INFLUENCE OF CEMENT AND LIME ADDITIVES ON THE COMPACTION PROPERTIES AND SHEAR PARAMETERS OF FINE GRAINED SOILS

DER EINFLUSS VON ZEMENT UND WEISSFEINKALK AUF DIE DIE SCHERFESTIGKEIT VON SCHLUFF UND AUSGEPRÄGT PLASTISCHEM TON

INFLUENCE DE CIMENT ET CHAUX SUR LA RESISTANCE AU CISAILLEMENT DE LIMON ET ARGILE FORTEMENT PLASTIQUE

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ABSTRACT

The effect of cement and lime on the shear parameters, as determined in the direct shear test, of a typical silt and a highly plastic clay are investigated. With cement the better results are achieved. The increase in stiffness and strength was noticeable with cement and lime. With cement the improvement of cohesion was very large. The results so far suggest that the size of the soil clumps resulting mixing can affect the shear parameters.

ZUSAMMENFASSUNG

Es wurde der Einfluss von Zement und Weißfeinkalk auf die Scherparameter eines typischen Schluffes und eines ausgeprägt plastischen Tones mit direkten Scherversuchen untersucht. Mit beiden Bindemitteln wurde schon bei Dosierungen von 4 % (bezogen aus das Trockengewicht des Bodens) eine wesentliche Erhöhung der Festigkeit und Steifigkeit erzielt. Im Hinblick auf die Steigerung der Kohäsion war die Zugabe von Zement besonders effektiv. Einen wesentlichen Einfluss auf die Scherfestigkeit hatte die durch das Einmischen des Bindemittels erzeugte Kornstruktur des Bodens.

RESUME

L'influence du ciment et de la chaux sur les paramètres de cisaillement d'un limon typique et d'une argile fortement plastique a été déterminé par des essais de cisaillement directs. Avec les deux liants, une augmentation substantielle de la résistance et de la rigidité a été obtenue dès un dosage de 4 % (par rapport au poids sec du sol). En ce qui concerne l'augmentation de la cohésion, l'addition de ciment était particulièrement effective. La structure granulaire du sol résultant

de l'incorporation du liant a une influence substantielle sur la résistance au cisaillement.

1. INTRODUCTION

Cement or lime are often added to fine grained soils when the water content is well above the optimum water content in order to improve the compactability. In road construction it is a well known fact that in addition to improving the compactability the compressive strength of the soil is also improved .[1, 2] In the construction of earth dams or embankments however, the shear parameters of the soil are of special importance in order to calculate the stability of the slopes. In the following a typical cement used in soil stabilisation and lime were mixed with a silt and a clay in the amounts 2%, 4%, 6% and 8% of the dry weight of the soil. In order to investigate the influence of the additives alone all the samples for the shear tests were prepared with the same dry density and water content. The dry densities and water contents selected were equivalent to 97% of the Proctor density of the natural soils used, on the wet side. The shear strength was determined in the direct shear box using normal load of 50, 100 and 200 kN/m².The sample sizes were 6×6×3cms. and the rate of loading was 0.05mm/min.. The shear parameters were determined at 3,7,14 and 28 days after sample preparation. The silt used had 60% coarse silt, 20% medium silt and 10% clay. The rest was fine silt. The liquid limit was 26.9% and the plasticity index 11.3%. The natural lime content was 17%. The clay consisted of 60% clay, 30% fine silt, the rest was medium to coarse silt. The liquid limit was 61% and the plasticity index 41.4%. The natural lime content of this soil was 11%. The cement used was a special cement for use in road construction from the Heidelberger Cement factory type HT-35.

2. INFLUENCE OF THE ADDITIVES ON THE COMPACTION PROPERTIES

After mixing the soils with the appropriate amounts of additive, standard Proctor tests were carried out. The maximum densities achieved with the various amount of additive are shown in Fig.1.

