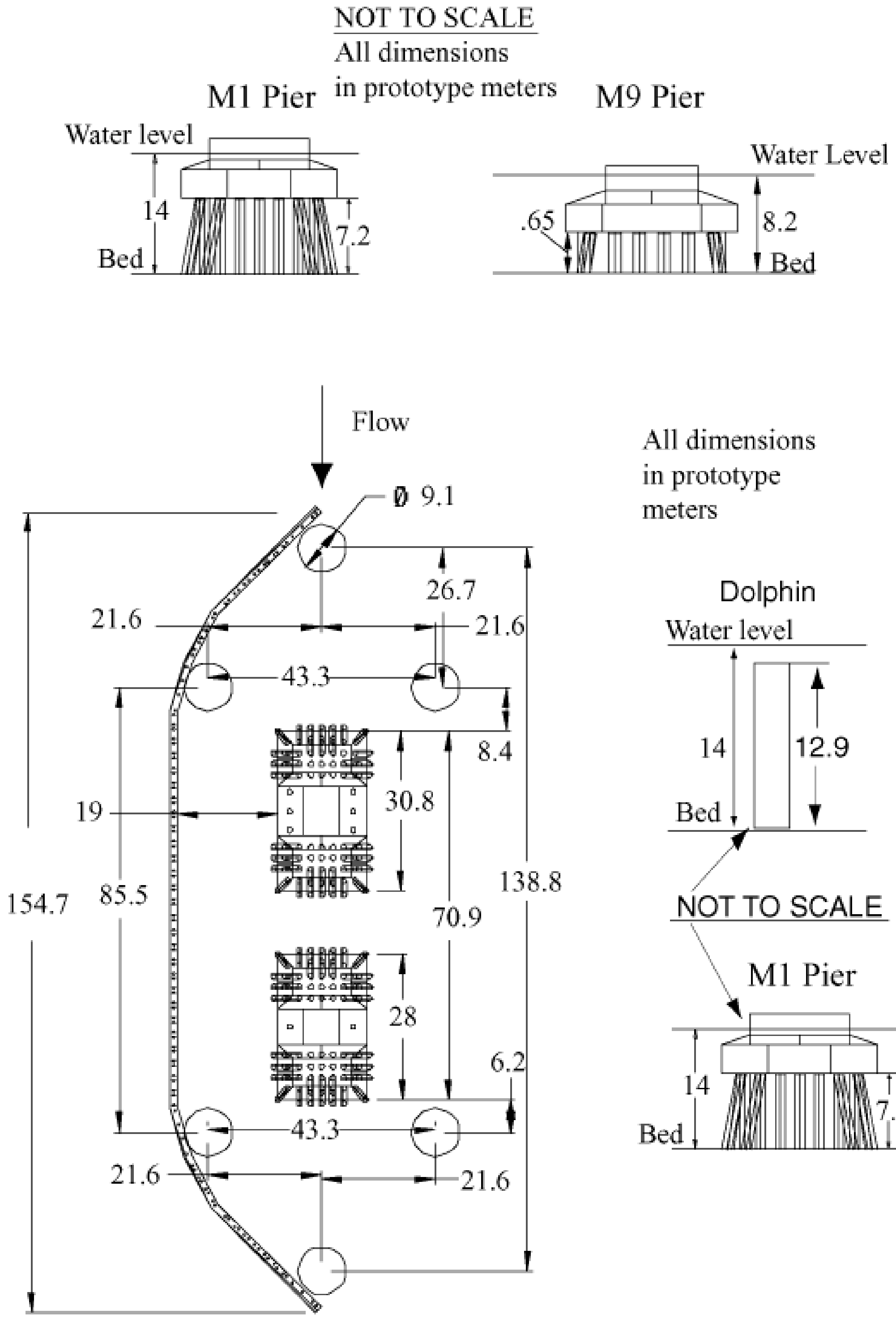

Figure 2. Diagram of the proposed Woodrow Wilson M1 pier with the dolphin and fender system.

Figure 3. Before and after test photographs of the M9 (top) and the M1 (bottom) proposed Woodrow Wilson Replacement Bridge piers

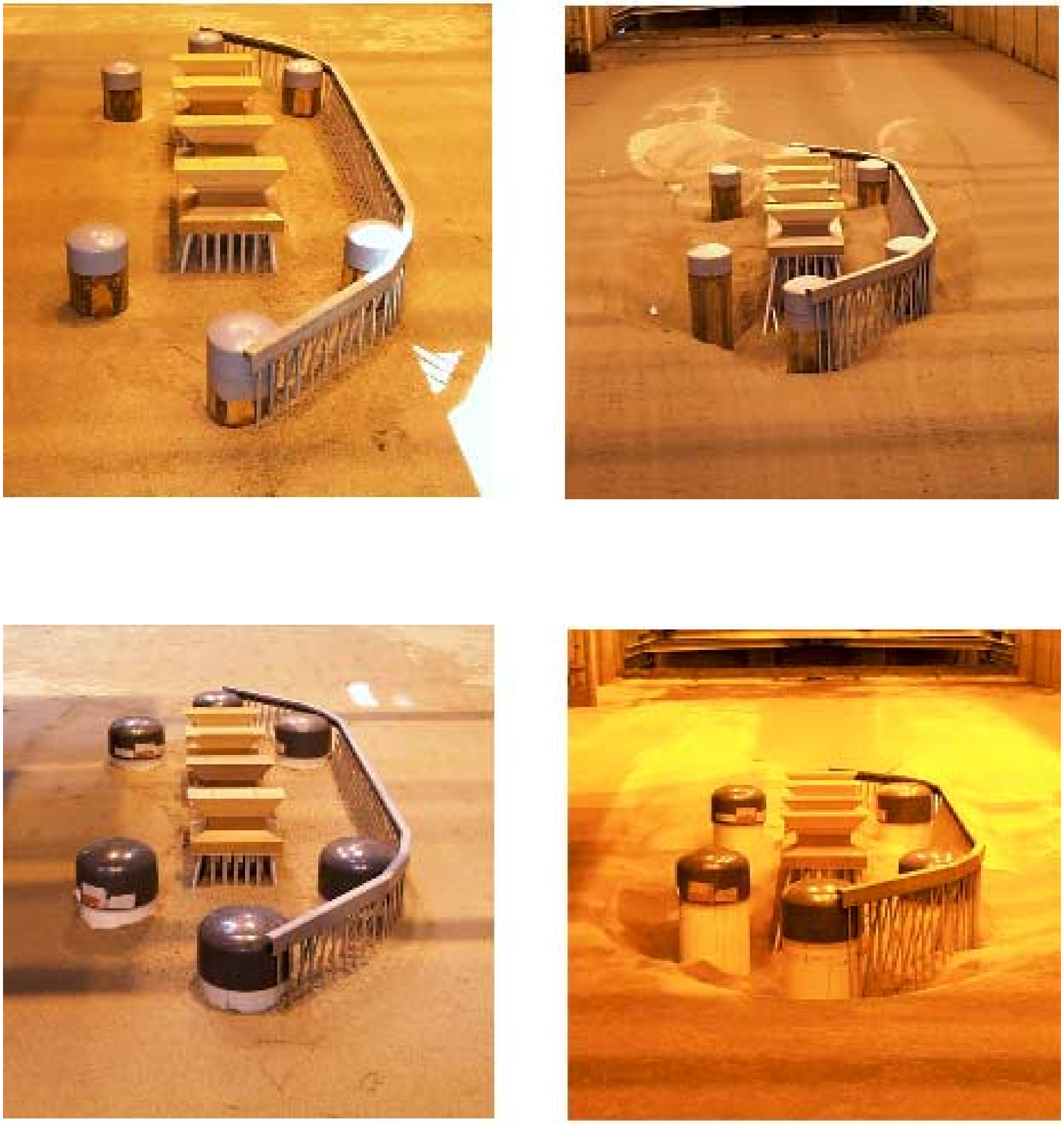

Figure 4. Before and after test photographs of the M1 pier with the 9.15 m (30 ft) dolphin system (top) and the Mi pier with the 13.72 m (45 ft) dolphin system (bottom) for the Woodrow Wilson replacement bridge.