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CEC input to evaluate the butyl diammonium dichloride as a swelling reducer in clay rich material

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ABSTRACT

Previous research suggest that repeated swelling of the clay minerals involve differential strain during wetting and drying cycles which may induce decay under a fatigue of the clay rich material. Scaling due to this process has been observed on some stone binding clay but also on earthen material used in architecture. Since recent years, research on the conservation of clay-rich sandstones lead to the development of bifunctional cationic surfactants as swelling reducers for sandstones with high hygric and hydric dilatation. In this paper, the butyl diammonium dichloride surfactant was experimented on earthen material to reduce important hygric dilatation which leads to fast and important decay of earthen material. It has been directly added into the clay mixture of molded adobe brick that was to be physically and mechanically tested. The aim is to further investigate the interaction of the surfactant with clay minerals. Series of experiments showed great impact on various physical-mechanical properties of the molded earthen mixtures. Some could have been expected according to the function of the surfactant, which is to block the micropores within the clay mineral structures, responsible for the swelling. Thus, the decrease of the specific surface area as well as the hygric dilatation is understandable. However, according to the concentration of surfactant used within the adobe mixture, other properties are also affected such as the ultrasonic velocity, the water uptake coefficient, the hydric shrinkage and the compressive strength. Therefore this paper underlines important influences in changes of properties of molded adobe according to the concentration of surfactant used, and the cation exchange capacity of the material. The paper will show a new approach consisting in adapting the concentration of surfactant as a function of cation exchange capacity (CEC) of the material.

1. Introduction

The effect of the butyl diammonium ions is to block the micropores within the clay mineral structures which are responsible for the swelling. Functional groups can be fixed at the negative charge centers of neighboring clay mineral layers, so that a stable configuration is achieved (Fig. 1). Previous studies showed that clay rich sandstones treated with surfactant did not modify the water ingress or porosity of the sample, but significantly reduced the swelling, and thus actively contribute to the reduction of damage (Snethlage and Wendler, 1991; Wendler et al., 1996). More recent studies showed that swelling reductions on the order of 50% can be reached (Gonzalez and Scherer, 2004). Additional treatment with the surfactant does not increase the swelling reduction, so that concentration of 1% and 5% by weight were sufficient. Gonzalez and Scherer (2004) demonstrated that the surfactant seems to create stick-slip which raises the initial modulus of elasticity, and that once slip is initiated, the surfactants seem to act as lubricants, raising the stress relaxation.

Clays minerals with a high exchange capacity and inter-layer cations like montmorillonite swell in response to an increase in water vapor pressure or water content by hydration of the interlayer cation (Sparks, 1986). This type of swelling is negligible for clay mineral types with a low cation exchange capacity (CEC, e.g. kaolinite). Maximal effect of the bifunctional surfactants is reached when all cation exchange sites are neutralized, the one of the exchangeable cations, are clogged (Utz, 2004). Therefore, in a soil it may be logical that a higher amount of surfactant may be necessary to reach the maximal swelling reduction than in clayey stone. Very few values of CEC are presented in correspondence with the concentration of surfactant used. For instance, in clay rich sandstone (Sander sandstone) the cation exchange capacity

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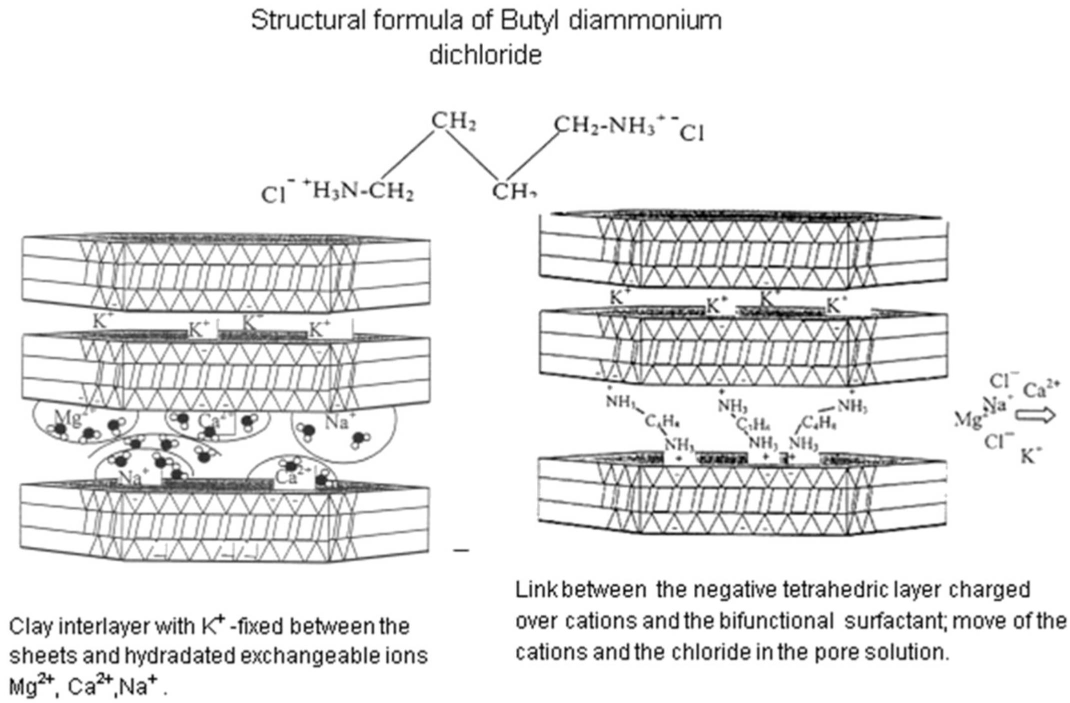

