Sedimentation Team Final Research Report

Sedimentation Hydraulics Team Spring 2011 Final Report

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AguaClara Reflection Report
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Date Submitted: 05/07/11

Date Revised: 05/07/11

Abstract

Our objective has been to determine the minimum angle of repose necessary for floc blanket formation. We had hypothesized that for an insert angle below 60 degree, a floc blanket would not form because the slope of the insert would be insufficient for directing settled flocs to the resuspending jet.

With an angle of repose to 30 degrees, a floc blanket formed. Experiments outlined in this report confirmed this result and showed that for a 15 degree angle of repose, floc blanket formation resulted when a buildup of sludge along the incline increased the effective angle. Insight was also gained into the mechanism of floc formation by observing the patterns of movement of flocs during the various trials.

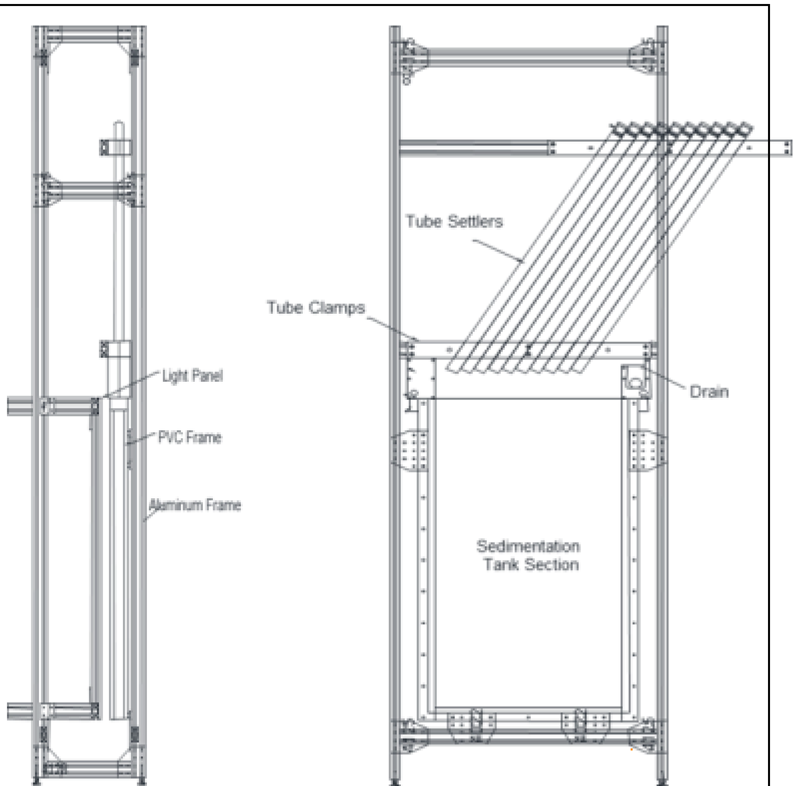
Introduction

Previously, we ran an experiment with a 30 degree incline in a 1/2 inch wide tank, which models a 2-dimensional cross section of the AguaClara sedimentation tank, believing that 30 degrees was less than the minimum angle of repose to resuspend flocs and that a floc blanket would not form. A floc blanket formed very quickly after some large air bubbles were accidentally introduced into the tank, which caused large scale mixing of flocs and sludge. Within 20 minutes, the flocs in the entire tank transitioned from a state of differential settling to hindered settling, therefore it seems that the concentration of flocs of the bulk fluid needs to be sufficiently high before hindered settling and floc blanket formation can occur. Before the floc blanket was formed, the angle of repose formed by the accumulated sludge was close to that of the incline, and the settled flocs were continuously returned to the jet. Therefore we concluded that **the minimum angle of repose is less than or close to 30 degrees. When the angle of repose is less than this minimum value, flocs that settle on the incline are unable to return to the jet and remain as sludge, resulting in no floc blanket formation.** We repeated our experiment with the 30 degree incline to ensure reproducibility, and conducted a second experiment with a 15 degree incline.

