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Sodium salt admixtures for enhancing the foaming characteristics of sodium lauryl sulphate

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ABSTRACT

This study identifies admixtures to enhance the effectiveness of Sodium Lauryl Sulphate (SLS) as a foaming agent by increasing the foam density and stability. Sodium hydroxide, sodium carbonate and sodium chloride were chosen based on common ion effect to increase the viscosity of the foaming solution in order to achieve ASTM recommended range of foam density. Response surface methodology is used to study the responses like viscosity, foam density and foam stability of all the admixtures. Viscosity is observed to have a linear relationship with foam density, bubble size distribution and stability. Foam density increases with the dosage of admixture, irrespective of foam generation pressure (FGP). Use of appropriate dosage of these admixtures with SLS provides the foam density specified by ASTM. Relatively lesser dosage of NaOH is sufficient to achieve ASTM recommended foam density, which is attributed to the fact that mole percent of sodium in NaOH is higher than NaCl and Na_2CO_3. The stability of the foam has also been demonstrated through a typical mix of foam concrete.

1. Introduction

Foam used for the manufacture of foam concrete requires to be stable with desired density, which is produced using either natural or synthetic foaming agents (FAs). Foaming agents are **s**urfactants which generally produce foam by reducing the surface tension of water. The synthetic foaming agents can be classified into (i) anionic, (ii) cationic and (iii) non-ionic [1]. Several surfactants are used in the manufacture of detergents and cosmetics [2]. One of the common anionic surfactant widely used in various products is Sodium Lauryl Sulphate (SLS). SLS has also been used for (i) the intrusion of gas in wet gypsum paste, which reduced the density between 30% and 35% [3] and (ii) foam concrete production. Foam density is an important property as it influences the dosage of foaming agent required to achieve the desired density of foam concrete. It has been reported that a stable foam could be obtained using SLS with a maximum density of 25 kg/m^3 [4]. An increase in dosage of SLS (i.e., dilution ratio up to 1:10) resulted in marginal increase in viscosity but did not enhance the density of foam due to more intrusion of gas in foam. ASTM C 796 [5] suggests a foam density range of 32–64 kg/m^3 for its use in foam concrete. When the density of foam is low, the foam volume has to be increased in order to achieve the desired density of foam concrete [4]. Such higher dosages will in turn affect the strength of foam concrete. Hence there is a need to increase the density of foam generated using SLS. Apart from the need to achieve foam with initial foam density satisfying ASTM standards, the likely deterioration of foam density with time has to be considered. This property is represented in terms of stability of the foam. Stability of the foam is reduced due to (i) bursting of foam bubbles due to evaporation and (ii) drainage of water from the interstices of foam films, which results in the reduction of the mixing time of foam in foam concrete production [6–9]. This necessitates identification of suitable admixture for enhancing the viscosity of SLS, which would in turn enhance the density as well as the stability of the foam. Earlier studies concluded that (i) a stable foam could be produced by using highly viscous foaming solution, and (ii) domestic shampoos could be thickened by adding salts like sodium chloride [1]. Angarska et al. [10] have reported that (i) an addition of Mg^{2+} ions from $MgCl_2$ enhanced the stability of foam at low concentration of SLS by bringing the negatively charged head group of SLS together, which in turn increased the viscosity of the foaming solution, and (ii) at higher concentration of SLS, Mg^{2+} destabilizes the SLS, which was caused by dense adsorption of monolayers. Polymer admixture like poly(vinyl pyrrolidone), when added to SLS, is

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reported to increase the surface viscosity and steric repulsion by positioning itself near the head group of the SLS, thereby enhancing the stability of the foam [11].

Porter [1] reported that surfactants with carbon atoms in the range of 12–18 have the foaming ability. It has been noted that admixtures like alkyl alcohol, which has the same number of carbon atoms as that of SLS (i.e., 12), enhanced the stability of SLS [12]. Patist et al. [13] have concluded that tetraalkylammonium chlorides in SLS increased the micellar stability of SLS due to the ionic interactions up to a critical concentration, beyond which the stability gets reduced. Gonzenbach et al. [14] reported that the use of inorganic colloidal particles enhanced the stability of the foam by adsorption at the interface of the bubbles. Foam stability is assessed using the variation in foam density and the volume of solution drained over time under gravity. Ranjani and Ramamurthy [4] have reported that (i) foam generated using SLS leads to 40% reduction in density after 10 min, which is due to its inability to retain the liquid in the foam and (ii) the drainage increased with an increase in dilution ratio of SLS.

The above review indicates that the density and stability of the foam can be increased by adding suitable admixtures, which have the ability to increase the viscosity of the solution. Based on the above review, three commonly available sodium salts have been chosen as admixtures for assessing their potential in enhancing the foam density and foam stability. Statistically designed experiments have been undertaken to identify a range of factors and their relative influence on the foam density and stability.