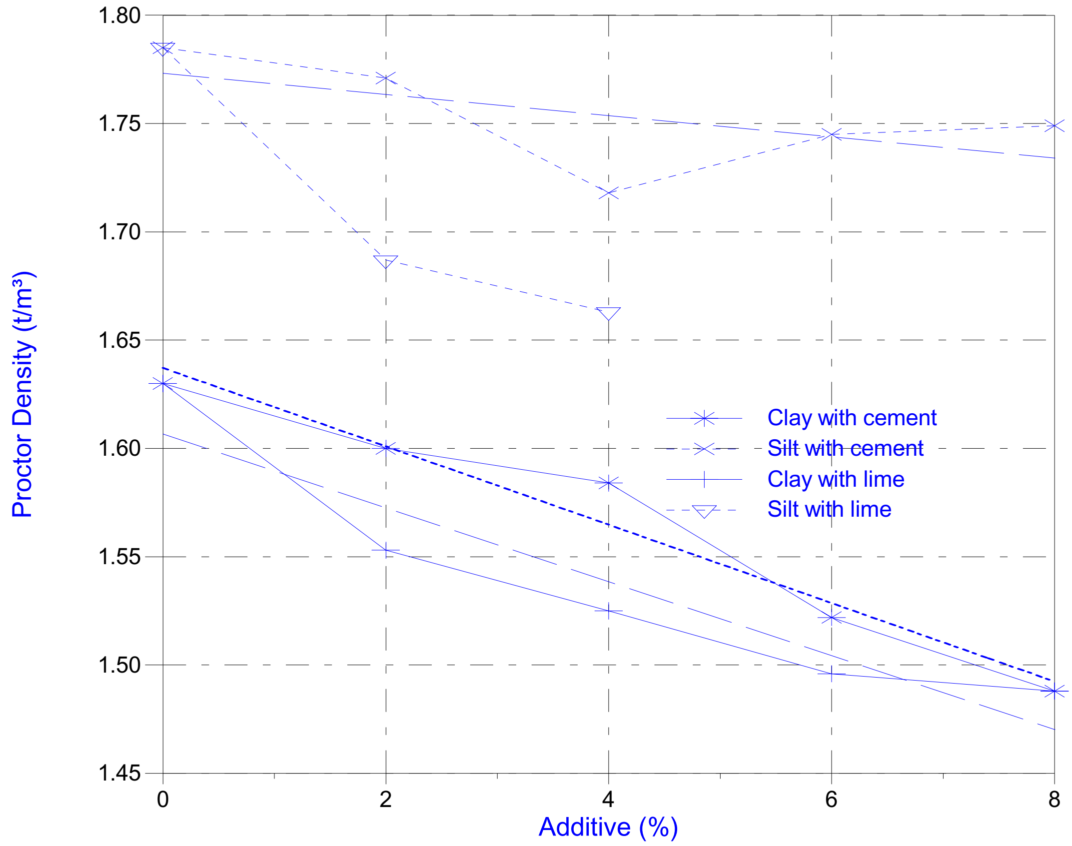


Fig. 1. Proctor density v Amount of additive

As to be expected the maximum densities decreased with increasing amounts of additive. With the cement additive there is a linear decrease in maximum density with both soils with increasing additive amounts. The decrease in the density of the clay soil is more pronounced.

With the lime additive there is an initial sharp decrease in the maximum density with small amounts of additive (2%) after which the rate of decrease becomes linear and approximately parallel to the decrease due to the cement additive. In general higher densities can be achieved with the cement as an additive compared with equal amounts of lime.

The effect of the additives on the optimum water content is shown in fig.2.

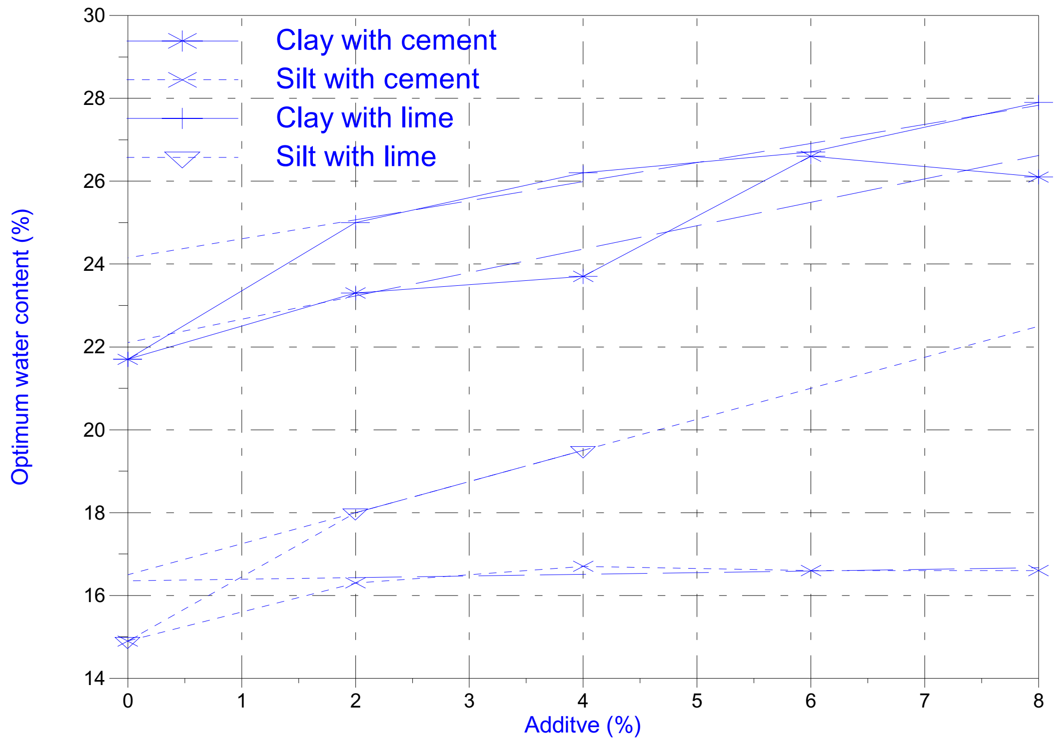


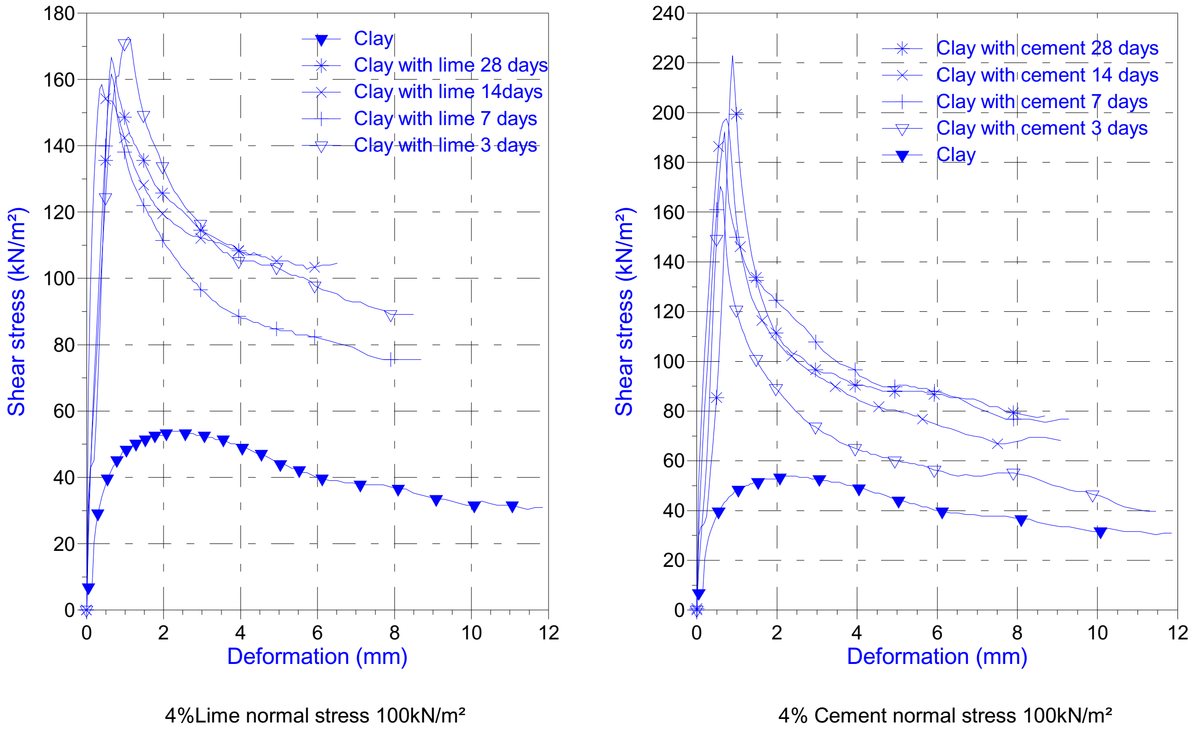
Fig. 2. Optimum water content v Amount of additive