Experimental Design

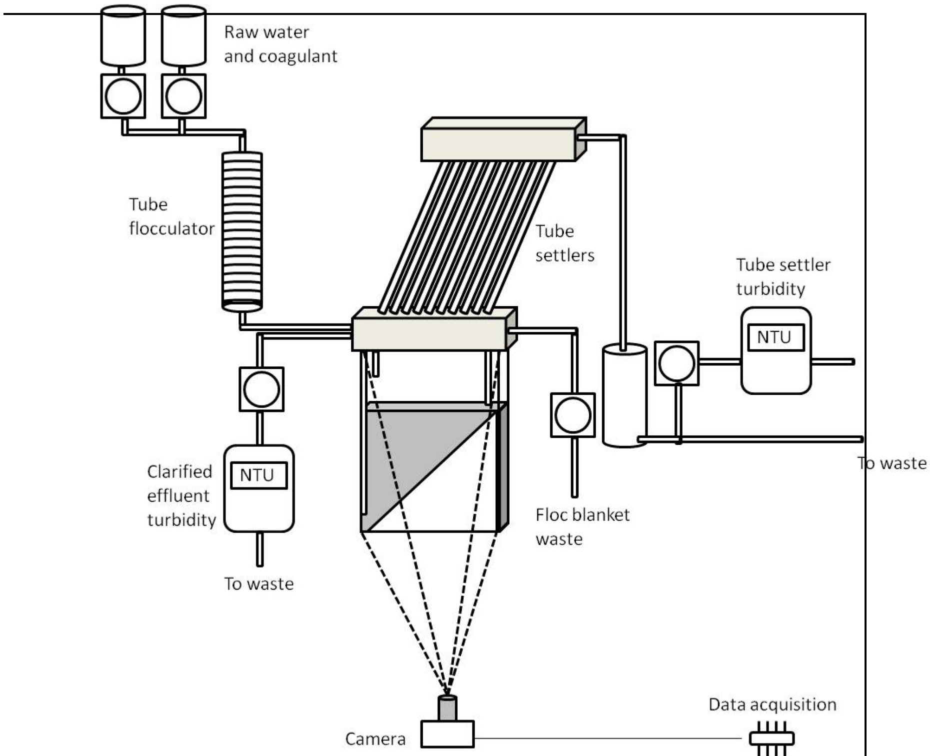
Experimental Set Up

We used the same experimental apparatus and procedure as with our previous experiment, which is documented in the Sedimentation Tank Team's Research Report 1. Figure 1 shows our half inch wide sedimentation tank.



ıre 1. AutoCAD renderings of the side view and ıt view of the sedimentation tank and light panel tem (not to scale) (Paul Charles. 2011

Floc blanket formation in the sedimentation tank was simulated using a flow of 460 mL/min of aerated water containing 45mg/L of alum. The average influent turbidity was 100 NTU made from a concentrated kaolinite clay stock regulated by the Process Controller. The raw water and alum were mixed and run through a flocculator before being expelled through a vertical downward-pointing jet suspended 10 cm from the bottom of the sedimentation tank. A triangular foam insert resting on a 10 cm high length of PVC board occupied the width of the tank bottom, leaving a small space for the jet. The tank was lit by a back light, and images of the tank were acquired every 30 seconds with a shutter speed of 20 (400 μs light exposure per shot) using data acquisition software programmed in a LabVIEW environment. These images were compiled into a video to analyze the process of floc blanket formation. This procedure is summarized in Figure 2 below.



ure 2. Schematic of water and data flow for the
ire experimental system.

Experimental Objectives

Our first experiment was a repeat run with the 30 degree insert, checking to make sure that the Process Controller was working and that the aerated water tank was full to avoid air bubbles. The purpose of this repeated experiment is to verify that a floc blanket can still form even without the large scale mixing caused by the air bubbles, as well as to check for reproducibility of our results.

We then conducted a second experiment with a 15 degree insert. We anticipated that a significant amount of sludge would accumulate on the insert until the minimum angle of repose is reached. Our observations of sludge accumulation and floc roll-off along the insert would be able to provide insight as to whether our hypothesis is correct, and we would be able to measure the minimum angle of repose when steady state is reached. This experiment would also allow us to observe the differences, if any, in the stages of floc blanket formation due to a difference in the angle of the insert.

Results and Discussion

Simplified Mass Flux Processes

Figure 3 shows a simplified model of the mass flux processes in the sedimentation tank. Before a floc blanket forms, the angle of repose is not large enough for all settling flocs to be returned to the jet, hence the settling flocs accumulate on the incline and $\dot{m}_{return} > \dot{m}_{settle}$. When the minimum angle of repose is reached, all settling flocs are returned to the jet and $\dot{m}_{return} = \dot{m}_{settle}$. At steady state, the floc blanket is fully formed and its height is maintained by continuously draining flocs by means of a floc weir. Therefore, the rate of change in mass of the floc blanket can be represented by

