SAND2014-15953D

Sandia National Laboratories

Exceptional service in the national interest

Particle Resuspension in Water Tanks

Jason Slavin
University of Texas at Austin, BS Mechanical Engineering, May 2016
Manager: Subhash Shinde
Mentor: Cliff Ho
Concentrating Solar Technologies, 06123
Sandia National Laboratories
Albuquerque, New Mexico 87185
U.S. Department of Energy
31 July 2014

Abstract

Objective:

Determine the flow characteristics when a water tank is draining and filling and what characteristics drive particle resuspension during draining and filling.

To accomplish this, a 1/32 scale model was constructed to simulate tank draining and filling conditions. Silica sand and glass beads were used to represent typical particles found in a water tank.

Major findings and conclusions:

Smaller particles experienced a greater amount of resuspension as compared to larger particles of the same density. The affected area surrounding the drain did not exceed about 7/10 of the drain diameter. The majority of the water tank experiences a negligible wall shear stress along the tank bottom, but near the drain, the shear stress increases exponentially.

Municipal water tank under construction (Albuquerque, NM)

1/ 32 scale water tank (SNL, NM)

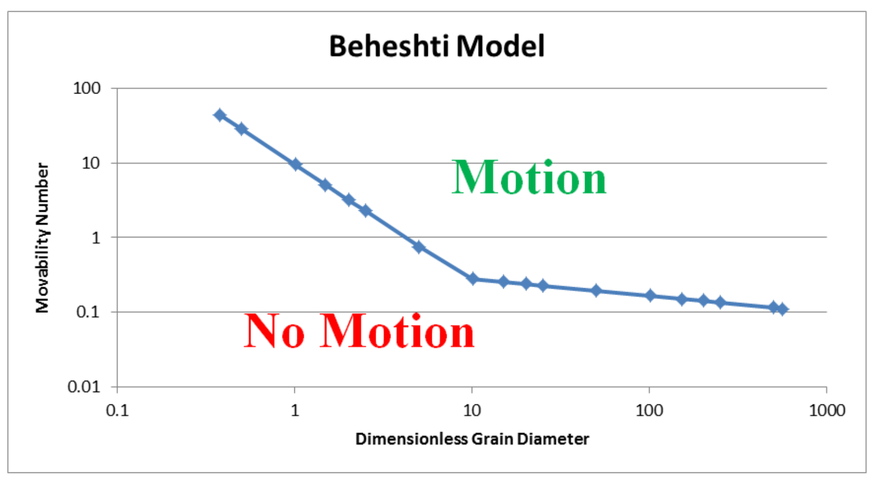
Introduction

Background and Problem:

EPA is concerned about public exposure to contaminants due to resuspension of sediments in drinking water storage tanks. Particle resuspension can occur during filling or draining and is predicted using the Beheshti model, which stipulates that the critical shear stress along the tank bottom must be great enough to initiate particle movement.

Task:

Run tests with the scale model, quantify results, compare to computational fluid dynamics (CFD) results and draw conclusions concerning which factors drive particle resuspension.

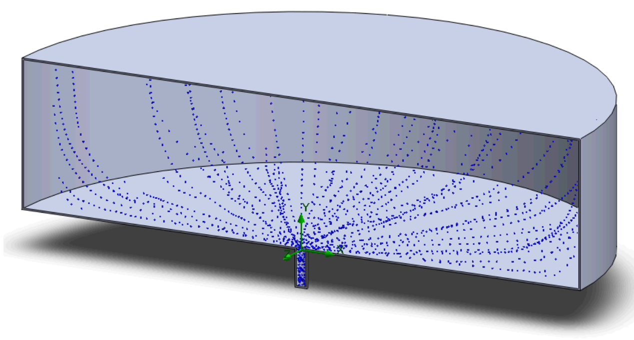


Particle resuspension occurs if the actual movability number is above a particle's critical movability number. This is represented graphically above – particle motion is initiated if the movability number at a particular point is above the curve.

Methods

Simulations:

CFD modeling was performed using Solidworks Flow Simulations. Simulations were run to model the tank draining.