As to be expected there is an increase in optimum water content with increasing amounts of additive. Clay with cement showed a linear increase. Silt with cement however had an initial increase followed by only a slight increase with increasing cement amounts. Both soils with lime as an additive showed a sharp increase in optimum water content with small amounts of additive followed by a linear increase. Whereby the increase in optimum water content of the silt/lime mixtures was more pronounced than with the clay lime mixtures.

3. INFLUENCE OF ADDITIVES ON THE SHEAR-DEFORMATION CHARACTERISTICS

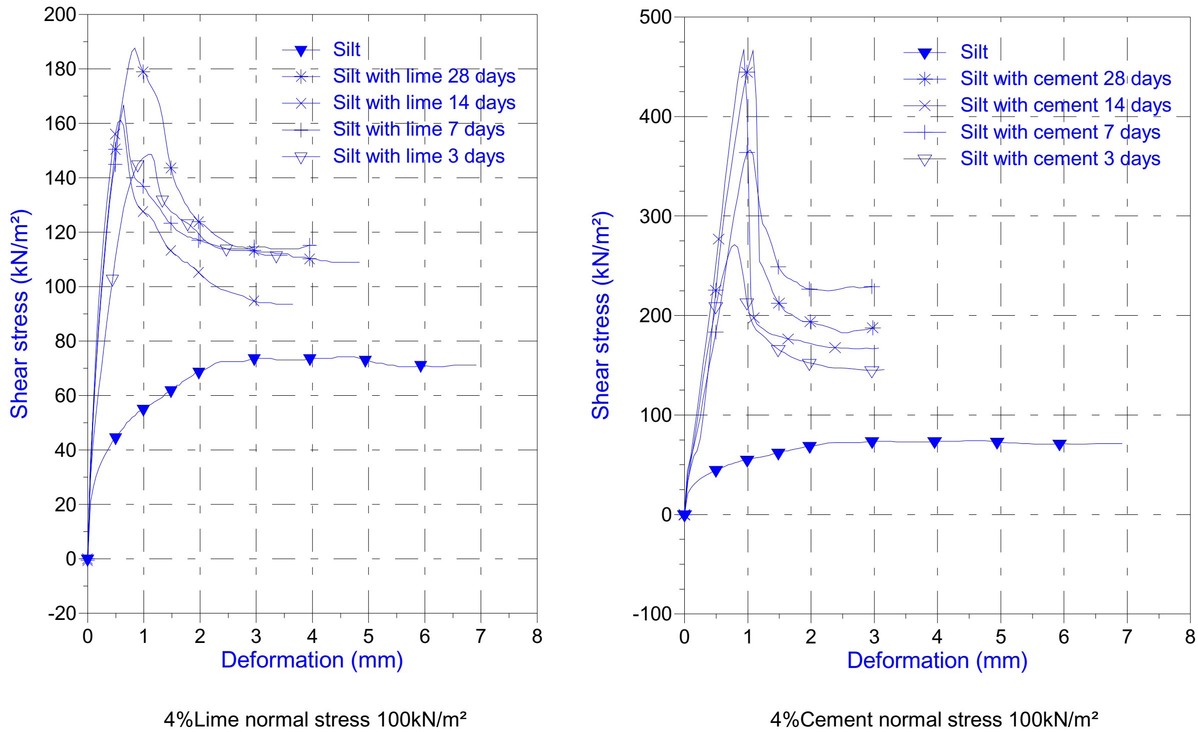
All the clay samples were compacted to a dry density of 1.58t/m³ at a water content of 24.4% which is equivalent to 97% of the maximum density of the natural soil. The silt samples had dry densities of 1.73t/m³ and water contents of 18.2%. These are also equivalent to 97% maximum density of the natural soil.

Typical shear stress v deformation curves are shown in figs.3 and 4. It can be clearly seen that with both soil types the shapes of the curves are very similar for both additives. Compared with the natural soils the mixtures are very brittle. In all cases after reaching a maximum, the shear stress rapidly falls off until a rest shear stress is reached which remains approximately constant with increasing deformation.



