Pumping Stations Design
For Infrastructure Master Program
Engineering Faculty-IUG

Lecture 7: Design of sludge pumping stations

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7.1 General introduction

- **Sludge definition:**
  Sludge is a fluid composed of a mixture of water and solids. Some of these solids are dissolved and some are suspended. The suspended solids are the most important part and their concentration is in the range of 1% to 10% according to sludge type.

- **Types of sludge:**
  1. Primary sludge (solids concentration 3-5%)
  2. Secondary sludge (solids concentration 1-1.5%)
  3. Digested sludge (Solids concentration 6-7%)
  4. Thickened sludge (Solids concentration 8-10%)
7.2 Hydraulics of Sludge pumping

- The sludge is a non-Newtonian fluid, so its flow properties is different from Newtonian fluids such as water and wastewater. Thus, the equations used to determine the hydraulics of water and wastewater doesn't apply for sludge.

- The main cause of classifying sludge as a non-Newtonian fluid is the presence of solids in the range of 1% and above.

- The hydraulics of sludge pumping is highly dependent on the concentration and properties of the solids in the sludge.

- The sludge flow is classified into laminar flow or turbulent flow.
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7.2 Hydraulics of Sludge pumping

Laminar flow in sludge pumping systems:

Bingham equation is used for defining the hydraulics of sludge in the laminar range:

\[ \frac{h}{L} = \frac{16s_y}{3D \rho g} + \frac{32\eta V}{\rho g D^2} \]

Where,

- \( h \) = headless in the pipe, m
- \( L \) = pipe length, m
- \( s_y \) = yield stress of the sludge, N/m\(^2\)
- \( \rho \) = sludge density, kg/m\(^3\)
- \( D \) = pipe diameter, m
- \( g \) = gravitational acceleration, 9.81 m/s\(^2\)
- \( \eta \) = coefficient of rigidity, kg/(m.s)
- \( V \) = flow velocity, m/s
7.2 Hydraulics of Sludge pumping

Laminar flow in sludge pumping systems:

To apply the Bingham equation the flow should be laminar. Bingham defined the lower critical velocity \( (V_{lc}) \) to check for laminar flow. If the selected design velocity of sludge pumping is less or equal to \( V_{lc} \) then the flow is laminar, otherwise the flow is turbulent.

\[
V_{lc} = \frac{1000\eta + 1000\sqrt{\eta^2 + s_y \rho D^2 / 3000}}{D\rho}
\]

Note:
• The values of \( s_y \) and \( \eta \) are taken from figures 19.2 and 19.3.
• The Bingham equations are valid for laminar flow only.
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Figure 19-2. Yield stress versus sludge solids.

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Figure 19-3. Coefficient of rigidity versus sludge solids.
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7.2 Hydraulics of Sludge pumping

Turbulent flow in sludge pumping systems:

Hanks and Dadia equation is used for defining the hydraulics of sludge in the turbulent range:

\[
\frac{H}{L} = \frac{2fv}{gD}
\]

or

\[
\Delta p = \frac{2f\rho LV}{D}
\]

Where,

- \( H \) = headless in the pipe, m
- \( L \) = pipe length, m
- \( \Delta p \) = pressure drop, N/m²
- \( \rho \) = sludge density, kg/m³
- \( D \) = pipe diameter, m
- \( G \) = gravitational acceleration, 9.81 m/s²
- \( f \) = friction factor
- \( V \) = flow velocity, m/s
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7.2 Hydraulics of Sludge pumping

The friction coefficient ($f$) is found from figure 19.6 after calculating ($He$) and ($R$) from the following equations:

Hedstrom number:

$$He = \frac{D^2s_y \rho}{\eta^2}$$

Reynolds number:

$$R = \frac{DV \rho}{\eta}$$

Where:

- $He$ = Hedstrom number, dimensionless
- $R$ = Reynolds number, dimensionless
- $s_y$ = yield stress of the sludge, N/m²
- $\rho$ = sludge density, kg/m³
- $D$ = pipe diameter, m
- $H$ = coefficient of rigidity, kg/(m.s)
- $V$ = flow velocity, m/s
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7.2 Hydraulics of Sludge pumping

Figure 19-6. Theoretical friction factor for sludge analyzed as a Bingham plastic. After EPA [2].
7.2 Hydraulics of Sludge pumping

- Approximate method for headless calculations

Figure 19.5 gives the headless as a factor of the headless calculated for water or wastewater using the equation of Hazen Williams with a coefficient of Friction C=140.
7.2 Hydraulics of Sludge pumping

- Typical sludge pumping system curve compared to water pumping system curve

Using the headless equations you can draw the system curve for sludge systems. Figure 19.10 is an example of a system curve for a 6 in pipe. Notice the difference between the system curve for water and for sludge having different solids concentrations.

![System curve comparison](image-url)
7.2 Hydraulics of Sludge pumping

- Sludge pressure pipes sizing:
  - Max. design velocity is 1.8 m/s.
  - Min. velocity is 0.6 m/s.
  - Min. pipe diameter is 6 in.
  - Pump connections should not be less than 4 in.
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7.3 Sludge pumping stations

- Sludge pumping stations types:
  1. Submersible pumps
  2. Dry pumps

Submersible pumps and dry pumps are similar to wastewater pumping stations in terms of wet wells and dry wells and the piping layout and valves.

- Types of pumps used for Sludge pumping:
  1. Centrifugal Vortex pumps
  2. Diaphragm pumps
  3. Rotary pumps
  4. Progressive cavity pumps
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7.3 Sludge pumping stations

- Sludge pumping stations types:

Centrifugal Vortex pump
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7.3 Sludge pumping stations

- Sludge pumps types:

Progressive cavity pump
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7.3 Sludge pumping stations

- Sludge pumps types:

Diaphragm pump
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7.3 Sludge pumping stations

- Sludge pumps types:
  - Rotary Lobe pump
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7.4 Typical location of sludge pumping stations

Sedimentation Tank

Submersible sludge pumping station
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7.4 Typical location of sludge pumping stations