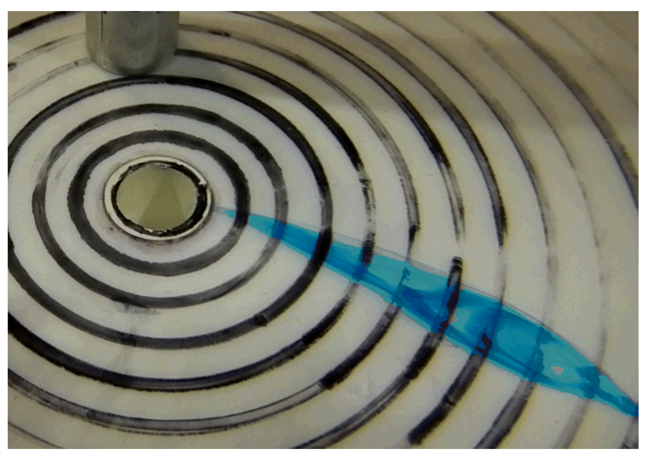


Solidworks simulation showing flow patterns during draining.

Hydraulics Testing:

Dye was used to study flow patterns during draining and filling

- Waterproof camera put in water and set to record
- Dye was injected along the bottom of the tank and at different heights
- Velocity was determined by timing the movement of the dye tracer over a known distance



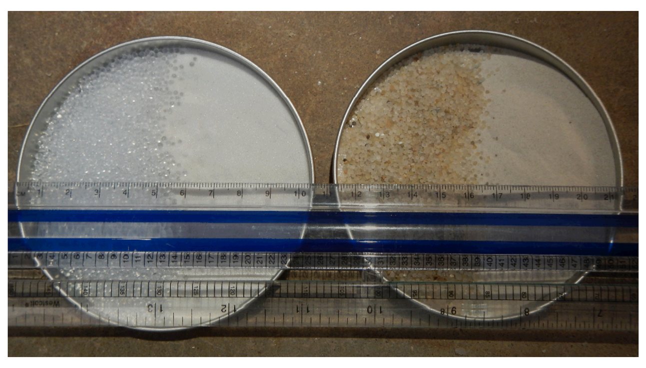
Example of hydraulic testing and velocity measurements using dye as a tracer in the water-filled tank (concentric rings are 1cm apart).

Resuspension Testing:

Three possible tank conditions were identified to test:

1. Tank filling
2. Tank draining
3. Tank undergoing a series of filling and draining cycles

- The water tank was initially filled to its starting head of water (6" for a filling test, 12" for a draining test, 9" for a cycle test)
- Particles were weighed and then poured in, uniformly surrounding the drain – particles included silica sand and glass beads
- The test was run to completion (fill to 9" for a filling test, drain to 6" for a draining test, fill to 12" and drain to 9" for a cycle test)
- Drained particles were collected in sieves, then dried and weighed
- Location of suspended particles was recorded



Particles used for testing. Note: Glass beads on left, silica sand on right.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