(a) *(b)*

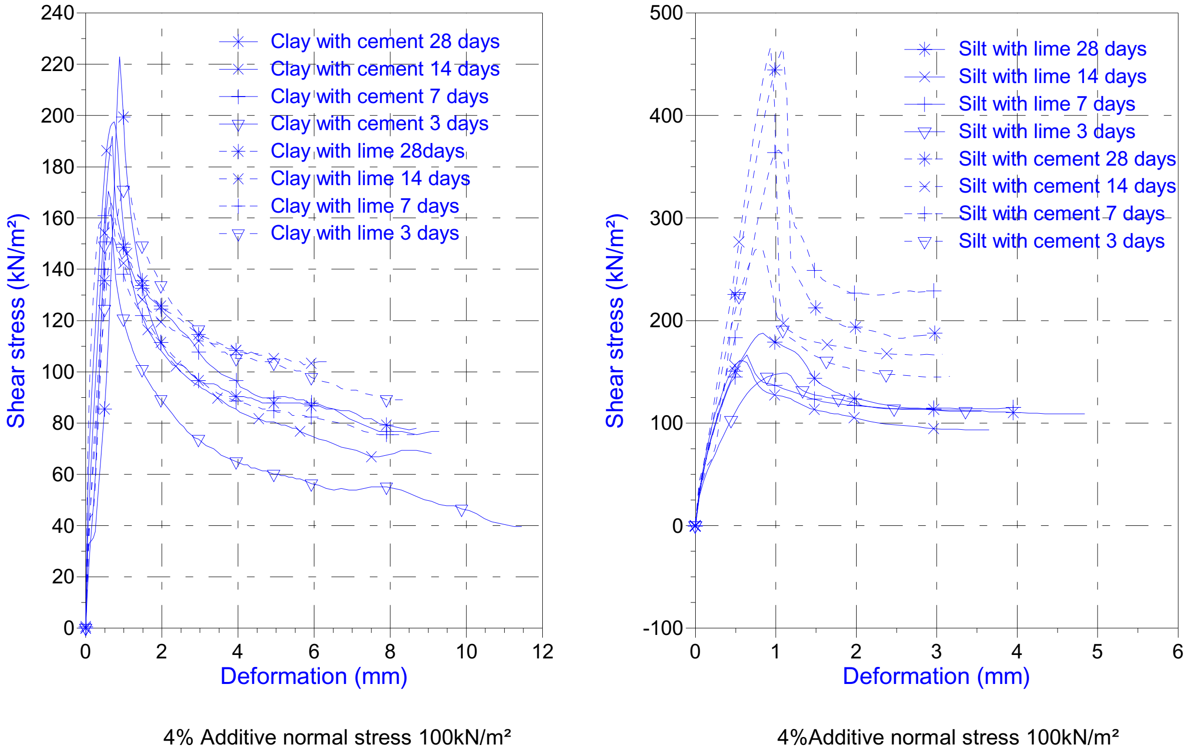
Fig.3. Shear stress and deformations of clay with additives



(a) *(b)*

Fig. 4. Shear stress and deformations of silt with additives

A comparison of the effects of the two additives on the stress-deformations curves for each soil type are shown in fig. 5.



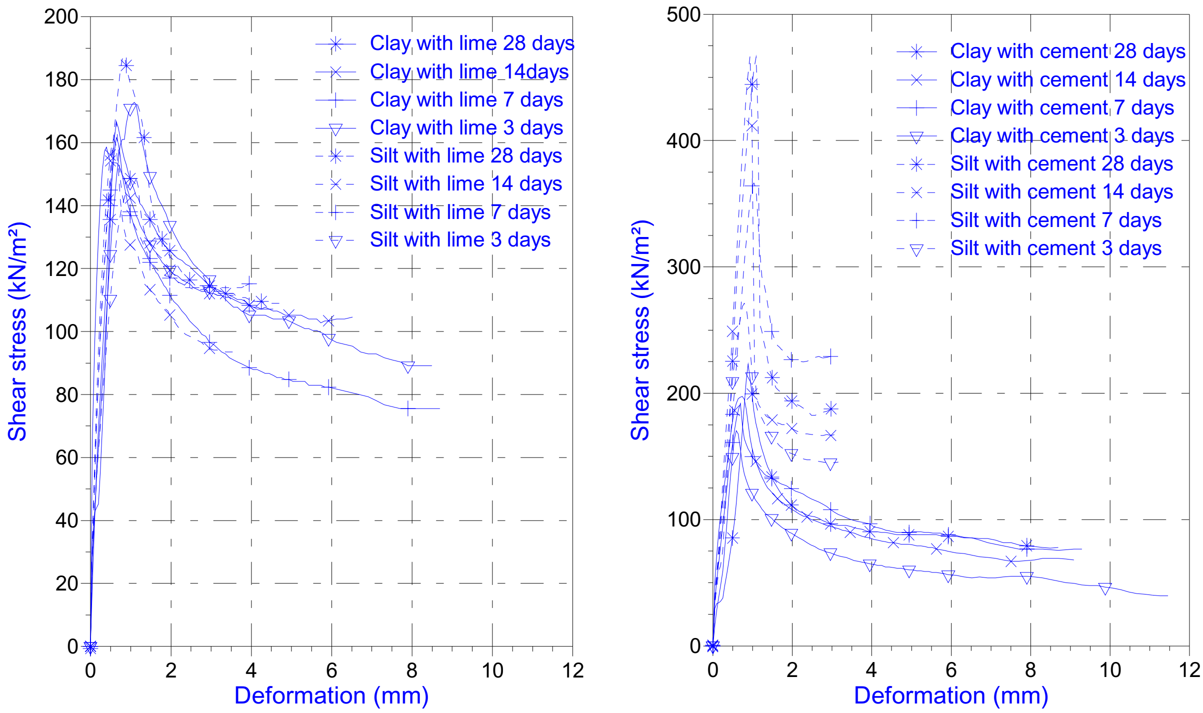
(a) *(b)*

Fig.5. Shear stress and deformations of clay and silt with additives

With the clay (see fig.5a) there is little or no difference in the slopes of the curves in the initial phases of loading. The maximum shear stresses are slightly higher with the cement as additive. The rest shear stresses after large deformations however are higher with lime as additive especially after short curing times.