Fig. 1. Mechanism of micropores blocking by the butyl diammonium dichloride surfactant and the consecutive releasing of ions (Wirkstoff in surfactant) in an aqueous solution (after Keßler, 2000).

is in the range of 4–12 meq and the concentration of surfactant used is about 0.2 mol/l. Some experiments done on soil (Utz, 2004) used a concentration of 0.66 mol/l for a CEC ranged between 20 and 30 meq.

The aim of the present study is to look at the impact of the surfactant on swelling reduction and other properties of molded adobe according to its concentration and the CEC of the earthen material.

2. Samples composition and preparation

Clays minerals:	Ca-Montmorillonite (STx-1) University of Missouri-Columbia - USA Kaolinite (Kga-1b) University of Missouri-Columbia - USA
Silt:	ground silica < 75 μm SIL-CO-SIL-75 (SCS-75U.S. Silica; Oklahoma/USA)
Sand:	CEN-NORMSAND DIN EN 196-1 (Hans-Böckler – Beckum/Germany)
Surfactant:	Löningen/Germany Butyl diammonium dichloride.

Different amounts of surfactant had been directly added during the process of molding adobe cubes. Compositions are shown in Table 1. For each mixture 12 samples cubes were prepared, of 5 × 5 × 5 cm each.

The different mixtures were prepared with the water content equal to 10 bumps for closing the groove with the Cassagrande apparatus according to ASTM D4318. The value is therefore inferior to the liquid limit of the soil mixture. The mixing process has been carried out for 20 min in a mortar. The mixtures have been allowed to rest for 24 h. Then the soil has been mixed for an additional 10 min, mold and jolted on a jolting table 10 times in order to obtain reproducible and not too intensive compaction.

Samples stayed in the molds under standard environmental conditions (65% RH/20 °C) until the samples could be removed from the mold (after one week).

Table 1
Composition of the adobe mixtures in m/m.

Name	% sand	% clay		% silt	CEC	
		Montmorillonite	Kaolinite		meq/100 g	meq/cube
Clay15Mt	59	15	–	25.5	8.4	21
Clay15	59	7.5	7.5	25.5	4.2	10.5

3. Selection of surfactant amount and CEC

The first amount of surfactant selected is 22% in m/m of product in solution (corresponding to the water necessary to achieve plastic limit) and is directly mixed with the artificial adobe mixtures Clay15 and Clay15Mt during the mixtures preparation process, replacing thus the water content. Then, lower amounts are selected according to the cation exchange capacity of the mixtures. Thus, surfactant at 0.5% and 5% on the total amount was mixed in the artificial adobe mixtures Clay15 and Clay15Mt. For these two lower amounts of surfactant, the mixtures were completed with water up to 22% in order to obtain the adequate texture. The surfactant was also first diluted in the water and then added to the dry mixture. Thereafter B0.5, B5 and B22 will be noted after Clay15 and Clay15Mt to indicate the amount of surfactant added if any three cubes have been prepared for each amount (Table 2).

Molar mass of butyl diammonium = 90 g/mol.
Weight equivalent butyl diammonium = 45 g/mol.
Molar mass of butyl diammonium dichloride = 161 g/mol.
Active material = 4.2%.

Table 2
Content in g, mmol and meq for the different amounts of surfactant per cube of 250 g.

Amount of surfactant in %	0.5	5	22
Mass of active material (g)	0.05	0.53	2.31
mmol	0.31	3.29	14.35
meq	0.62	6.6	28.7