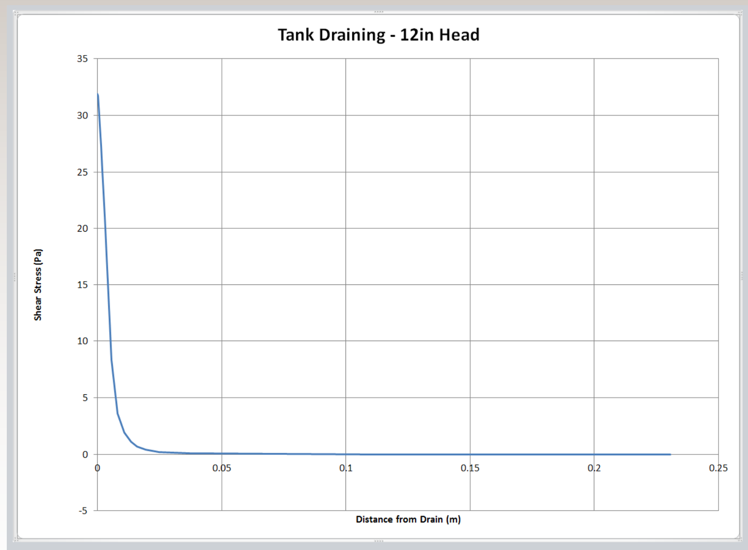
Sandia National Laboratories

Exceptional service in the national interest

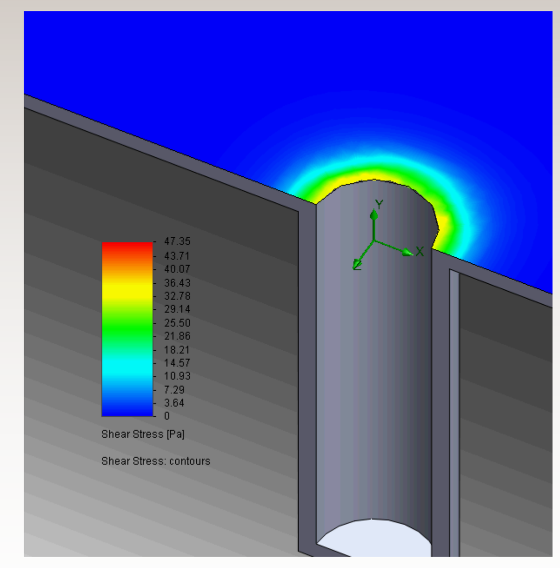
Results – Current as of 9 July

Simulation:

Solidworks simulations revealed that, during draining, shear stresses along the tank bottom were very close to zero across the majority of the tank. But within 1cm of the drain, shear stresses increased exponentially. Surface plots in Solidworks also confirmed this information.



Wall shear stresses along tank bottom using Solidworks Flow Simulation.



Contours of simulated shear stress along tank bottom near drain.

Hydraulics Testing:

Filling Test:

- Flow velocities very high within inlet area
- 1 to 2mm from drain, velocities are small as compared to inlet velocities.

Draining Test:

- Fluid velocities obtained from simulations were much higher than blue dye test results, but mirror real characteristics.
- Fluid velocities along the tank bottom far away from drain negligible compared to velocities within 2cm of drain.

Resuspension Testing:

The following controls were in place for all tests:

- Particles were distributed as a monolayer of particles within a 10cm radius surrounding the drain

Metrics:

- Mass of drained particles as a percent of the initial mass of particles.
- Radial extent of suspended particles from the drain.

Filling Tests:

- Particles within 1 to 2mm of the drain were resuspended during filling. Outside this 1 to 2mm radius of the drain, particles remained undisturbed.

Draining Tests:

- Larger particles experienced less resuspension compared to small particles of the same density.
- For large particles, the area affected during draining was within 0.4 diameters of the drain (about 0.8cm).
- For small particles, the area affected during draining was within 0.7 diameters of the drain (about 1.4cm).

Cycle Tests:

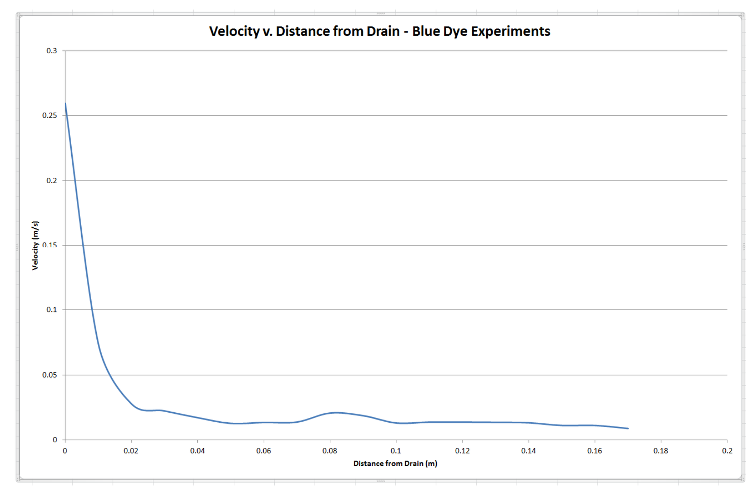
- Less large particles were drained during cycle test as compared to a pure draining test.
- More small particles were drained during cycle test as compared to a pure draining test.