The differences in maximum shear stresses between cement and lime as an additive are more pronounced with the silt soil (see fig.5b) and the samples with cement as an additive are stiffer in the initial loading phases. With the silt soil however the rest shear stresses after large deformations are much higher with cement as an additive compared with lime.

A comparison of the effects of each additive on the two soil types is shown in fig. 6. In fig. 6(b) it is quite clear to see that cement has a much better effect on the shear stresses with silt soils than with clay soils. Both the maximum shear stresses and the rest shear stresses are much higher than with the clay soil. On the other hand lime seems to equally well with both clay and lime soils (see fig. 6a).



4%Lime normal stress 100kN/m²

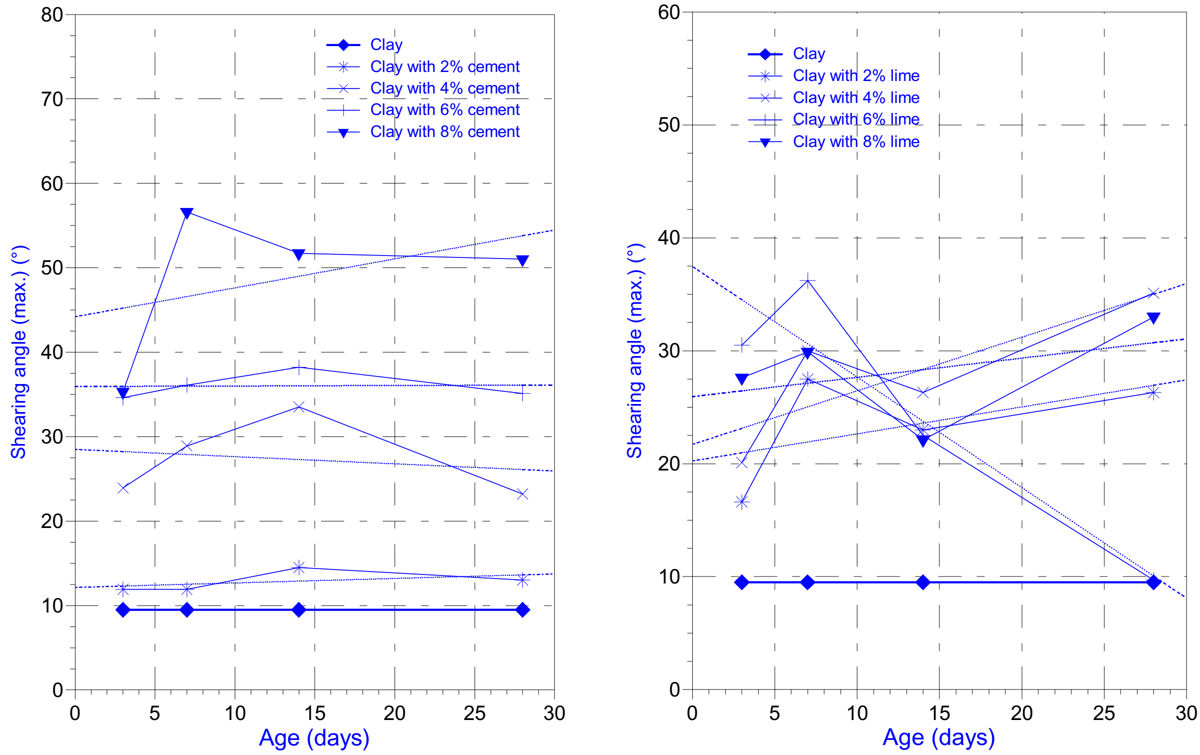
4% Cement normal stress 100kN/m²

(a) *(b)*

Fig. 6. Influence of additive on the shear deformation characteristics of the two soil types

