Sedimentation Team Research Report 1

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Sedimentation Tank Team Reflection Report

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AguaClara Reflection Report
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Abstract

Previously our team worked on designing a scaled down model of sedimentation tank in order to study floc blanket formation in 3D models. However, we decided that it would be more effective to continue the study with the existing 2D sedimentation tank.

Using this tank our first objective was to determine the minimum angle of repose. We have hypothesized that for an insert angle below 60 degree that a floc blanket would not form. The slope of the insert would not be sufficient for the flocs to be transported to the jet, thus the flocs would accumulate on the incline.

However, even when we decreased our angle of repose to 30 degrees, we were successful in forming the floc blanket.

Introduction

The formation of a floc blanket in sedimentation tanks could significantly improve effluent performance and reduce clean water waste from frequent draining. A floc blanket is a fluidized highly concentrated bed of particles. Necessary for floc blanket formation are: 1) downward-pointing jets with $v_{scour} > v_{settling}$ 2) sloping sides that transport settled particles to the re-suspending jet.

It is believed that for flocs entering the tank before blanket formation $C_{jet} > C_{bulk}$, and settling flocs rapidly entrain the bulk fluid. This, and the incline, causes movement of flocs towards the downward-pointing jet. Resuspension may increase individual floc size causing differential settling out along the length of the incline, changing the angle of repose. Constant resuspension eventually causes the jet to become neutrally or positively buoyant ($C_{jet} \leq C_{bulk}$) and a floc blanket is formed. Flocs entering the sedimentation tank are added to the blanket with little bulk mixing.

We wish to find the minimum angle of repose to resuspend flocs. This 1) maximizes the effective area of the tank, 2) decreases tank height. Differential settling out of floc sizes along the incline may change the effective angle of repose. It is hypothesized that for slight angles of repose, settled flocs are unable to return to the jet and remain as sludge. We tested this hypothesis for a 30 degree angle of repose.

Experimental Design

A flow of 4 60 mL/min of water containing 45mg/L of alum and an average influent turbidity of 100 NTU made from a concentrated kaolinite clay stock regulated by Process Controller was run through a flocculator before being expelled through a vertical downward-pointing jet suspended 10 cm from the bottom of the sedimentation tank. A 30 degree incline made of foam resting on a 10 cm high length of PVC board occupied the width of the tank, leaving a small space for the jet. The incline was measured and cut using a razor blade and then soaked before the paper layer was removed and the foam laminated with tape. The position of the PVC board was maintained by drilling two holes in the board to hold magnets and placing additionaly magnets outside the tank. Clean aerated water in the tank was replaced by the influent starting at t=0, and images of the tank were acquired every 30 seconds with a shutter speed of 20 (400 µs light exposure per shot) from data acquisition software programmed in a LabVIEW environment . These images are taken to record the presence of a floc blanket and to observe the characteristics needed for floc blanket formation.

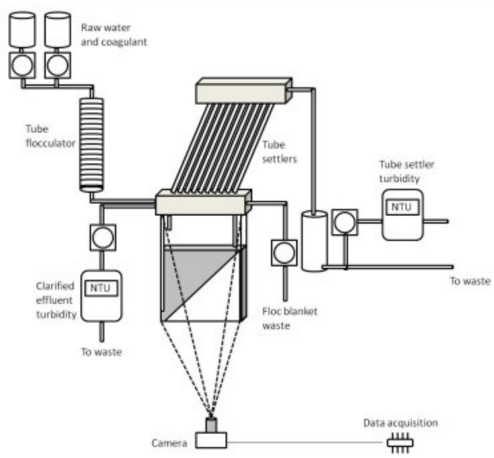

Figure 1. Schematic of turbid water flow through flocculator and sedimentation tank and data acquisition

Results and Discussion

Summary of Results

The video of our first experiment showed the formation of a floc blanket when the angle of incline was 30°. However this only occurred after some large bubbles were unexpectedly pumped into the tank, causing excessive turbulence and mixing.

Initially, flocs were transported upwards by the incoming jet, before settling on the incline, causing a thick layer of sludge to build up. The sludge occasionally slid down the incline and was re-suspended by the upward jet (Figure 1).

At 00:21 in the video, a dense cloud of flocs was re-suspended from the bottom of the incline, as large air bubbles were pumped into the tank (Figure 2). This was immediately followed by very large eddies that caused mixing of flocs and water throughout the whole tank (Figure 3). Upon settling, most of the flocs remained in suspension in the region directly above the incline, forming a floc blanket with a distinct floc-water interface at 00:30 (Figure 4). The jet continued to re-suspend settled floc particles which settled on top of the floc blanket, and the flocculator continued to add mass, causing the blanket to increase in height. The thickness of the sludge layer on the incline remained fairly constant.

At 1:12, huge eddies was generated again, presumably due to more large air bubbles, significantly stirring up flocs and essentially destroying the floc blanket (Figure 5).

