Stress-Strain Relationship and Creep Properties of a Sodium Silicate Grouted Sand

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Abstract The effect of dimethyl-ester (DME) on the gelling time of sodium silicate grout, and stress-strain relationship of grouted sand (GS) was investigated. Increasing the DME in the grout reduced the gelling time of the grout mix. The grouted sand with 7% DME had the highest strength. The maximum creep level (no failure) was 45% for the grouted sand with 7% DME respectively.

1. Introduction

Engineering properties of chemically grouted sands have been assessed by unconfined compression and unconfined creep tests. Shen and Smith (1972) assessed the behavior of sodium silicate GS and reported a strength of 230 psi (1650 kPa) at a strain of 0.15% and no failure under a stress level of 50% in uniaxial creep tests. Littlejohn and Haji-Bakar (1992) performed compression tests on silicate-ester GS, and reported that strength increased with curing time. Creep tests showed that failure occurred when the stress ratio was higher than 25% (Littlejohn and Mollamahmutoglu, 1992). Ata and Vipulanandan (1998) reported an increase of 10% in the strength of the grouted sand from the 3rd to the 7th day and almost no increase from that age forward. In 1999 they reported that stress levels higher than 48 percent caused creep failure in GS. Ribay, Cabrillac and Gouvernot (1999) examined the triaxial creep behavior of grouted sand; they concluded that the sodium silicate GS failed at stress levels of 30% or higher, and that soils grouted with other grouts reduced the creep behavior significantly.

2. Objectives

The overall objective was to compare the mechanical and creep properties of a sodium silicate grouted sand with published data in the literature.

3. Materials and Testing Method

N-Sodium Silicate and a catalyst dimethyl ester (DME) were used in this study. Sand with USCS classification of SP, and d_{50} = 0.45 mm was used. A preliminary study was done on neat grout by performing gelling and syneresis tests. It was performed by adding different amounts of DME into water and stirring them for 5 minutes; then, each was added to sodium silicate and mixed up to gelling. When the grout was injected into sand specimens the mix was constantly stirred using the same technique. Then, unconfined compression tests, and creep tests on sands grouted with selected grout mixes were performed.

4. Results and Discussion

The average unit weight of the sand used was 106 pcf with a standard deviation of 1.8% and a variance of 6.23 pcf. After grouting the average unit weight increased of 10% to 115 pcf and the standard deviation was 3.5%. Gel time for the grout varied from 35 to 60 min, and decreased linearly with increasing amount of DME (Figure 1). The stress-strain relationship for the GS after 21 days of curing was obtained. The failure strain varied from 0.4% to 1% for the 7 % DME samples, the average Young's modulus was 49.3 ksi (340 MPa), and the strength ranged between 147 and 278 psi (1015 and 1923 kPa). Results after 28 days showed a strength increase of up to 30% at similar failure strain.

Creep failure occurred after 300 minutes at a stress levels (D) of 60 % for GS with 7% DME. Logarithmic creep models have been proposed by Borden, Krizek, and Baker, (1982), and Ata and Vipulanandan (1998) and the equations were $t_f = 10^{(10-14D)}$ and $t_f = 10^{(9-12D)}$, respectively, where t_f : time to reach failure. A new power function (eq. 1) is proposed, for $t_f < 10000$ min which include several past data

$$D^* t_f^{0.070464} = 0.76535 \quad (1)$$

5. Conclusions

1. The compressive strength of silicate grouted sand tested in this study was in the range of 41 to 271 psi (300 to 1900 kPa) as reported in the literature.
2. Creep failure was observed above 60% of the unconfined compressive strength and no failure happened for samples with stress levels of 45% or lower after one week. A new model is proposed based on current results and other published data.

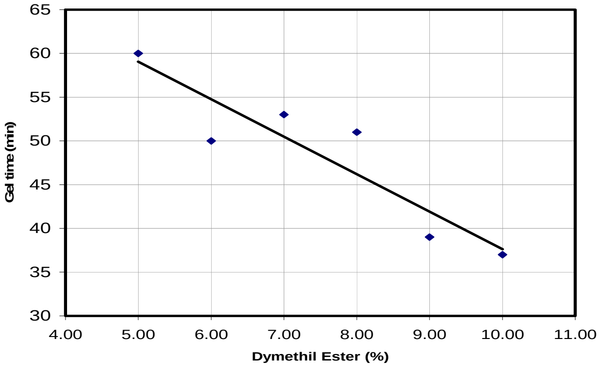

Figure 1 Gel time Vs. Amount of Dymethil Ester

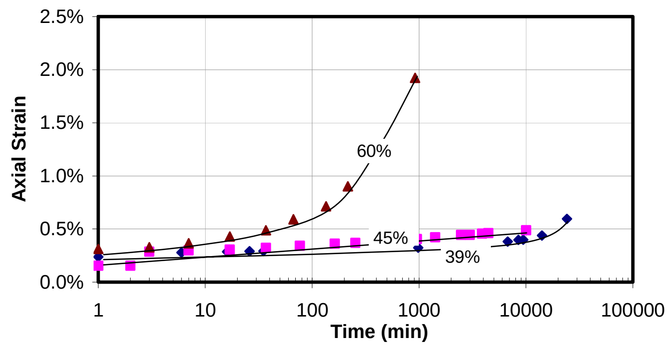

Figure 3 Creep Behavior of Dimethyl-Silicate Grouted Sand

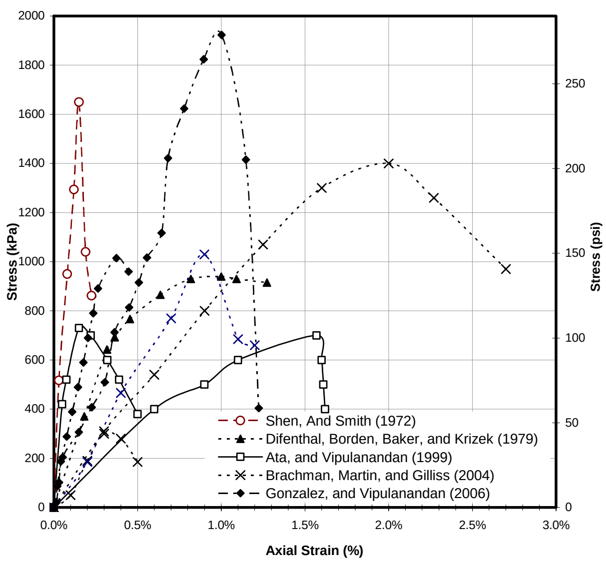

Figure 2 Stress strain curves for samples of 21 days or older from various authors

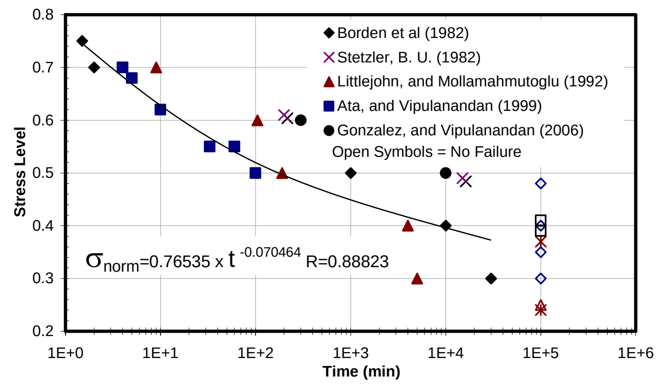

Figure 4 Stress level Vs. Time to Failure for Fine to Medium Uniform Sand

5. Acknowledgements:

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