Measurement of Parameters Affecting the formation and breakage of floc

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Neha Bhadbhade, Jason Vogel, Daniel Storm, Billy Barfield, Aaron Mittlestet, Hayat Azawi Kareem, Karl Garbrecht, Alex Tobergte
Oklahoma State University, Stillwater, OK
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Sediments from construction site are the primary pollutant in stormwater runoff

Construction sites can add up to 35-45 tons of sediment per acre each year

Excess sediment can impair the streams, cause ecological damage and also impede navigation

Source: EPA
BMP for Sediment and Runoff Control

Sedimentation Basin

Grass lined channel

Silt Fence

Vegetative Filter Strip

Fiber rolls

Source: EPA
Most commonly used in water and wastewater treatment

Two step process: Coagulation and Flocculation

Coagulation: Particle destabilization

Flocculation: Particle aggregation and growth

Source: Environmental Outlook
Objectives of the project

“Develop a model which can determine the parameters that affect the floc formation and breakage for a particular soil type”
Parameters Affecting Flocculation

* Collision of particles: Brownian Motion, Laminar or turbulent shear, Inertia in turbulent flow and differential settling

* Efficiency of the flocculation process depends
  - Collision frequency
  - Stickiness coefficient

* Breakage of the flocs is caused by turbulent shear forces on the surface of the floc
Flocculation model used is based on the research work done by Krishnappan and Marsalek (2002).

The model consists of the following stages
- Coagulation equation to determine the balance of the number of particles undergoing flocculation
- Advection-diffusion equation for settling
Flocculation Model: Mathematical Formulation

\[
\frac{d n_i}{dt} = - \sum_{j=i}^{N_{\text{max}}} \beta_{ij} K_{ij}^{\text{eff}} n_i n_j + \sum_{j=1}^{i} \beta_i f_{ij} K_{ij}^{\text{eff}} n_i n_j + \sum_{j=1}^{i-1} \left(1 - f_{i-1,j}\right) \beta_{i-1} K_{i-1,j}^{\text{eff}} n_{i-1} n_j
\]

\[
\beta_{ij} = \text{the coagulation factor}
\]

\[
K_{ij}^{\text{eff}} = K_{i,j}^{Kh, BR} + \sqrt{\left(K_{i,j}^{Kh, Sh}\right)^2 + \left(K_{i,j}^{Kh, IN}\right)^2 + \left(K_{i,j}^{Kh, DS}\right)^2}
\]
### Flocculation Model: Mathematical Formulation

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Collision Frequency Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brownian motion</td>
<td>( K_{i,j}^{Kh,B} = \frac{2}{3} \frac{B_z T}{\rho \nu} \left(\frac{r_i + r_j}{r_i r_j}\right)^2 )</td>
</tr>
<tr>
<td>Turbulent shear</td>
<td>( K_{i,j}^{Kh,SH} = \frac{4}{3} \left(\frac{\varepsilon}{\nu}\right)^{0.5} \left(r_i + r_j\right)^3 )</td>
</tr>
<tr>
<td>Inertia of particles in turbulent flow</td>
<td>( K_{i,j}^{Kh,IN} = 1.21 \frac{\rho_{si}}{\rho_j} \left(\frac{\varepsilon^3}{\nu^5}\right)^{0.25} \left(r_i + r_j\right)^2 \text{abs}\left(r_i^2 - r_j^2\right) )</td>
</tr>
<tr>
<td>Differential settling</td>
<td>( K_{i,j}^{Kh,DS} = \frac{2\pi g}{9\nu} \frac{\rho_{si} - \rho_w}{\rho_w} \left(r_i + r_j\right)^2 \text{abs}\left(r_i^2 - r_j^2\right) )</td>
</tr>
</tbody>
</table>

\[
\beta_{i,j} = \alpha_0 \left(1 - \frac{R_{i,j}}{S+1}\right)^n
\]

- \( \alpha_0 \) = the stickiness coefficient
- \( R_{i,j} \) = floc size in the bin
- \( S \) = maximum floc size
Flocculation Model: Mathematical Formulation

Advection Diffusion Equation:

\[ \frac{\partial C_k}{\partial t} + w_k \frac{\partial C_k}{\partial z} = \frac{\partial}{\partial z} \left( D \frac{\partial C_k}{\partial z} \right) \]

- \( C_k \) = concentration of the particle
- \( w_k \) = settling velocity of the particle
- \( D \) = turbulent diffusion coefficient
## Experimental Setup

