APPENDIX C

THE DETERMINATION OF SLURRY DENSITY BASED ON THE VOLUME AND WEIGHT CONCENTRATION OF THE SOLID PARTICLES

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This section explains how the specific gravity of a slurry (SG_M) is related to the solid's particle weight and volume concentration.

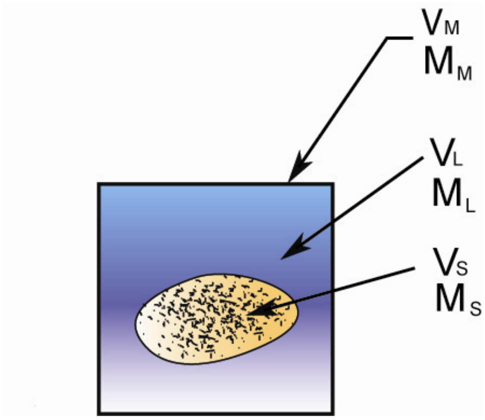

Figure C-1 Variables related to the calculation of the specific gravity of a slurry.

Definitions

V_M : volume the slurry mixture
M_M : mass of the slurry mixture
V_L : volume of the liquid portion of the mixture
M_L : mass of the liquid portion of the mixture
V_S : volume of the solid portion of the mixture
M_S : mass of the solid portion of the mixture
C_V : concentration by volume of the solid particles in the mixture or the **ratio** of the volume of the solids to the total mixture volume
C_W : concentration by weight of the solid particles in the mixture or the **ratio** of the weight of the solids to the total mixture weight
SG_S : specific gravity of the solids portion of the mixture
SG_L : specific gravity of the liquid portion of the mixture
SG_M : specific gravity of the mixture
ρ_S : specific gravity of the solids portion of the mixture
ρ_L : specific gravity of the liquid portion of the mixture
ρ_M : specific gravity of the mixture
ρ_{WA} : specific gravity of water at standard conditions
M : mass flow rate
q : volumetric flow rate

The mass of the solid particles (M_S) is:

$$M_s = \rho_S \quad V_S$$

and the solids density ρ_S can be expressed as a specific gravity. Specific gravity is a ratio of the density of the substance to the density of water at standard conditions ρ_{wa} :

$$\rho_s = SG_S \quad \rho_{WA}$$

By definition $C_w = M_S/M_M$

The volume of the mixture can be expressed as the sum of the solids volume and the carrying liquid volume:

$$V_T = \frac{C_W M_M}{\rho_S} + \frac{(1 - C_W) M_M}{\rho_L}$$

If we divide both sides of the equation by M_M we obtain:

$$\rho_M = \frac{1}{\frac{C_W}{\rho_S} + \frac{(1 - C_W)}{\rho_L}} \qquad \text{[C-1]}$$

It is often easier to use the specific gravity (SG) of the substance instead of the density. Since $\rho_S = SG_S \times \rho_{WA}$, $\rho_M = SG_M \times \rho_{WA}$ and $\rho_L = SG_L \times \rho_{WA}$ then

$$SG_M = \frac{1}{\frac{C_W}{SG_S} + \frac{(1 - C_W)}{SG_L}}$$

Similarly the weight of the mixture can be expressed as the sum of the solids weight and the carrying liquid weight:

$$M_M = C_V V_M \rho_S + (1 - C_V) V_M \rho_L$$

If we divide both sides of the equation by V_M we obtain:

$$\rho_M = C_V (\rho_S - \rho_L) + \rho_L \qquad \text{[C-2]}$$

and expressed in terms of specific gravity:

$$SG_M = C_V (SG_S - SG_L) + SG_L$$

We can establish a relationship between C_V and C_W without using the specific gravity of the mixture SG_M. Notice that the right hand sides of equations C-1 and C-2 are equal, therefore:

$$C_V(\rho_S - \rho_L) + \rho_L = \frac{1}{\dfrac{C_W}{\rho_S} + \dfrac{(1-C_W)}{\rho_L}}$$

and expressed in terms of specific gravity and If the liquid is water with $\rho_L/\rho_{WA} = 1$ then the above simplifies to:

$$C_V(SG_S - 1) + 1 = \frac{1}{\dfrac{C_W}{SG_S} + \dfrac{(1-C_W)}{1}}$$

$$C_V = \left(\frac{1}{\dfrac{C_W}{SG_S} + \dfrac{(1-C_W)}{1}} - 1 \right) \times \frac{1}{(SG_S - 1)}$$

$$\boxed{C_V = \left(\frac{1}{C_W\left(\dfrac{1}{SG_S} - 1\right) + 1} - 1 \right) \times \frac{1}{(SG_S - 1)}} \qquad \text{[C-3]}$$

By definition $C_V = V_S/V_M$ and $V_S = C_W \times M_M / \rho_S$

Therefore by substitution

$$C_V = \frac{C_W\,\rho_M}{\rho_S} = \frac{C_W SG_M}{SG_S}$$

or

$$\boxed{SG_M = \frac{C_V\,SG_S}{C_W}} \qquad \text{[C-4]}$$

which means that there is a direct relationship between the specific gravity of the mixture SG_M and C_V and C_W if you know the density of the solids.

Usually the concentration by volume (C_V), the concentration by weight (C_W) and the specific gravity (SG_S) of the solid particles will be given or known for a particular slurry. This is enough information to calculate the specific gravity of the slurry (SG_M) using equation [C-3].

Often the purpose of the slurry mixture is to pump solid particles in a fluid form to a discharge point at a distance. In that case, we are mainly interested in the amount of tons per hour of solids that are transported.

The mass flow rate is given by:

$$M = \rho_s \; C_V \; q = SG_S \; \rho_{WA} \, C_V \; q$$

The density of water at standard condition is 62.34 lbm/ft^3 using the appropriate units to obtain Imperial tons per hour (2000 lb/h):

$$M\left(\frac{ton}{h}\right) = SG_S \times \frac{62.34 \; lbm}{ft^3} \times C_V \times q\left(\frac{USgals.}{\mathrm{min}}\right) \times \frac{60 \; \mathrm{min}}{h} \times \left(\frac{ft^3}{7.48 USgals.}\right) \times \frac{ton}{2000 \; lbm}$$

After simplification, the mass flow rate is:

$$M\left(\frac{ton}{h}\right) = 0.25 \; SG_S \; C_V \; q\left(\frac{USgals.}{\mathrm{min}}\right) \qquad [C\text{-}5]$$