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# Utilization of a new soil stabilizer for silt subgrade

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**Abstract**

Silt cannot satisfy the requirements of highway construction because of its low strength. A new stabilizing agent (SEU-2) was developed to improve the mechanical performance and applicability of silt in road. Laboratory tests, including unconfined compression and shrinkage tests, were performed. Test results show that the new stabilizing agent can significantly increase the strength and the water stability, and decrease the shrinkage strain of silt. Field tests were also carried out and the results indicated that the new stabilizing agent could effectively improve the entire stiffness of subgrade. From the point of view in mechanics and applicability in road, adding 4% new stabilizing agent is an economic and reasonable method to stabilize the silt. The stabilized silt has high early strength, small shrinkage deformation, and high entire stiffness. It can satisfy the requirements of highway subgrades.


*Keywords:* Highway; Stabilization; SEU-2 stabilizing agent; Subgrade; Silt

## 1. Introduction

Silt is a kind of sedimentary geomaterial consisting primarily of very fine particles, including fine sand particles, silt particles, and some clay particles which are often less than 10% by weight. Silt is a type of transitional soil between sand and clay. A soil is defined as silt if its plasticity index is no greater than 10 and the amount of particles greater than 0.075 mm is no greater than 50% of the total (MCPRC and GAQSIQPRC, 2002). The minerals in silt are predominantly quartz, feldspar, and mica. Consequently, silt has weak linkage among grains and low activity, which usually does not satisfy the requirements of highway construction. Therefore, soil additives are used to stabilize such kind of silt.

Application of stabilizing agents on soils has a long history (Clare and Cruchley, 1957). Cement was first used as stabilizing agent at the beginning of the twentieth century to mix with soils and form road materials in the United States. Since then, many other kinds of materials, such as lime (Bell, 1996), fly ash (Dermatas and Meng, 2003), organic polymers (Lahalih and Ahmed, 1998), and their mixtures (Indraratna, 1996), have been used as stabilizing agents. When stabilizing agents are added to soils, a series of reactions will take place, including pozzolanic reaction, cation exchange, flocculation, carbonation, crystallization, and dissociation (Gong, 2005). These processes strengthen the linking between grains and fill up the voids in soils, which improves the engineering properties of soils, such as strength and stiffness. The reactions occurring between stabilizing agents and soils are related to soil types. Most of the existing stabilizing agents are specially developed for stabilizing clay soils, so the silts stabilized by such kind of stabilizing agents usually cannot meet the requirements of road construction. The encountered problems mainly are lower early strength, greater shrinkage, easy cracking, and bad water stability (Bell, 1995; Sheng and Ma, 2001).

A new agent for stabilizing silt, named SEU-2, was developed (Zhu, 2006). It is composed of cement, fly ash, quick lime, additive A, and expansive component A. This paper aims at evaluating the effects of the new stabilizing agent on the engineering properties of silt.

## 2. Materials and test methods

Silts used for this study were acquired from the northern part of Jiangsu Province, China. The chemical and mineralogical

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Table 1
Chemical composition of silt sample

| Composition | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $TiO_2$ | CaO | MgO | $K_2O$ | $Na_2O$ | $P_2O_3$ | $SO_3$ | LOI | Organic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Content (%) | 74.64 | 6.53 | 10.20 | 0.54 | 0.63 | 0.74 | 1.44 | 0.57 | 0.08 | 0.03 | 0.52 | 4.10 |

LOI: loss on ignition.

compositions of silt are given in Tables 1 and 2, respectively. The predominant component in the silt is silicon dioxide with a percentage of 74.64%, followed by aluminium oxide of 10.20%. The primary mineral is quartz with a percentage of 40%. The non-clay minerals account for 65%, whereas the clay minerals account only for 25%. The particle-size distribution of the silt is indicated in Table 3.The plasticity index is 6.8. The value of CBR (California Bearing Ratio) is approximately 2.45%, which is smaller than the requested CBR value of 3–4% for highway subgrade (SIHSD, 2004).