$$\dot{m}_{floc\ blanket} = \dot{m}_{influent} - \dot{m}_{waste}$$

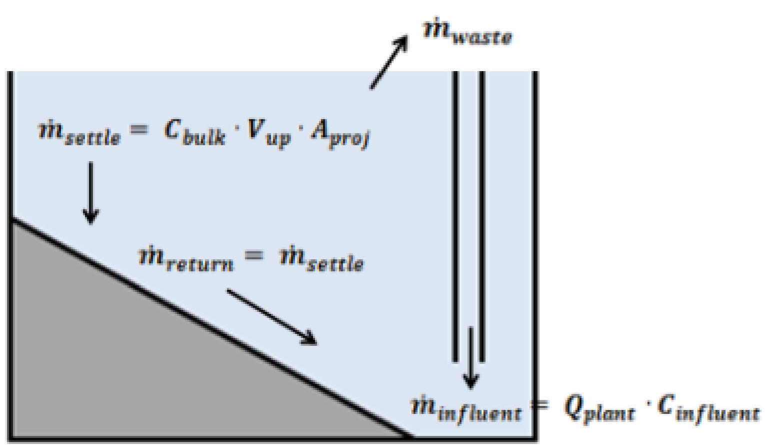


Figure 3. Simplified model of the mass flux process in the sedimentation tank.

General Results and Discussion

Floc blankets formed for both the 30 degree angle of repose and the 15 degree angle of repose, those for the latter experiment, the effective angle caused by sludge buildup was greater than 15 degrees. The time it took for floc blanket formation was greater for the more slight angle of repose, as it was first necessary to achieve the minimum angle of repose via sludge build-up. It is thought a minimal angle is necessary for the gravitational force and current forces acting on a settle floc to overcome frictional forces.

By observing the movement of flocs for the 30 degree and 15 degree angle of repose trials, we gained insight into the process of floc blanket formation. For the 30 degree trials, flocs entering the tank at the start of the trials are negatively buoyant, as flocs are more dense than water and $C_{jet} \square C_{bulk}$. Because of their small size, flocs reach the water surface before settling out. Particles generally settle out along the half of the incline closer to the jet. As the settled flocs move down the incline and are resuspended, they gain in size and settle out more quickly, the result being that they entrain the bulk fluid via large-scale mixing, facilitating floc resuspension. Because smaller flocs settle further from the jet and larger flocs fall closer to the jet to be continually resuspended, sludge built up along the incline due to friction forces increases the effective angle of repose. Constant re-suspension eventually causes the jet to become neutrally or positively buoyant, i.e. $C_{jet} \leq C_{bulk}$, and a floc blanket is formed, as shown in Figure 4. Flocs entering the sedimentation tank are added to the blanket with little bulk mixing.

For the 15 degree angle of repose trial, the initial angle of repose is not sufficient to cause resuspension of flocs. Flocs entering the tank at the start of the trial simply build up along the incline until the effective angle of repose is great enough to cause resuspension of flocs. This angle was found to be 23 degrees as illustrated in Figure 5.

