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ORIGINAL ARTICLE

# Swelling soils treatment using lime and sea water for roads construction

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**KEYWORDS**

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**Abstract** The cyclic heave and settlement of expansive soils could be the main reason to considerable damages to the structures, roads and highways. In Egypt there are many regions containing such expansive soils especially at the desert lands. The remote areas are used now for establishing many projects such as (wind farms, solar plants, irrigation projects and nuclear power plants). The use of a mixture of lime-treated swelling soil mixed with potable water to overcome the swelling potential of these soils is available in many countries especially in U.S.A. For the projects located adjacent to the coasts of Sea, the sea water is available instead of potable water. This paper presents an experimental and field case study on the lime-treated soil but mixed with sea water instead of potable water. The effect of using sea water instead of potable water on the swelling behavior, engineering properties, and the consolidation parameters were studied. On the other hand, this research deals with the behavior of the lime-treated soil in swelling state as well as in consolidation state. Tests results showed that there are significant reductions in the swelling potential, engineering properties, and the consolidation parameters in case of using sea water instead of potable water as mixing water. The environmental and economic impact gained from such process was put into consideration.



## 1. Introduction

Many problems in the civil engineering are caused by swelling soils. The consequences of swelling soils are most obvious in arid and semi-arid areas [1]. The existence of swelling soils in construction sites has serious consequences on planning, design, construction, and the overall performance especially of engineering infrastructures. An increase or decrease in water contents has a great influence on the swelling behavior of such soils. The initial dry density also affects the swelling behavior of such soils. As the initial dry density increases, the swelling potential increases. Soil which has dry density ($\gamma_d$) equal or bigger than 1.7 g/cm$^3$ exhibits a high swelling potential. In addition, there are other factors that affect the swelling potential of the swelling soils, such as the clay fraction (F = % finer than 0.002 mm in soil diameter) and its mineralogy, Montomorillonite clays. As the clay fraction (F) increases, the swelling potential increases. There are a great effect of the

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activity soil (A) on the swelling behavior of soil (A = P.I/F), where P.I (P.I = Liquid Limit (L.L) – Plastic Limit (P.L)) is the plasticity index of soil. As the soil activity (A) increases, the swelling behavior increases. The smaller the particle size, the higher is the surface activity [2]. An increase in concentration of the medium surrounding the swelling soil causes a decrease in swelling potential. A salty medium leads to a dramatic reduction in the expansive behavior [3]. Tables 1 and 2 illustrate the influence of plasticity index (P.I) and clay fraction (F) on the swelling behavior of soils.

In some clays, swelling caused due to the reduction of stress, is so dangerous that it disturb roadways or structures. If swelling is restricted by construction, extremely large forces may develop and soils are said to be swelling [1]. The swelling behavior causes volume changes which can lead to extensive damages to civil engineering infrastructures; light weight structures, shallow foundations, high ways, roads, airport pavements, and pipelines. Many additives were used to reducing the swelling behavior [6–9].

Lime stabilization of swelling soils has been widely used to improve their physical and mechanical properties [10–13]. Lime-treated soils were used as modified subgrade, sub-base and base course materials in pavement constructions. Lime stabilization of swelling soils has been widely used to improve their physical and mechanical properties [14,15]. Using Lime as a stabilizer to improve the engineering properties of soft deposits has given better results in the presence of sea water. Also, many studies reported that sea water had a strong impact on the engineering behavior of swelling soils [16–19]. Furthermore, using Lime as a stabilizer to improve the engineering properties of soft deposits has given better results in the existence of sea water [20]. The use of sea water in mixing Lime-treated soil was found to be very effective and has improved its unconfined compressive strength. In addition, the plasticity index of the soil has been reduced to a very low level after treatment [21].

Different papers suggest multiple remedial techniques in order to overcome the problems posed by swelling soils and to develop economic methods in road and rail construction [22–25].

**Table 1** The effect of plasticity index on the swelling behavior [4].

| Plasticity Index (P.I) (%) | Degree of Swelling |
|---|---|
| (0–15) | Low |
| (15–30) | Medium |
| (30–60) | High |

**Table 2** The effect of soil activity on the swelling behavior [5].

| Activity of Soil (A = P.I/F) | Degree of Swelling |
|---|---|
| (0–0.75) | Low |
| (0.75–1.25) | Medium |
| (1.25 or more) | High |

where A = Activity of soil, P.I = Plasticity Index (Liquid Limit – Plastic Limit), (P.I = L.L – P.L), and F = Clay Fraction (% finer than 0.002 mm in soil diameter).

This paper reports the results of a testing program on soils treated with lime. In addition, the effect of using sea water instead of potable water as mixing water for the lime-treated soil and its effect on the swelling behavior, engineering properties, and the consolidation parameters. Also, the environmental and economic impact benefits gained from using the sea water and the existing materials from the site location.

## 2. Methodology and material

The methodology comprises of collection of soil sample from the study area (roads serving the wind farms at Zafarana region) located in Arab Republic of Egypt on the Red Sea coast about 120 km south of Suez. Also, the sea water was from the Red Sea water at such region. The project area starts at a distance of about 1 km from the sea and extends about 3.5 km inland. One of the point in the project site is located at E32 35′45″, N29 13′42″. The site is located in a desert area with favorable wind conditions. Fig. 1 shows the location of wind farms at Zafarana.

### 2.1. Material used

#### 2.1.1. Soil

The natural soil existing at the site of wind farms at Zafarana region. The soil was extracted from depth of about 3.0 m below ground surface. The soil color is light yellow to gray hard laminated silty clay with some fine sand. Table 3 shows the soil physical properties. He testing program was conducted on the three types of soil according to the rules of ASTM and the Egyptian Code of Soil Mechanics and Foundations [26]. All tests were conducted at the laboratories of Faculty of Engineering, Cairo University and that of New and Renewable Energy Authority (NREA). The conducted tests were as following: sting program was conducted on the three types of soil according to the rules of ASTM and the Egyptian Code of Soil Mechanics and Foundations [26].

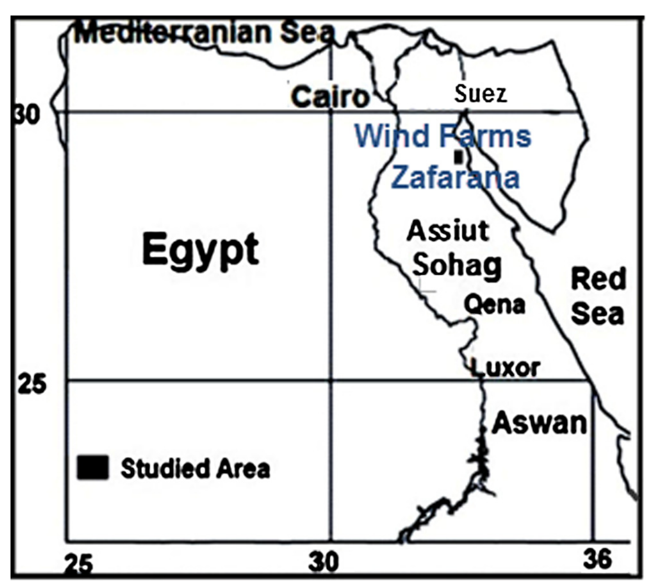


**Fig. 1** Location map of the studied area [23].

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