The new stabilizing agent is composed of cement, additive A, fly ash, lime, expansive component A (Zhu, 2006). Cement was supplied by Jingyang Cement Mill. The moisture content of cement was 0.54%, and the specific surface area was 3520 $cm^2/g$. The compositions of the cement clinker are indicated in Table 4. Additive A is by-products of cement mill, with specific surface of 4200–4300 $cm^2/g$. Expansive component A is a mixture of alum, gypsum, and sodium sulphate. Through a lot of orthogonal and optimization tests, the composition for the new stabilizing agent is determined. The amount of individual components in SEU-2 is 20% for cement, 24% for fly ash, 9.5% for lime, 24% for additive A, and 22.5% for expansive component A by weight, respectively (Zhu, 2006).

Considering the utilization of silt in highway subgrade, the unconfined compression and shrinkage tests were used to evaluate the effect of this new stabilizing agent on silt by parameters of unconfined compressive strength, coefficient of water stability, and shrinkage strain. In order to compare the effects of different additives on the silt, six laboratory test programs, as indicated in Table 5, were performed to determine the appropriate scheme and the reasonable content of new stabilizing agent.

Laboratory tests were performed according to Test Methods of Soils for Highway Engineering (JTJ051-93) (IHMCC, 1993) and Test Methods of Materials Stabilized with Inorganic Binders for Highway Engineering (JTJ057-94) (IHMCC, 1994). The specimen was statically compacted at optimum water content into a cylinder with a diameter of 5 cm. The height of the cylinder was 5 cm for unconfined compression test and water stabilization test, and 10 cm for shrinkage test. When the compacted specimen was taken out of the mould, it was put into a sealed wet box and moved into the humidity room where the specimen was cured under the temperature of 25 °C ± 2 °C. The specimen was soaked into water in the last day of the curing period. Then, it was taken out and the water on its surface was wiped off.

Following different curing periods, which change from 7 to 90 days, specimens were tested to determine their unconfined compressive strength, water stability, and linear shrinkage. The effectiveness of the SEU-2 on silt was evaluated on the basis of the unconfined compressive strength, coefficient of water stability, and shrinkage strain. All strength and shrinkage tests were performed on specimen duplicates and average values were used. In addition, scanning electron microscopy (SEM) determinations were used to elucidate the mechanical properties of stabilized silt by SEU-2.

## 3. Laboratory test results

### 3.1. Unconfined compressive strength

Fig. 1 shows the unconfined compressive strength of stabilized silt samples corresponding to the six test programs in Table 5. For each program, the unconfined compressive strength increases with time. It increases more rapidly within the early 28 days than after 60 days. Stabilized silts in programs S1 and

Table 2
Mineralogical composition of silt sample

| Mineral | | Content (%) |
|---|---|---|
| Non-clay minerals | Quartz | 40 |
| | Feldspar | 7 |
| | Mica | 8 |
| | Calcite | 7 |
| | Dolomite | 3 |
| Clay minerals | Montmorillonite | 10.2 |
| | Kaolinite | 4 |
| | Illite | 5.6 |
| | Chlorite | 5.2 |
| Others | | 10 |

Table 3
Particle-size distribution of the silt

| Range of particle size (mm) | Content (%) |
|---|---|
| 2–0.075 | 2.9 |
| 0.075–0.005 | 73.8 |
| <0.005 | 23.3 |

Table 4
Chemical composition of cement clinker

| Composition | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $SO_3$ | LOI |
|---|---|---|---|---|---|---|---|
| Content (%) | 22.12 | 3.34 | 5.41 | 65.67 | 1.31 | 0.53 | 0.20 |

Table 5
Laboratory testing programs for different additives

| Program | Lime (%) | Cement (%) | New stabilizing agent (%) |
|---|---|---|---|
| S1 | 6 | | |
| S2 | 3 | 2 | |
| S3 | | | 3 |
| S4 | | | 4 |
| S5 | | | 6 |
| S6 | | | 8 |