Deep Mixing Material Report

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Table of Contents

1 Subject

To determine the range of realistic material property values that can be used in the design of Deep Mixing projects, mixture calculations are carried out using the approach outlined in the "Federal Highway Administration Design Manual: Deep Mixing for Embankment And Foundation Support". This involves obtaining the amount of binder required for the column in all soil layers that the DSM column interacts with.

2 Mixture Physical Properties

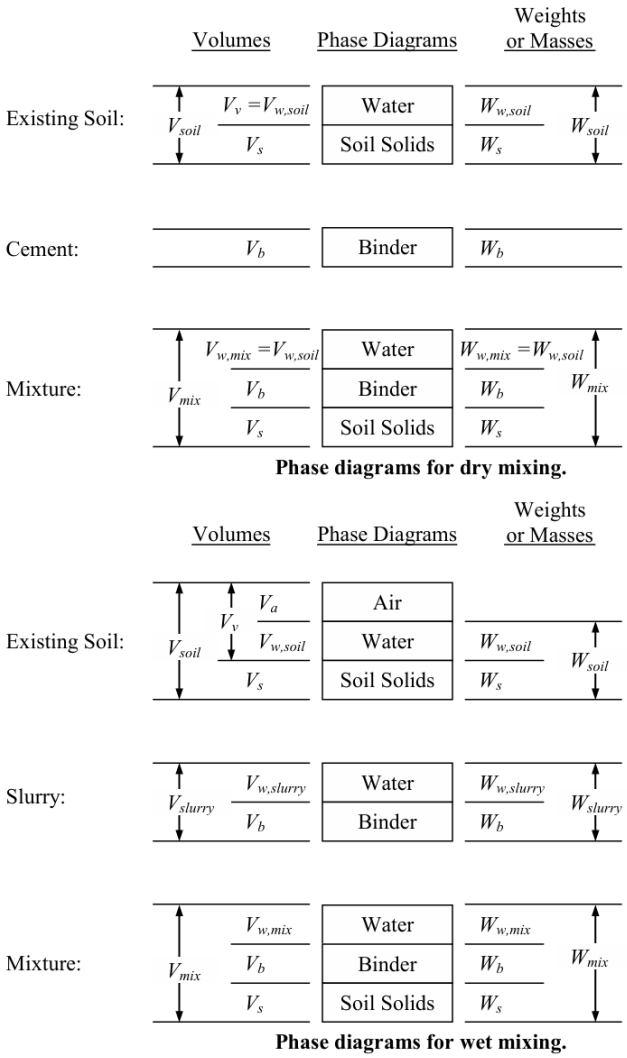

Figure 1: Phase Diagrams

V_a : Volume of air

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$V_{w,soil}$: Volume of water in the soil before mixing

$W_{w,soil}$: Weight of water in the soil before mixing

V_s : Volume of the soil solids

W_s : Weight of the soil solids

V_b : Volume of the binder.

W_b : Weight of the binder

$V_{w,slurry}$: Volume of water in the slurry for wet mixing

$W_{w,slurry}$ = Weight of water in the slurry for wet mixing

$V_{w,mix}$ = Volume of water in the mixture

$W_{w,mix}$ = Weight of water in the mixture

The sums of these amounts include the following:

V_v : Volume of voids in the soil before mixing $(V_a + V_{w,soil})$

V_{soil} : Volume of soil before mixing $(V_s + V_{w,soil} + V_a)$

W_{soil} : Weight of soil before mixing $(W_s + W_{w,soil})$

V_{slurry} : Volume of slurry before mixing $(V_b + V_{w,slurry})$

W_{slurry} : Weight of slurry before mixing $(W_b + W_{w,slurry})$

V_{mix} : Volume of the mixture $(V_s + V_b + V_{w,mix})$

W_{mix} : Weight of the mixture $(W_s + W_b + W_{w,mix})$

Specific gravity of the soil solids:

$$G_s = \frac{W_s}{V_s \gamma_w} \tag{1}$$

Specific gravity of the binder(cement):

$$G_b = \frac{W_b}{V_b \gamma_w} \tag{2}$$

Unit weight of water:

$$\gamma_w = \frac{W_w}{V_w} \tag{3}$$

3 Deep Mixing Parameters

Binder factor:

$$\alpha = \frac{W_b}{V_{soil}} \tag{4}$$

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Binder factor in-place:

$$\alpha_{in-place} = \frac{W_b}{V_{mix}} \tag{5}$$

Binder content:

$$a_w = \frac{W_b}{W_s} \tag{6}$$

Total water-to-binder ratio:

$$w_T : b = \frac{W_{w,mix}}{W_b} \tag{7}$$

Water-to-binder ratio of the slurry:

$$w : b = \frac{W_{w,slurry}}{W_b} \tag{8}$$

Volume ratio:

$$VR = \frac{V_{slurry}}{V_{soil}} \tag{9}$$

4 Dry Mixing

γ_b : Unit weight of the binder solids (W_b/V_b)

γ_{dsoil} : Dry unit weight of the soil (W_s/V_{soil})

w : Water content of the soil ($W_{w,soil}/W_s$)

In dry mixing, the w_T:b ratio is determined based on the required column strength for the project. Using the inputs G_b, $w_T : b$, and $\gamma_{d,soil}$, the values of α, $\alpha_{in-place}$, and a_w are calculated.

$$\alpha_{in-place} = \frac{\alpha\gamma_b}{\alpha + \gamma_b} \tag{10}$$

$$a_w = \frac{\alpha}{\gamma_{d,soil}} \tag{11}$$

$$w_T : b = \frac{w\gamma_{d,soil}}{\alpha} \tag{12}$$

Unit weight of DSM column (mixture):

$$\gamma_{mix} = \frac{\gamma_b\left(\gamma_{soil} + \alpha\right)}{\gamma_b + \alpha} \tag{13}$$

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5 Wet Mixing

In wet mixing, the w_T:b ratio required for the target column strength and the w:b ratio for the slurry are determined. Using the inputs G_b, $w_T : b$, $\gamma_{d,soil}$, and $w : b$, the values of α, $\alpha_{in-place}$, a_w, VR, and $\gamma_{d,slurry}$ are calculated.

$$\alpha = \frac{w\gamma_{d,soil}}{w_T : b - w : b} \tag{14}$$

$$VR = \frac{\alpha}{\gamma_{d,slurry}} \tag{15}$$

$$VR = \frac{\alpha_{in-place}}{\gamma_{d,slurry} - \alpha_{in-place}} \tag{16}$$

$$VR = \frac{\gamma_{d,soil}}{\gamma_{d,slurry}} a_w \tag{17}$$

Unit weight of DSM column (mixture):

$$\gamma_{mix} = \frac{\gamma_{soil} + VR\gamma_{slurry}}{1 + VR} \tag{18}$$

6 Layer: Silty Clay (Alluvium) [-4.5m]—[-11m]

Layer Properties

Thickness H=6.5m

DSM column diameter D=40cm

Soil Properties

Material: Silty Clay (Alluvium)

Dry unit weight $\gamma_{d,soil}$ =13kN/m^3

Unsaturated unit weight γ_{soil} =17.2kN/m^3

Naturel water content w_n =0.324

Binder Properties

Wet mixing

Total water-to-binder ratio $w_T : b$ =1.18

Specific gravity of cement G_b =3.15

w:b =0.8

Mixture Calculations

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The unit weight of binder solids γ_b is derived from the given specific gravity.

$$G_b = 3.15 gramf/cm^3 \rightarrow \gamma_b = 30.891 kN/m^3$$

Dry unit weight of the slurry:

$$\gamma_{d,slurry} = \frac{G_b}{G_b w : b + 1} = \frac{3.15}{3.15 \times 0.8 + 1} = 0.895 gramf/cm^3 = 8.776 kN/m^3$$

The binder factor α is calculated using Equation (14).

$$\alpha = \frac{0.324 \times 13}{1.18 - 0.8} = 10.945 kN/m^3 = 1116.101 kgf/m^3$$

The volume ratio VR is determined using Equation (15).

$$VR = \frac{10.945}{8.776} = 1.25 = \%125$$

The binder factor in-place $\alpha_{in-place}$ is calculated using Equation (16).