Figure 1. Settling flocs causing buildup of sludge on incline

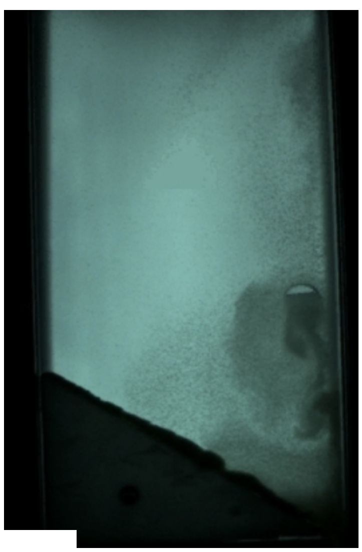

Figure 3. Large eddies mix flocs and water throughout the tank.

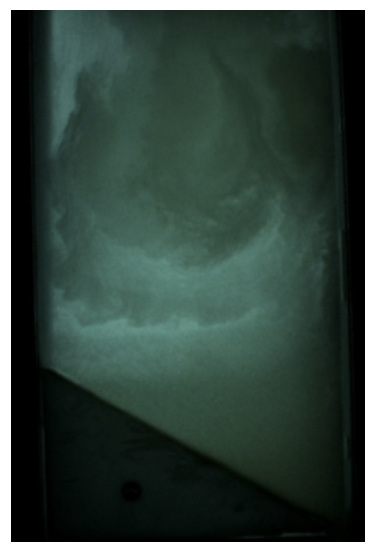

Figure 5. Floc blanket is destroyed when more air bubbles cause large scale mixing.

Discussion

Our observations for the period before 00:21 were consistent with our hypothesis that flocs will initially settle on the incline and form sludge. It is only when sludge accumulation sufficiently increased the angle of repose that the flocs were able to roll down the incline and become re-suspended by the upward jet. From the images, the angle of repose formed by the accumulated sludge was very similar to that of the incline, therefore we hypothesize that the minimum angle of incline is close to or less than 30°.

As the floc blanket formed within 10 min of the appearance of air bubbles, it seems that large scale mixing helped to initiate and speed up the process of floc blanket formation. Initially, the flocs exhibited characteristics of flocculated settling – they settled as distinct individual particles with settling velocities directly proportional to the density of flocs. We suspect that when the settled sludge was stirred up, the flocs transitioned from the flocculated settling state to the hindered settling state, which is the favorable state for floc blanket formation. In hindered settling, the flocs interact with each other to form a fluidized blanket of particles and their settling velocity decreases as the density of the fluidized blanket increases. We hypothesize that the density of the bulk fluid needs to be sufficiently high before hindered settling can take place, hence large scale mixing could have encouraged this type of settling by stirring up concentrated sludge, increasing the concentration of flocs in the bulk fluid.

Large scale mixing is not desirable after the floc blanket has been formed, as this can cause the blanket to be destroyed. From the video, it seems that eddies from large bubbles pulled the flocs upwards and out of the tank. In a real AguaClara plant, this implies that flocs from the floc blanket are forced up through the plate settlers at high velocity, which will significantly increase effluent turbidity. This is one of the potential drawbacks of having a floc blanket in the sedimentation tank. Besides the occasional presence of large air bubbles, circular flow in the sedimentation tank could also cause large scale mixing. Circular flow occurs as a result of the horizontal velocity component of jets leaving the orifices of the inlet manifold.

Upon investigation, we later found out that the bubbles were the result of the Process Controller ceasing communication with the raw water tank; hence the tank was not refilled and eventually ran out of water. In our next experiment, we will fix the technical problem with the Process Controller and run the same experiment again to test if 30° is a sufficiently steep angle of incline for floc blanket formation.

Future Work

Since we were not conclusive in determining the minimum angle of repose, we would like to continue with experimenting with smaller angles. We have already prepared an insert for an angle of 15 degrees. We are hoping that this experiment will help us to measure the angle of the sludge settlement on the insert which will help us to determine the minimum angle of repose.

We would also like to see the effects on the floc blanket formation with different jet heights. Currently our jet is placed 10 cm above the bottom of the tank, however, we do not know whether this is the ideal position of the jet. We would want to vary the height to see the different effects on floc blanket formation and then model this affect with jet equations.

Team Reflections

Our team had trouble deciding what to do after knowing that our 3 - D model might not be the best design to pursue with our research. For a while we were contemplating on the idea of exploring the fabrication method for attaching diffusers to existing manifold. However, we were lucky enough to continue our research using the 2-D model. We were still able to work on producing optimal design of the bottom of sedimentation tank for floc blanket formation.

Although we did not get to start our experiments early in the semester, using the apparatus, through working on designing and studying the different equations that govern the floc blanket formation, our team was able to learn many things that would help us in understanding the parameters that affect floc blanket formation. So it may have seemed like we were not making any progress, but, we believe that our experiments that we desire to run with 2-D models can be done efficiently and effectively because we have spent a reasonable amount of time learning and understanding the theory behind it.

We are still in the stage of learning how to operate the complex 2-D sedimentation tank apparatus. It is complicated because it has many steps such as alum dosing, turbidity monitoring and tube flocculation that needs to be done properly before running our sedimentation tank in order to produce desirable flocs for optimal floc blanket formation.

In terms of team dynamics, all of us are very enthusiastic and interested in this research, which makes the team more efficient and effective.