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Dimension/ Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Separator</td>
<td>Rectangular flume with overflow weir plate at the outlet</td>
<td>Flume: 10ft x 8in x 4ft (LxWxH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weir Plate: 12in x 8 in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weir depth= 1.18 in</td>
</tr>
<tr>
<td>Sediment injection system</td>
<td>Conical tank with backflow and normal flow systems and impeller for mixing</td>
<td>Capacity: 450 gallons</td>
</tr>
<tr>
<td>Flocculant injection system</td>
<td>Peristaltic pump system</td>
<td>Capacity of Flocculant Tank: 16 gallons</td>
</tr>
<tr>
<td>Oscillating grid Assembly</td>
<td>Three sets of oscillating grids each having three individual grids</td>
<td>Rod diameter: 3/16 in Grid dimension: 6in x 6in</td>
</tr>
<tr>
<td>Constant head tank</td>
<td>Rectangular tank with flow straighteners and V-notch weir at the outlet.</td>
<td>10 ft x 5 ft x 3 ft (LxWxH)</td>
</tr>
<tr>
<td>Sedimentation Basin</td>
<td>Rectangular Flume with sampling ports along the flume</td>
<td>30 ft x 1.5ft x 0.5ft (LxWxH)</td>
</tr>
</tbody>
</table>
Experimental Setup

Soil Separator

Sediment injection system
Experimental Setup

Constant Head Tank

Flocculant injection system
Experimental Setup

Oscillating grid assembly

Flume with sampling ports
Three soils from Greenville county of South Carolina were tested: Hiwassee, Pacolet and Cecil.

Flow rate of water in the flume: 0.1 cfs (6 in flow over V notch)

Concentration of the flocculant in flume: 0.05 g/L

Four types of experimental runs
- Control run with agitation
- Control run without agitation
- Low speed flocculation run
- High speed flocculation run
Experimental Setup

* Duration of Experimental run: average 15 minutes

* Sampling: 10 samples at five stations were collected from top and bottom port

* Sampling interval: 90 seconds

* Sampling volume: 250 ml

* Turbidity measurement: Inlet and outlet of the flume
Data Analysis: Hiwassee Soil

High Speed Flocculation Run (Turbidity)

- Turbidity, NTU
- Sample number

Low Speed Flocculation Run (Turbidity)

- Turbidity, NTU
- Sample number

High Speed Flocculation run (TSS)

- TSS, g/L
- Sample number

Low speed flocculation run TSS

- TSS, g/L
- Sample number

Turbidity:
- High Speed: Station 1 top port, Station 2 top port, Station 3 top port, Station 4 top port
- Low Speed: Station 1 top port, Station 2 top port, Station 3 top port, Station 4 top port

TSS:
- High Speed: Station 1 top port, Station 2 top port, Station 3 top port, Station 4 top port
- Low Speed: Station 1 top port, Station 2 top port, Station 3 top port, Station 4 top port
Data Analysis: Pacolet Soil

High Speed Flocculation Run (TSS)
- Station 1 top port
- Station 2 top port

Low Speed Flocculation Run (TSS)
- Station 1 top port
- Station 2 top port
- Station 3 top port
- Station 4 top port

High Speed Flocculation Run (Turbidity)
- upstream
- downstream

Low Speed Flocculation Run (Turbidity)
- upstream
- downstream
Data Analysis: Trapping Efficiencies

Hiwassee

- None
- Low Speed
- High Speed
Data Analysis: Trapping Efficiencies

Pacolet

None  Low Speed  High Speed

C3  C4  F6  F8  F7  F9

TE

Bar chart showing trapping efficiencies for different Pacolet models at low and high speeds.
Data Analysis: Trapping Efficiencies

TE

Cecil

C6 None

C5

Low Speed

F11

F10 High Speed

F12

Efficiency Levels:
- None
- Low Speed
- High Speed
Data Analysis: Local Soil
Current Modeling Stage and Future Work

* The model is being coded using Visual Basic
* The model will be tested using the experimental data
* The stickiness coefficient will be estimated for the three soils
* More soils will be tested to validate the model
Contributors

Faculty advisors : Dr. Jason Vogel, Dr. Daniel Storm

Subject Matter Specialist: Dr. Billy Barfield

Mr. James Riddle, Woolpert Inc.

Greenville county, South Carolina

Graduate Students: Neha Bhadbhade, Aaron Mittlestet, Karl Garbrecht, Alex Tobergte Hayat Azawi Kareem, Erin Daly, Flint Holbrook
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<th>Year</th>
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<tr>
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Questions ??