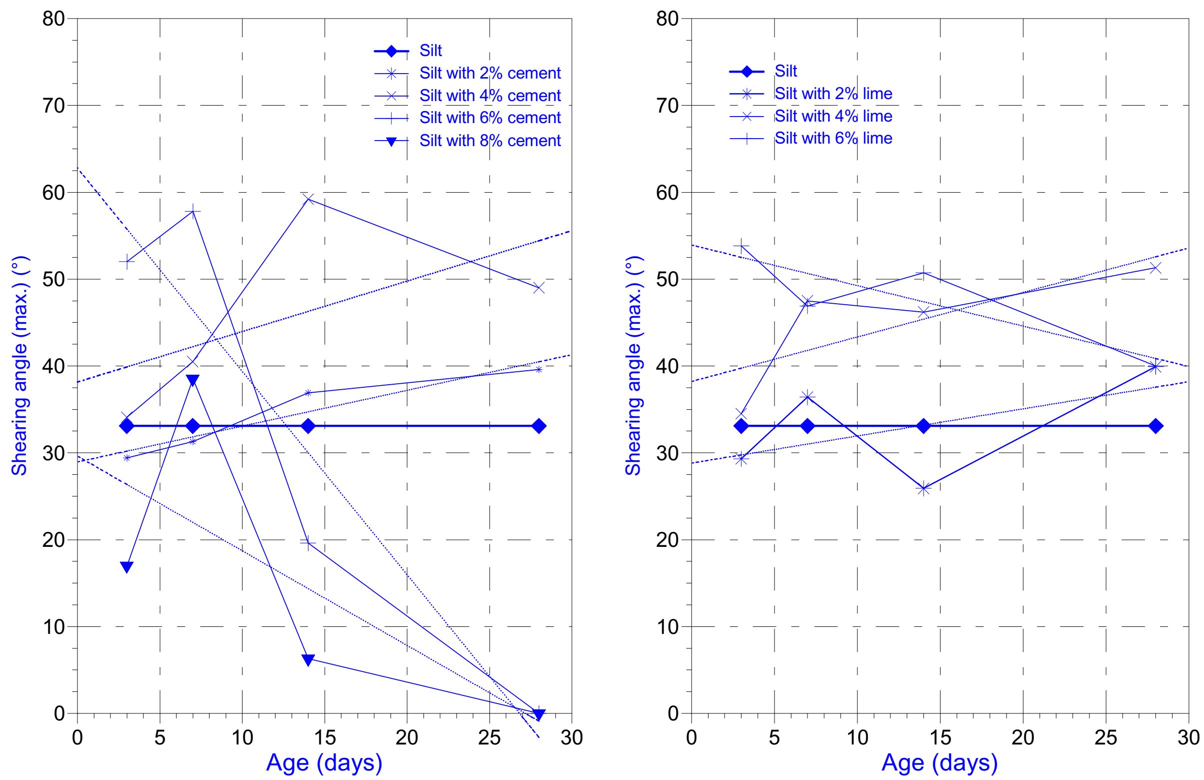
4. INFLUENCE OF THE ADDITIVES ON THE SHEAR PARAMETERS

In slope stability analyses the maximum shear strength is generally of primary importance. For this reason only the shear parameters using the maximum shear stresses were calculated. The dependence of the shearing angle for the various mixtures with age is shown in figs. 7 and 8. The largest increases both with silt and clay occur when cement is used as an additive. The most dramatic increases occurred with cement and clay (see fig. 7(a)). In this diagram there appears to be no increase in shearing angle with increasing age. This tendency can in spite of scattering be seen in the other diagrams. Occasionally with certain mixtures especially with larger amounts of cement there is a decrease in shearing angle with age and it can sink down to 0°.(see figs. 7(b) and 8(a)).However as will be seen later this is coupled with high cohesion values. These samples act as soft rocks and the normal loads used in these tests are not high enough to compress the soil structure to activate the frictional properties between aggregates.



(a) *(b)*

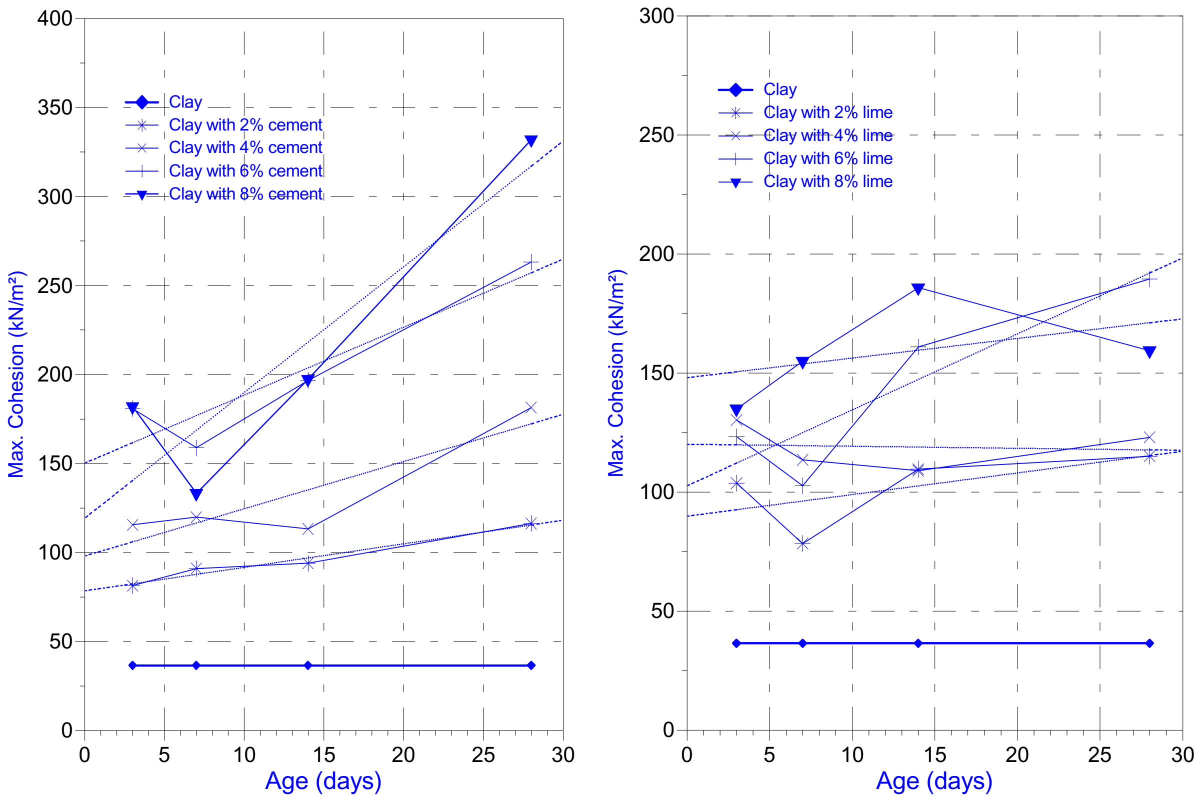
Fig. 7. Influence of additive on the shearing angle of the clay



