Filling of Polyurethane with Fly Ash

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Abstract

In this study, the effect of adding Class F fly ash as a filler to a commercially available polyurethane grout was investigated.

1. Introduction:

Expansion of polyurethane grout is caused by two simultaneous processes; urethane forming and carbon dioxide (CO_2) generation. The three reactants involved in this process are hydroxyl group ended resin, polyisocyanate, and water. Polyurethane forming is a continuous process and can be divided into four regions; mixing and bubble nucleation, rising liquid foam, phase separation which leads to rapid modulus rise and cell opening, and foamed elastomer (Safiullina 2002). All four stages of formation are highly exothermic. Cell formation is considered the most important as it determines the mechanical properties and durability. The porosity and unit weight of rigid, closed or open cell polyurethane foam could influence the strength and stiffness of the material (Mattey 2001). Addition of Class F fly ash could significantly alter the behavior of the polyurethane grout.

2. Objectives:

The overall objective was to investigate the use of fly ash as filler in polyurethane.

3. Materials and Testing Method:

Polyurethane resin (AV-202), water, and Class F fly ash were used in this initial study. Several factors play key roles in their material and mechanical properties. The ones most concerned with are density, yield strength, expansiveness, expansion pressure generated, modulus of elasticity, maximum temperature, and cure time. These properties are determined by the weight percent (wt %) of water, fly ash, and resin used in the mix design of the grout. Molds with a volume of 100 ml were used to determine the pressure and temperature generated during the curing of the filled polyurethane. Filled polyurethane samples that were tested had a volume 70 ml and 50 ml under this fixed-volume condition.

Results and Discussion:

Several combinations have been tested to determine material property trends with the various mix designs (Figure 1). These samples use equal volumes ratios of water and grout, thus allowing the effect of varying fly ash ratios to be explored. The time to peak pressure was significantly shortened as the percent of fly ash was increased (Figure 2). Interestingly, the peak pressure measured is actually increased with the addition 30 percent of fly ash. Additionally, the measured maximum temperature that was reached does not correspond with the maximum pressure reached. Strength and modulus properties still need to be measured to determine the correlations. Further testing under fixed volume conditions are needed to determine the optimal mix design where water, grout, and fly ash ratios are changed to find maximum pressure generated. The fixed volume tests must be correlated to represent a zero percent volume expansion which should translate into higher maximum pressure generated.

Measured density will be used to correlate the density of the sample to the strength and modulus properties of the sample (Summarized Table 1). These equations are based on a simplified open cell model by Gibson and Ashby (Goods 1998). Research using aluminum filled polyurethane suggests that increasing the amount of filler causes the effective density of the network to increase by a factor of two (Safiullina 2002). This filled polyurethane could possibly be used for geotechnical applications such as ground improvement.

Figure 1. Influence of Fly Ash on Pressure, Temperature, and Volume Expansion.

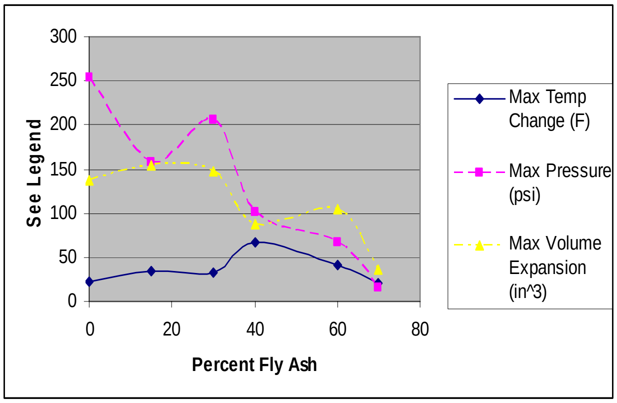

Figure 2. Influence of Fly Ash on Time to 90% Maximum Pressure and Temperature

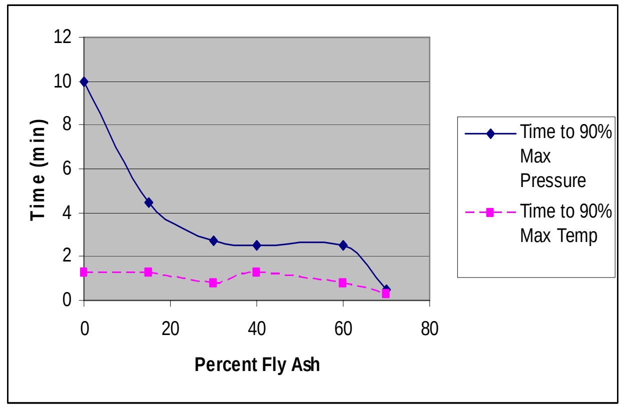

Table 1. Relationship for correlating density to strength and modulus

Modulus	$E^* = E_s\left[\theta^2\left(\frac{p^*}{p_s}\right)^2 + (1-\theta)\frac{p^*}{p_s}\right]$
Strength	$\sigma_c^* = C\left(\frac{p^*}{p_s}\right)^2\left(1+\left(\frac{p^*}{p_s}\right)^{\frac{1}{2}}\right)^2$
C	Contains all of the geometric and is =0.03

E^*	Predicted modulus
E_s	Solid polymer modulus
p^*	Foam density
p_s	Solid polymer density
σ_c^*	Predicted yield strength
θ	Fraction of material in the cell strut and is =1.0 for a closed cell foam, but measured to be =0.9

4. Conclusion:

The maximum pressure generated was 236 psi with a maximum temperature change of 68 ˚F at 20% fly ash and 30% fly ash respectively. This confirms that the addition of fly ash as a filler in polyurethane grout significantly alters physical properties of the composite material.

5. Acknowledgements:

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6. References:

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