Characterizing the Behavior of Polyurethane Grout

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Abstract
The physical properties such as volume change, pressure and temperature change, microstructure, the compressive behavior, and bonding strength of a hydrophilic polyurethane grout is investigated. Unit weight of cured polyurethane specimens varied from 3.2 kN/m3 (20 pcf) to 10.4 kN/m3 (65 pcf). The water-to-grout ratio and the unit weight of the grout influenced the compressive strength-strain relationship.

Introduction
Polyurethane grouts are divided in two major categories, hydrophobic, and hydrophilic grouts. Hydrophilic grouts can incorporate large amounts of water into their chemical structure, thereby creating a gel with a variable water content, which volume increases several times its original volume. The incorporated water however can evaporate in a dry environment causing the hydrophilic material to shrink. Cell formation is considered to be an important stage since it determines the mechanical properties and durability. The porosity, unit weight of rigid, closed or open cell polyurethane foam can influence the strength and stiffness of the materials.

Objectives
The objective of this study was to investigate the curing and post curing behavior of polyurethane grout under controlled volume change. Specifically we: 1. Develop pressure-temperature-time relationship for curing polyurethane under controlled volume change. 2. Quantify the compressive stress-strain relationship for different cured polyurethane specimens. 3. Determine the bonding strength of different polyurethane grouts.

Materials and Specimens
Material. A commercially available AV-202 multigrout (Avanti International, Webster Texas) was selected for this investigation. Uncured grout is dark brown liquid with a viscosity of 2500 cps (at 30oC) with a specific gravity of 1.15.

Specimens preparation. Making of specimens simulated the condition in concrete cracks, where limited space will affect the volume change in the grout and thus generate large pressure. Total volume of the mold was 100 ml. Using this molds allowed us to change the initial mix volumes from 0.5 to 6. Changes in pressure and temperature, generated by the reaction of the grout with water were monitored till readings remained almost unchanged.

Test result and discussion
Pressure-Temperature-Time Relationships. The changes in pressure and temperature during curing for two grout mixes with 11% and 8% volume change with 1 and 6 water-to grout ratios respectively were analyzed. In both cases the temperature rises much faster than the pressure. The

peak temperature was reached in 2 and 4 minutes respectively. The pressure continued to rise in both cases and reach the values of 1.00 and 0.25 MPA in 16 and 23 minutes respectively. While the temperature continued to decrease rapidly the pressure remained almost unchanged after reaching the peak for longer period of time. Pressure as high as 1.3 MPa (180 psi) has been measured. The unit weights of cured polyurethane grouts varied from3.2 kN/m3 (20pcf) to 10.4 kN/m3 (65 pcf).

Mechanical Properties. Stress-strain relationship (ASTM D3574, C109): It showed to be nonlinear and inelastic, it also is affected by the water-to-grout ratio and void ratio. Test were performed at 1%/min. The strength of grout at comparable strain was depended in the water-to-grout ratio. The material is becoming stiffer with increase in strain, densification causes the stress to increase sharply. The average modulus in the initial 20% strain for the water-to-grout mix ratio of 1 and 6 are 0.86 MPa (120 psi) and 0.086 MPa (12 psi) respectively.

Bonding Strength. Bonding tests were done after at least two days of curing. Variation of tensile bonding strength with water-to-grout ratio occurred. Bonding strength was inversely proportional to the water-to-grout ratio.

Microstructure. The voids were spherical and were not connected, which reveal a closed structure of the grout. Also the voids were uniform in size and had diameters of the order of 400mm.

Conclusions

1. **Pressure-Temperature-Time Relationships:** This is affected by the water-to-grout ratio and the volume change allowed for the curing grout mix. Maximum temperature peaks first. Increasing the water-to-grout ratio reduced considerably the maximum pressure and temperature generated.
2. **Stress-Strain Relationship:** The compressive stress-strain behavior of cured grouts was non-linear, and inelastic. The specimen became stiffer with increasing strain. Compared to the unit weight of cured polyurethane, the initial water-to-grout ratio and volume change during curing were more important in influencing the compressive behavior of the grout.
3. **Bonding Strength:** Polyurethane grout bonds to the quartz (simulating siliceous sand) surface. The tensile strength reduced with increasing water-to-grout ratio.

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