(a) *(b)*

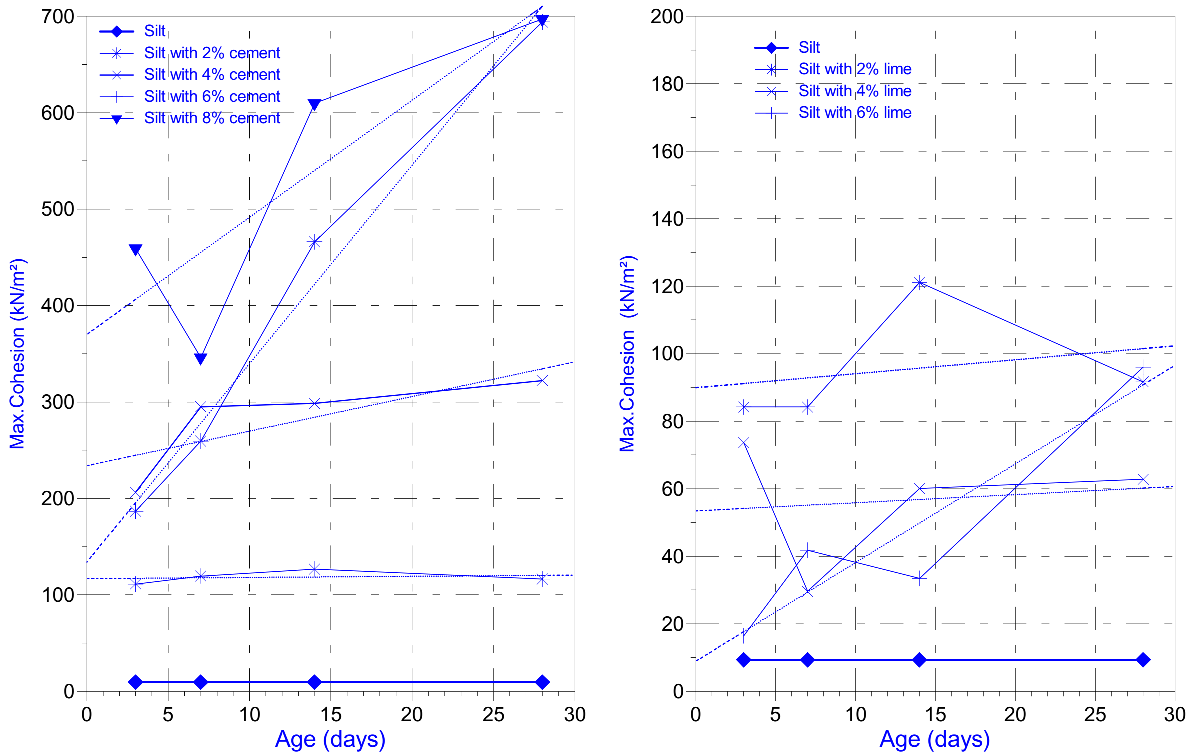
Fig. 8. Influence of additive on shearing angle of silt

The dependence of the cohesion on the additive amount and age is shown for the two soil types in figs. 9 and 10. In all cases there is a large increase in cohesion as compared with that of the natural soils. This is especially noticeable in both soils with cement as an additive. With these mixtures especially with higher cement contents there is a rapid increase in cohesion with age. The rate of increase after 28 days appears to be still constant so that further increases with increasing age are to be expected. With lime as an additive the main increase seems to be immediate and an increase in cohesion with age is not so pronounced. It occurs only in samples with high percentages of lime.



(a) *(b)*

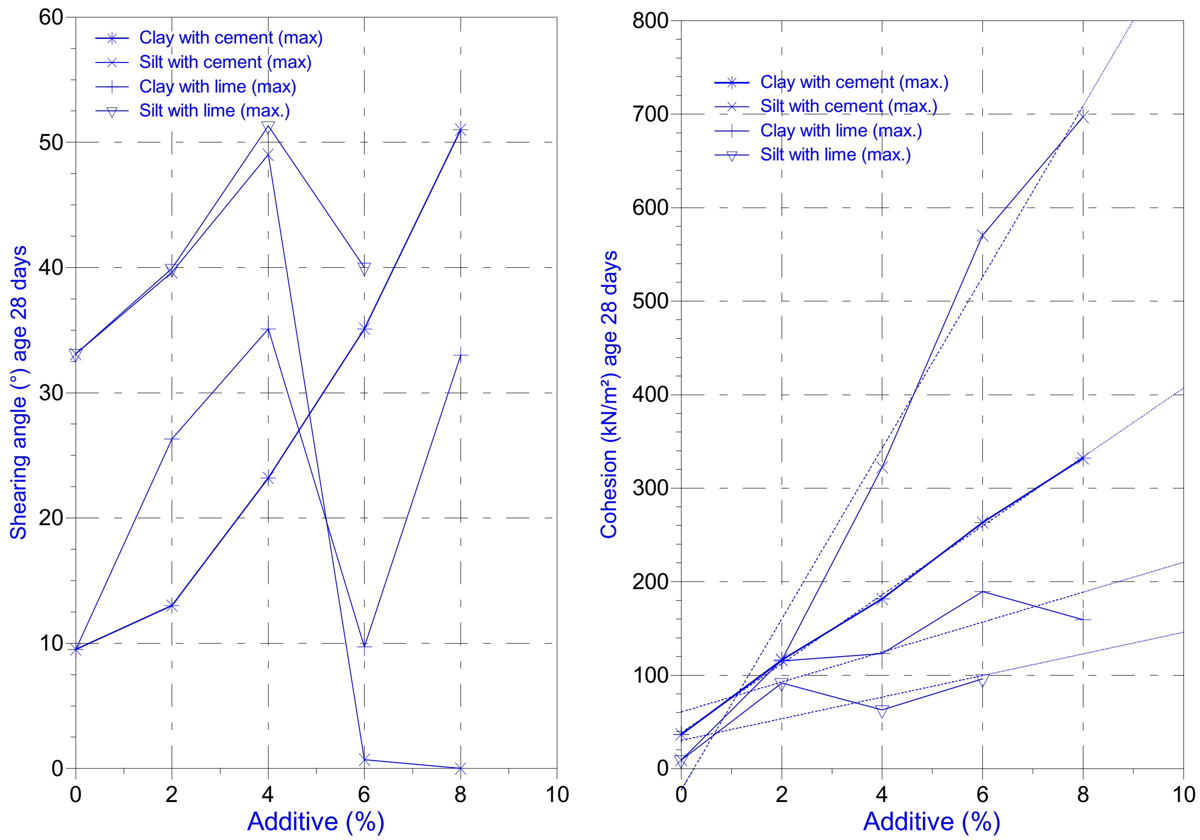
Fig. 9. Influence of additive on the cohesion of clay