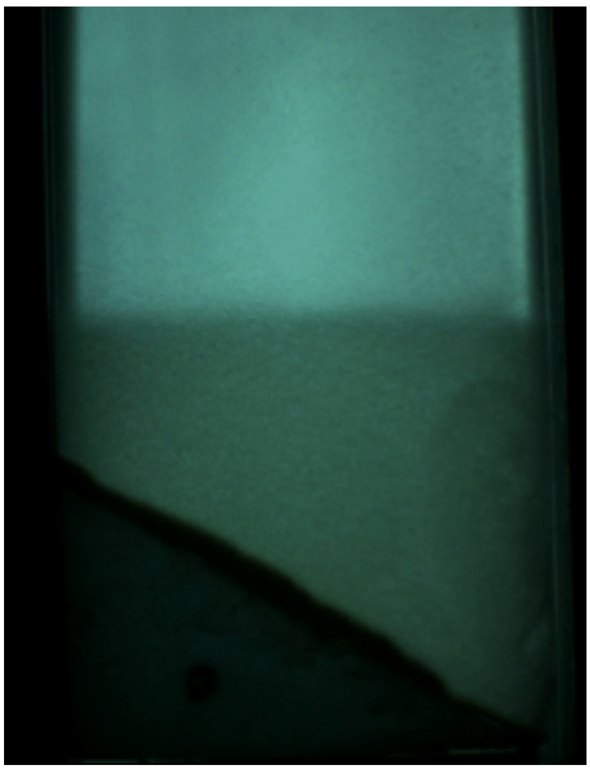


Figure 4. Floc blanket growth in sedimentation tank with angle of repose of 30°

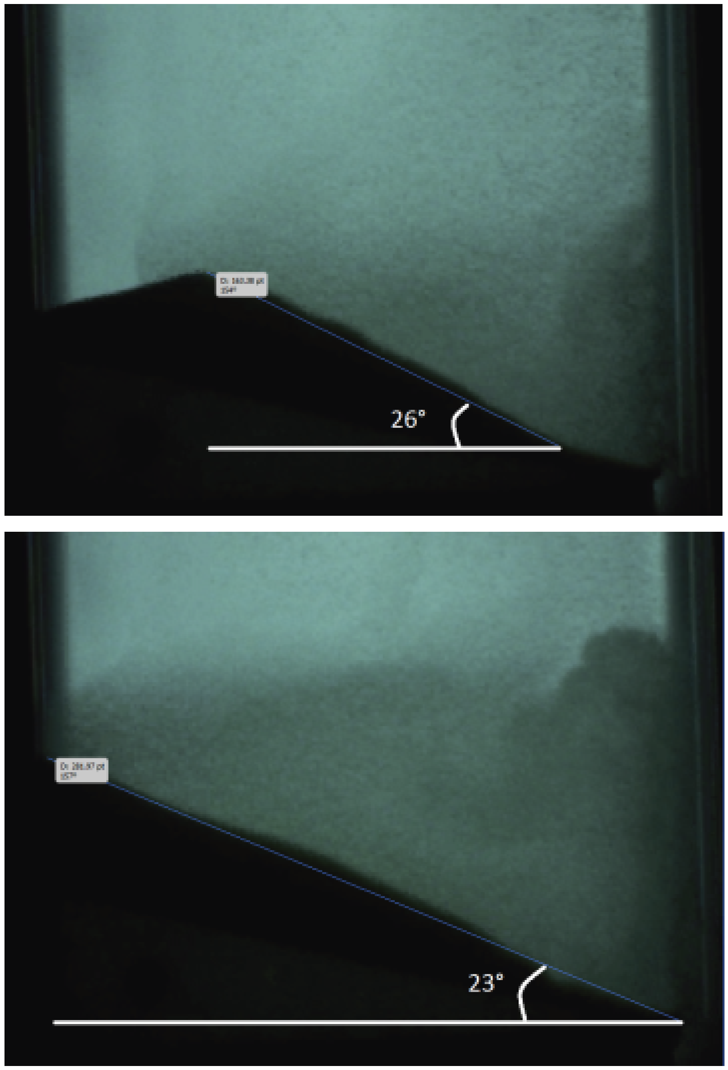


Figure 5. Sludge buildup and floc blanket formation for angle of repose of 15°. The change in the effective angle of repose may be due to redistribution of settled flocs.

Future Work

The next Sedimentation Tank Hydraulics team can conduct another experiment without the angled insert to check that the minimum angle of repose still stays at about 24 degrees. This will serve as an additional check on the validity of our hypothesis, as we expect the minimum angle of repose to be the same regardless of the angle of the insert.

We also propose moving the position of the jet from the side of the tank to the middle of the tank (see figure below). This geometry more closely resembles the bottom of the actual sedimentation tank, and wall effects on the jet are also eliminated, providing a more accurate representation of floc blanket formation.

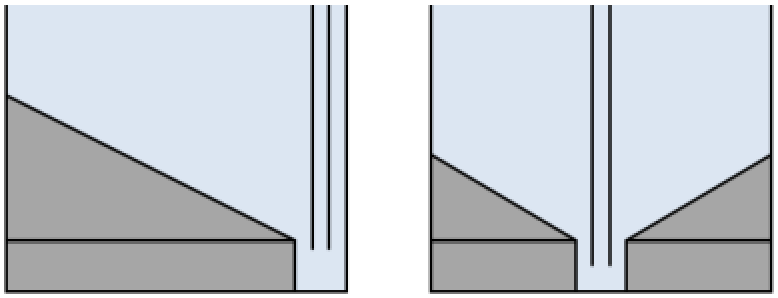


Figure 6. Current and future cross-sectional design of experimental sedimentation tank.

A [illegible] ght above the tank bottom can be varied to investigate their effects on floc blanket formation. The concentration of alum affects the stickiness of flocs on the incline while the jet height affects the effectiveness of floc resuspension, hence it is important to determine the appropriate values for these parameters.

Team Reflections

Our team faced technical difficulties with the Process Controller as we are not very familiar with the software. We were unable to get the computer to communicate with the experimental apparatus and had to rely on our team leader to help us to solve the problem. However when he fell sick, our progress was brought to a standstill. Our team should gain more familiarity with the apparatus and software so that we can conduct experiments and troubleshoot on our own when our team leader is unavailable.