# Effect of Surfactants on the Viscosity and Gelling time of the Acrylamide Grout

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**Abstract:** Greater application of acrylamide grouts demands further enhancement of the grout from the time of pumping to final setting. Surfactants have the potential to be part of the polymerization process and also improve the wetting characteristic of the grouts. In this study the changes in the working properties of an acrylamide chemical grout were investigated with the addition of an anionic surfactant, Sodium dodecyl sulfate (SDS) and a cationic surfactant, Cetyl trimethyl ammonium bromide (CTAB). Working properties such as viscosity, setting time and curing temperature of the grout were studied. The effect of initial temperatures of 40ºF (4.4ºC), 60ºF (15.5ºC) and 80ºF (26.6ºC) on the grout on the gelling time was also investigated.

## 1 Introduction

Soil stabilization through grouting has been a pivotal technique in the field of geotechnical engineering where the voids in the soil are filled by a viscous material which has the ability to undergo a phase transformation to solid. Since 1950s, chemical grouts have been used for stabilizing the soil and for resolving pipeline leaks (Vipulanandan et al. 2009; Ozgurel et al. 2004). Considering chemical grouts, their penetrability is primarily dependent on the viscosity of the solution that enables a reasonable flow of the grout at applied permissible pressures (Karol, 1982). In recent studies the behavior of acrylamide grouted sand have be characterized based on injectablitiy, strength and permeability (Ozgurel et al. 2004 and Vipulanandan et al. 1996 and 2009). Surfactants are organic chemicals which have both hydrophilic and hydrophobic groups in their structures. They are predominantly used in different applications because they lower the surface tension of the liquid to which they are added. Apart from their primary use as a detergent, they are also used in paints and emulsions and adhesives. Based on the charge carried by the surfactants, they are classified as cationic, anionic, zwitterionic and non-ionic surfactants.

## 2 Objective

The main objective of this study was to investigate the effects of adding an anionic and cationic surfactant on the gelling time behavior of an acrylamide grout.

## 3 Materials Required and Experimental Program

Commercially available Avanti AV-100 acrylamide chemical grout was used in this study. A catalyst and activator were used with the chemical grout in aqueous solutions that resulted in gel formation. The surfactants used were cetyl trimethyl ammonium bromide (CTAB, $[CH_3\ (CH_2)_{15}\ N\ (CH_3)_3]\ Br$), a cationic surfactant and Sodium Dodecyl sulfate (SDS, $C_{12}H_{25}SO_4Na$), an anionic surfactant. Viscosity was measured using the Brookfield Dial gage Viscometer. Spindle No. 1 was used at a speed of 60 rpm to measure the viscosity for the aqueous solutions made of 10% by weight of the aqueous solution of AV-100 and surfactants varying from 0% to 4% by weight of the aqueous solution was used. Gelling time is defined as the time taken for the free radical polymerization reaction to take place enabling the mix to undergo a phase transformation from liquid to solid phase. Curing temperature is defined as the highest temperature attained by the mix during the process of gelling. Gelling temperature was measured using a thermocouple which observed the rise in temperature of the mix with respect to time.

To study the effect of initial temperature, the solutions were tested at 40ºF, 60ºF and heated to 80ºF.

## 4 Results and Discussion

As shown in Fig 1, the viscosity measured with varying amounts of surfactants. It was evident that addition of cationic or anionic surfactant did not have any noticeable effect on the viscosity of the grout. Table 1 summarizes the gelling time and curing temperature of the grout solutions investigated in this study. Addition of 0.5% SDS decreased the gelling time at 40ºF. The gelling time with 0.5% SDS increased with increase in the initial temperature. The gelling time increased by 60 sec and 15 sec when the initial temperature was 60˚F (15.5˚C) and 80˚F (26.6˚C) respectively. A similar trend was observed with the addition of 4% SDS. Addition of 4% SDS increased the curing temperature at 40ºF, but the trend was reversed at other testing temperatures. On Addition of 0.5% of CTAB increased the gelling time of the grout at all three different initial temperatures, however, the least change was observed at 80˚F (26.6˚C). Addition of 4% CTAB increased the gelling time by 16785 sec, 5715 sec, 1335 sec for initial temperatures of 40˚F (4.4˚C), 60˚F (15.5˚C) and 80˚F (26.6˚C) respectively. Addition of surfactant reduced the maximum curing temperature of the grout, except at 40ºF with 0.5% CTAB. Also 4% CTAB had the highest reduction in the maximum curing temperature with the initial grout temperature of 40ºF.

**Table 1: Gelling times and Curing Temperatures of Grout Mixes**

| Surfactant | Surfactant % by weight | 40ºF | | 60ºF | | 80ºF | |
|---|---|---|---|---|---|---|---|
| | | Gelling time (s) | Curing temperature (ºF) | Gelling time (s) | Curing temperature (ºF) | Gelling time (s) | Curing temperature (ºF) |
| None | 0 | 615 | 95 | 165 | 114 | 45 | 134 |
| CTAB | 0.5 | 675 | 101 | 240 | 104 | 60 | 129 |
| CTAB | 4 | 17400 | 70 | 5880 | 104 | 1380 | 121 |
| SDS | 0.5 | 600 | 93 | 225 | 109 | 60 | 129 |
| SDS | 4 | 480 | 99 | 270 | 103 | 90 | 124 |

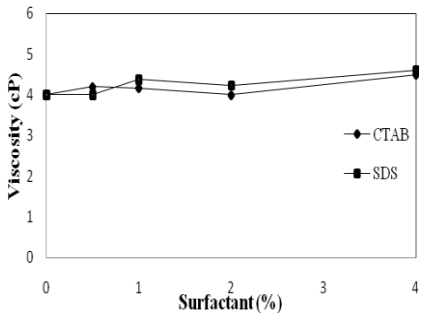


**Fig 1: Variation of viscosity with the addition of surfactants**

## 6 Conclusion

Based on the test results, following conclusions are advanced.

1. Addition of CTAB and SDS up to 4% by weight of the grout solution did not affect the viscosity of the grout solution.
2. The gelling time of the grout was increased with the addition of CTAB at all initial temperatures investigated in this study. Addition of SDS increased the gelling time at higher temperatures but reduced the gelling time when the test was conducted at an initial temperature of 40ºF (4.4ºC). Maximum curing temperature decreased with the addition of surfactants for most cases investigated.

## 7 References

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