2. Experimental design

2.1. Factors and their range considered

The parameters and their range which have been investigated in this study are:

(i) *Surfactant:* Sodium Lauryl Sulphate (SLS) has been used in this study. Preliminary studies indicated that SLS concentration of less than 0.5% did not produce foam, whereas beyond a concentration level of 2.5%, there is no significant variation in the density of the foam (Fig. 1). Hence, the SLS concentration has been varied between 0.5% and 2.5% (i.e. 0.5% concentration refers to 1 part of SLS and 200 parts of water by weight).

(ii) *Admixture and its dosage:* To manipulate the association, dissociation equilibrium of the SLS in water, three admixtures with a common positive sodium ion, namely, sodium chloride (NaCl), sodium carbonate (Na_2CO_3) and sodium hydroxide (NaOH) were used. Preliminary studies revealed that (a) the viscosity of the solution increased linearly with an increase in the sodium admixture dosage and (b) there is also an upper limit of viscosity beyond which the foam generation did not occur due to higher turbulence (i.e. foam is generated by allowing the compressed air to pass into the foaming liquid. This happens when there is a steady movement of air into the foaming solution. But when the viscosity of foaming solution is increased beyond optimal range, there will be unsteady movement of air into the foaming solution to generate foam. Hence this unsteadiness in air is represented as turbulence). Hence the maximum dosage of NaCl, Na_2CO_3 and NaOH in SLS have been maintained respectively as 7%, 8% and 4% by the weight of solvent (i.e., water).

(iii) *Foam generation pressure:* The laboratory based foam generator, designed and developed at IIT Madras [15] has been used in this study. The foam generator uses compressed air at suitable range, i.e., termed as foam generation pressure (FGP). A pressure regulator fixed in the compressor enables measurement and control of the foam generation pressure. The foam did not get generated below 78 kPa, as the compressed air could not penetrate into the foaming solution, whereas under a pressure level beyond 137 kPa, the compressed gas disrupted the foam formation of viscous solution. Hence the FGP level taken for the study has been limited between 78 kPa and 137 kPa.

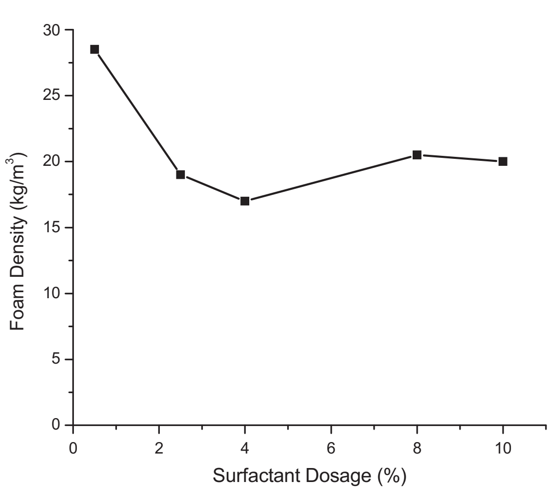

Fig. 1. Foam density achieved with a working pressure of 118 kPa.

Table 1
Parameters and its range for central composite design.

S. no.	Parameter	Range for analysis	
		Min	Max
1	SLS	0.5%	2.5%
2	NaCl	1%	7%
3	Na_2CO_3	1%	8%
4	NaOH	1%	4%
5	FGP	78 kPa	137 kPa

Table 2
Factors in un-coded values for the coded values for SLS and admixtures.

Notation	Factor	Coded values		
		+1	0	−1
		Uncoded values		
(i) SLS + NaCl				
X_1	SLS (%)	0.5	1.5	2.5
X_2	NaCl (%)	1	4.0	7
X_3	FGP (kPa)	78	108	137
(ii) SLS + Na_2CO_3				
X_1	SLS (%)	0.5	1.5	2.5
X_2	Na_2CO_3 (%)	1	4.5	8
X_3	FGP (kPa)	78	108	137
(iii) SLS + NaOH				
X_1	SLS (%)	0.5	1.5	2.5
X_2	NaOH (%)	1	2.5	4
X_3	FGP (kPa)	78	108	137

In order to study the individual effects and interaction effects of the parameters investigated (concentration of SLS, type and dosage of sodium admixture and foam generation pressure) on the foam properties like viscosity, foam density and foam density at various time intervals (i.e. 5, 15 and 30 min), response surface methodology [16] with face-centered central composite design (CCD) has been used. The quadratic model has been adopted using Statistical Analysis Software (SAS release 8.02) [17]. The ranges of parameters studied (i.e. which has been arrived based on initial experimental