(a) *(b)*

Fig. 10. Influence of additive on the cohesion of silt

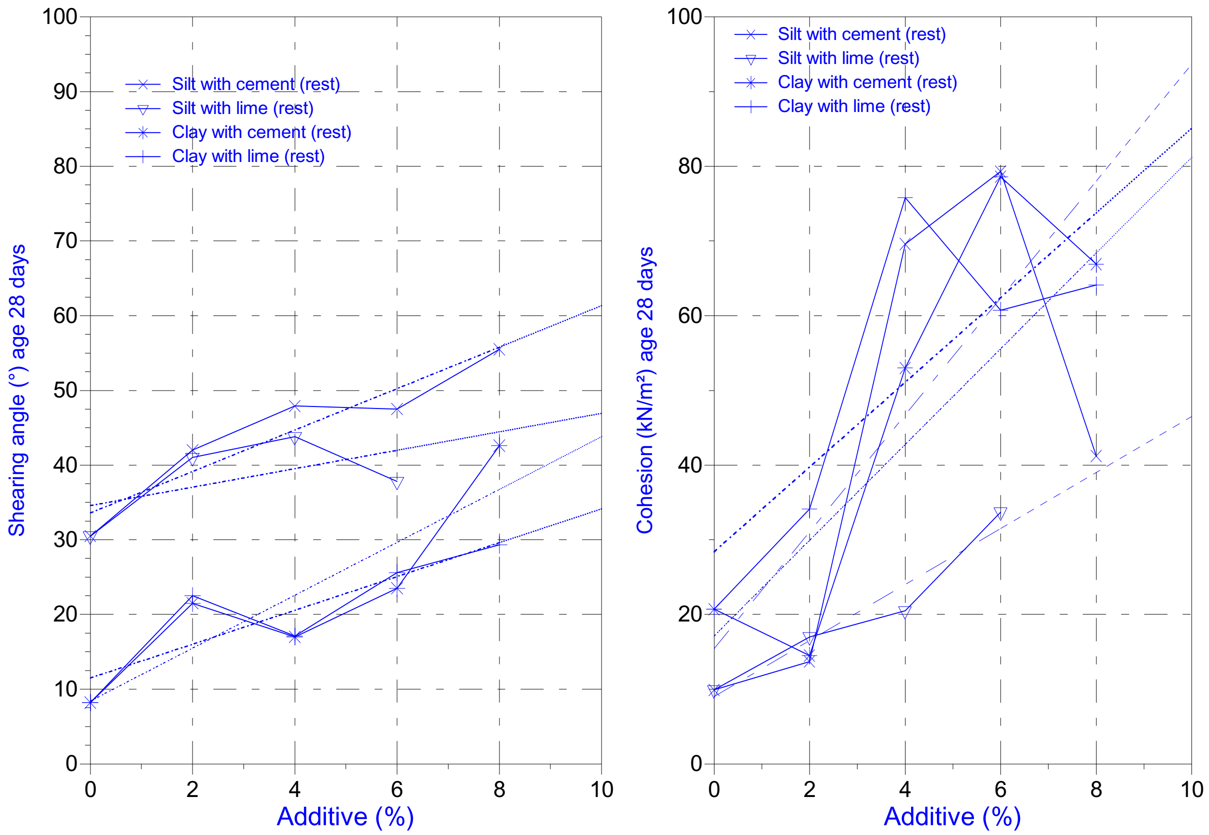
In order to show the effect of the amount of additive on the shear parameters those at age 28 days were selected. In fig 11 the changes in the shearing angle and cohesion at maximum shear stresses are shown in dependence on the amount of additive. Up to 4% additive there is an increase in shearing angle (see fig. 11(a)). Further increases in additive often result in a decrease in the shearing angle. This as has been mentioned before is probably a result of the high crushing strength of the resulting soil structures at higher additive contents. An exception is clay with cement. Here is a steady increase in shear angle with increasing cement content. Compared with the silt and the same amounts of cement it suggests that the soil structure of the clay samples consists of softer soil aggregates cemented together whereas with the silt which has a low plasticity the soil grains are cemented together. In fig. 11(b) it can be seen that in all cases the cohesion increases with increasing additive content. The highest cohesion is achieved with cement whereby silt has the best results. This is probably due to the fact that because of the low plasticity little or no clumps occur and the mixing with the cement is more intense producing a more homogeneous soil structure.



(a) *(b)*

Fig. 11. Influence of additive amount on the shear parameters

In fig. 12 the shear parameters at 28 days using the rest shear strengths are shown in dependence on the additive content. The shearing angles (see fig. 12(a)) increase with increasing additive content whereby the additive type seems to have not much influence. The rest shearing angles are always higher than the maximum shearing angles of the natural soils. Also the rest cohesion is higher than the maximum cohesion of the natural soils (see fig. 12(b)).



(a) *(b)*

Fig. 12. Influence of additive amount on the rest shear parameters

5. CONCLUSIONS

These preliminary test results show that the shear strength of fine grained soils can be improved through additives such as lime and cement. Generally better results can be obtained using cement. The tests suggest that the aggregate size during mixing can greatly influence the results. Large increases especially in the cohesion could advantageous in preventing surface erosion as well as increasing the slope stability. This can be achieved much better with cement than lime.

The mixtures are always more brittle than the natural soils themselves but the rest shear strength of the mixtures is always higher than the maximum shear strength of the natural soils.

We would like to thank Mr. Stefan Merz who carried the tests.

LITERATURE

[1] Eignungsprüfungen bei Bodenverfestigung mit Zement, TP BF-StB, Teil B 11.1

[2] Eignungsprüfung bei Bodenverbesserung und Bodenverfestigung mit Feinkalk und Kalkhydrat, TP BF-StB, Teil B 11.5

[3] Stefan Merz, Diplomarbeit 86, Institut für Geotechnik, University of Stuttgart 2000