Further research:

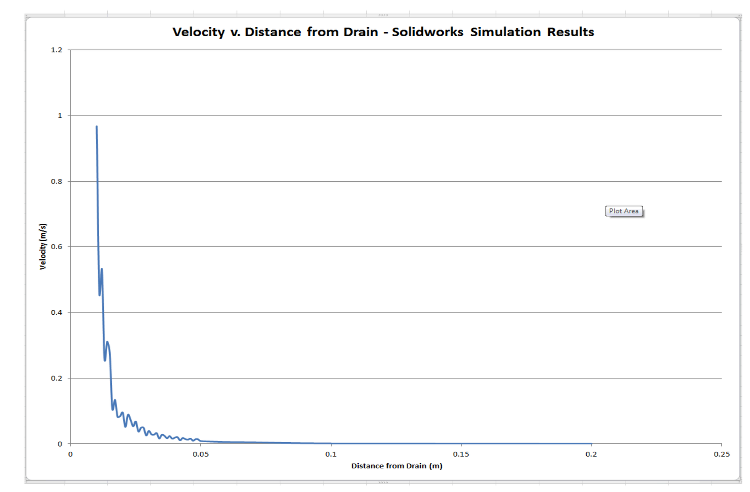
Run filling, draining, and cycle tests with lighter particles (glass beads). For any inconsistencies with data, run additional tests.

Drains in actual water tanks are not flush with the tank bottom, as is the case with our model. Preliminary Solidworks simulations predict that an extended drain will prevent particles from being resuspended during draining. Testing with the scale model will evaluate the extended drain setup.

Measured and Simulated Velocities Along the Tank Bottom During Draining



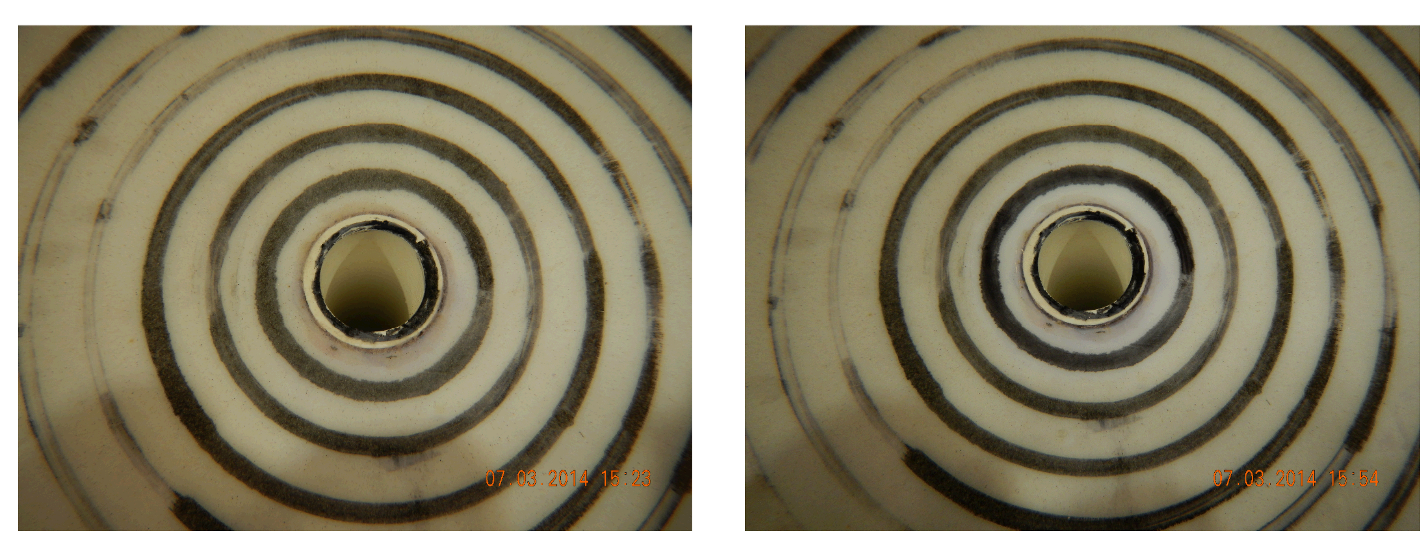
Velocities obtained from blue dye tests.