$$\alpha_{in-place} = \frac{1.25 \times 8.776}{1 + 1.25} = 4.871 kN/m^3 = 496.663 kgf/m^3$$

The binder content a_w is calculated using Equation (17).

$$a_w = \frac{1.25 \times 8.776}{13} = 0.84 = \%84$$

The unit weight of the slurry γ_{slurry} is calculated.

$$\gamma_{slurry} = \frac{G_b + G_b \cdot w : b}{1 + G_b \cdot w : b} = \frac{3.15 + 3.15 \times 0.8}{1 + 3.15 \times 0.8} = 1.611 gramf/cm^3 = 15.797 kN/m^3$$

The required amount of cement W_b for the DSM column in the Silty Clay (Alluvium) is calculated.

$$W_b = \left(\frac{\pi D^2}{4}\right) \cdot H \cdot \alpha_{in-place} = \left(\frac{\pi \times 0.4^2}{4}\right) \times 6.5 \times 496.663 = \mathbf{405.681 kgf}$$

The required amount of slurry for the DSM column in the same layer:

$$W_{slurry} = w : b W_b + W_b = 0.8 \times 405.681 + 405.681 = \mathbf{730.226 kgf}$$

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7 Layer: sand [-11m]—[-12.5m]

Layer Properties

Thickness H=1.5m

DSM column diameter D=40cm

Soil Properties

Material: sand

Dry unit weight $\gamma_{d,soil}$ =$14.4kN/m^3$

Unsaturated unit weight γ_{soil} =$15.1kN/m^3$

Naturel water content w_n =0.048

Binder Properties

Wet mixing

Total water-to-binder ratio $w_T : b$ =1.18

Specific gravity of cement G_b =3.15

w:b =0.8

Mixture Calculations

The unit weight of binder solids γ_b is derived from the given specific gravity.

$$G_b = 3.15 gramf/cm^3 \rightarrow \gamma_b = 30.891 kN/m^3$$

Dry unit weight of the slurry:

$$\gamma_{d,slurry} = \frac{G_b}{G_b w : b + 1} = \frac{3.15}{3.15 \times 0.8 + 1} = 0.895 gramf/cm^3 = 8.776 kN/m^3$$

The binder factor α is calculated using Equation (14).

$$\alpha = \frac{0.048 \times 14.4}{1.18 - 0.8} = 1.796 kN/m^3 = 183.155 kgf/m^3$$

The volume ratio VR is determined using Equation (15).

$$VR = \frac{1.796}{8.776} = 0.2 = \%20$$

The binder factor in-place $\alpha_{in-place}$ is calculated using Equation (16).

$$\alpha_{in-place} = \frac{0.2 \times 8.776}{1 + 0.2} = 1.491 kN/m^3 = 152.038 kgf/m^3$$

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The binder content a_w is calculated using Equation (17).

$$a_w = \frac{0.2 \times 8.776}{14.4} = 0.12 = \%12$$

The unit weight of the slurry γ_{slurry} is calculated.

$$\gamma_{slurry} = \frac{G_b + G_b \cdot w:b}{1 + G_b \cdot w:b} = \frac{3.15 + 3.15 \times 0.8}{1 + 3.15 \times 0.8} = 1.611 gramf/cm^3 = 15.797 kN/m^3$$

The required amount of cement W_b for the DSM column in the sand is calculated.

$$W_b = \left(\frac{\pi D^2}{4}\right) \cdot H \cdot \alpha_{in-place} = \left(\frac{\pi \times 0.4^2}{4}\right) \times 1.5 \times 152.038 = \mathbf{28.658kgf}$$

The required amount of slurry for the DSM column in the same layer:

$$W_{slurry} = w:bW_b + W_b = 0.8 \times 28.658 + 28.658 = \mathbf{51.584kgf}$$

8 Quantity Takeoff

Foundation: Temel1

Foundation area= $105.568m^2$

Number of DSM columns= 63

DSM column diameter=40cm

DSM column length=8m

Amount of cement in a single DSM column $405.681 + 28.658 = \mathbf{434.339kgf}$

Total amount of cement $= 63 \times 434.339 = \mathbf{27363.357kgf}$

Total Drilling= $63 \times 8 = \mathbf{504mt}$

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