Velocities obtained from Solidworks Flow simulation.

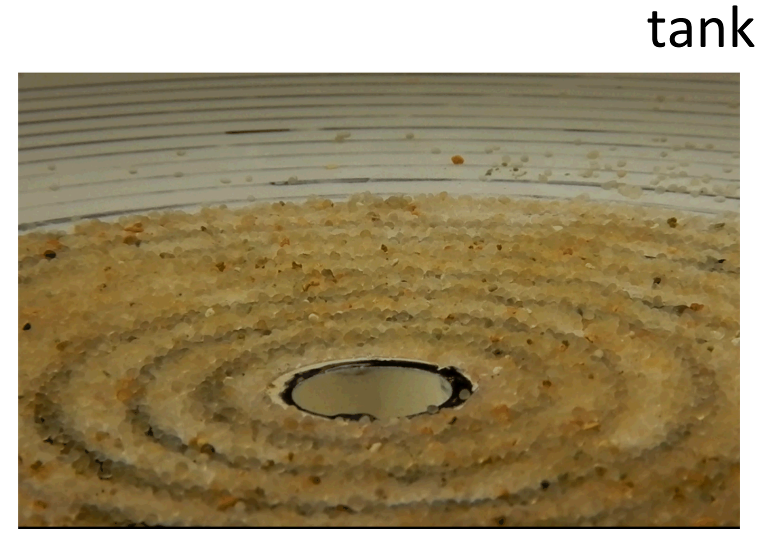
Samples from Resuspension Testing

Large grain (#12 - #20) silica sand before and after draining.

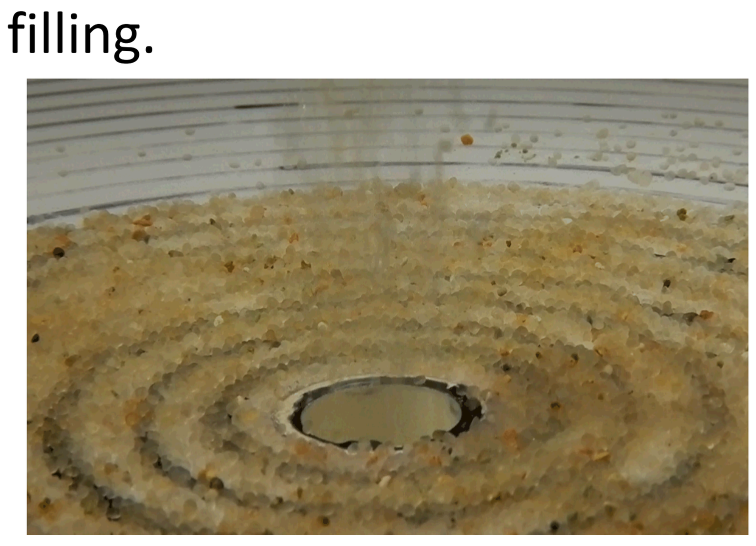


Small grain (#140 - #270) silica sand before and after draining.

Still images taken from footage of tank filling.



Before filling begins.



Onset of filling.

Discussion

The following characteristics drive particle resuspension: particle size, particle density, and wall shear stress near the drain. Particles within 0.7 diameters of the drain were resuspended. CFD results showed that shear stresses within about 1 diameter of the drain will be high enough to cause particle resuspension – these results were higher, yet consistent with test results. Simulations of commercial scale systems are consistent with the results of the smaller-scale models. Particle resuspension is expected to occur within 1 – 2 diameters of the drain when located in the center of the tank.

Funding provided by the U.S. EPA's Homeland Security Research Program

EPA United States Environmental Protection Agency

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration