It is seen that with increasing percentage of fly ash, the FSI decreases non-linearly. By addition of small percentage of lime the decrease in FSI is significant. The FSI value of untreated soil is around 195%, which reduces to around 80% by addition of 40% fly ash only. When lime added with fly ash there will be more reduction in FSI. It can be observed from figure that the optimum content of lime-fly ash admixture at 8% lime with 20% fly ash will reduce the FSI from 195% to around 20% i.e. a reduction of about 175% of untreated swell value.

4.2.2 Swelling pressure

The swelling pressure of the natural soil is 167 KPa. It is observed that the swelling pressure is reduced from 167 KPa to 0 KPa at 8% lime only or at 5% lime combined with 5% fly ash. This significant reduction in swelling pressure occurred by addition of lime only or by using lime-fly ash. Comparing the two options, lime-fly ash admixture is preferred to be used because of its low cost.

4.3. Effect of additives on strength properties

4.3.1 Compaction characteristics

The results of the compaction test showing the maximum dry density (MDD) and the optimum moisture content of the natural and lime-fly ash-stabilized clay are shown in Figure 3. As seen in figure, the MDD increases with increasing lime content from 5 to 8%, while a reduction in the MDD was observed when fly ash increases from 0 to 10%. Knowing that compaction of soil involves the packing of the soil particles such that its voids are reduced to the minimum. Thus an increment in MDD occurs at the minimum lime-fly ash content (i.e. 8% lime only), while a reduction in the MDD at the maximum lime-fly ash content of 5% lime and 10% fly ash. This result indicates that the lime-fly ash content in the soil-lime-fly ash mixture was in excess of the amount needed to improve the gradation of the soil. Also, Figure 3 reveals that optimum moisture content required to achieve the MDD increases with the addition of lime. It can be seen that the optimum moisture content at 5% lime with 10% fly ash combination content was greater than OMC required at 5% lime with 5% fly ash and 8% lime with 5% fly ash and 8% lime only. The maximum OMC was recorded at the combination of 5% lime and 10% fly ash content. This increase in the OMC observed with the addition of lime-fly ash is caused hydration reactions between the cations of the clay particles and the lime-fly ash.

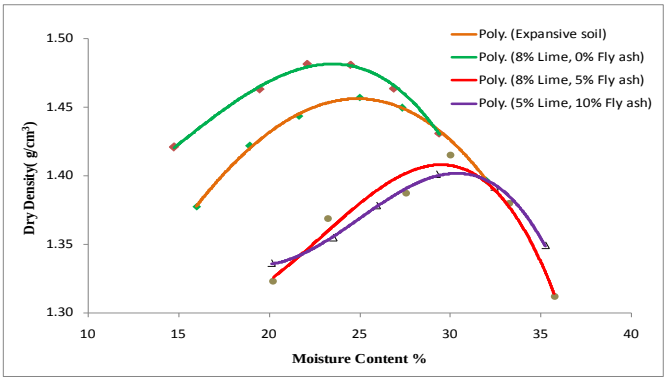

Figure 3: Variation of compaction characteristics (MDD and OMC) with Lime-Fly ash

4.3.2 CBR

The influence of lime-fly ash stabilized clay on CBR is shown in Figure 4. The unsoaked CBR values increase from 25% (untreated) to 70% with 8% lime only. Addition of fly ash led to decreased CBR. The plot in Figure 4 clearly demonstrated that cured strength increases in soaked CBR from 2.6% (untreated) to 151% with 8% lime only. This is considered to be extremely effective and necessary process to provide good subgrade. This result verified the presence of pozzolanic material responsible for the strength gain. While reduction in the CBR was observed at lime-fly ash of 5% lime and 10% fly ash. This reduction in the CBR might be due to the excess lime-fly ash in the clay not required for the early strength gain as a result of flocculation.

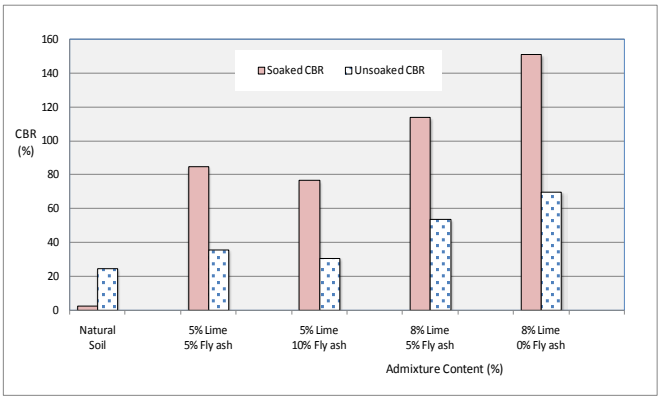

Figure 4: California Bearing Ration (CBR) versus lime-fly ash admixture

4.3.3 Unconfined compressive strength

The unconfined compressive strength variation with lime-fly ash additive is graphically presented as shown in Figure 5. It is observed that lime stabilization demonstrated very significant unconfined compressive strength gains. The increment of strength depends on the amount of lime added. When 8% lime added to the expansive soil studied, the unconfined compression strength increases from 400 KPa (untreated) to 1872 KPa. But using lime-fly ash content at 8% lime with fly ash 5% combination reduced the Unconfined Compressive Strength value to 1720 KPa. This may be fly ash added more fine to the soil leading to reduction in strength.

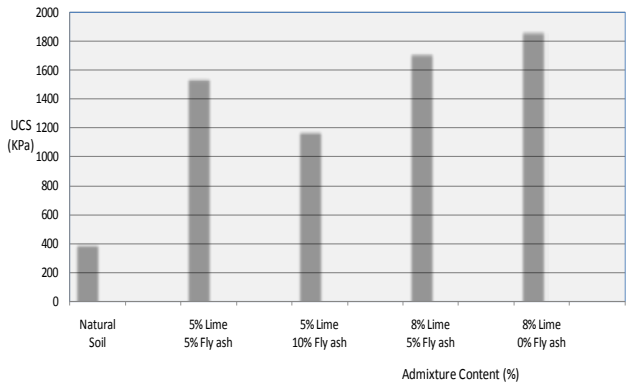

Figure 5: Influence of fly ash admixture on Unconfined Compression Strength (UCS) of the soil.

5. Conclusions

An extensive laboratory testing program was carried out to investigate the influence of using lime, fly ash and lime-fly ash admixtures on the characteristics of expansive subgrade soils. The observations and conclusions can be summarized as follows:

- The results show that lime and fly ash played an important role in improving the strength characteristics and swelling behavior of expansive soil.
- Addition of lime significantly improved consistency, swelling and strength properties of the expansive soil. However, the presence of fly ash fundamental to further improve the soil behavior, due essentially to the occurrence of a larger amount of time-dependent pozzolanic reactions. Moreover it is always encouraged to use fly ash for stabilization where easily and economically available.
- Some factors such as curing and compaction parameters have considerable effect on strength measured by the CBR and unconfined compression strength of the treated soil with time and have to be taken in account when executing earth work with such materials.
- Based on the tests results, it can be stated that, as the percentage of lime-fly ash increases the swelling decreases and the strength increases and the optimum lime-fly ash content at 8% lime with 10% fly ash.
- On the basis of economic considerations, use of good quality fly ash alone is recommended for treatment of clays with low to medium expansiveness. Whereas, for treating highly expansive clays, a combination of fly ash with small percentage of lime is recommended, so it is valuable option in Sudan to use lime-fly ash as a stabilizer.
- Immediate effects of lime in soil can promote reduction in plasticity, reduced moisture retention and improve compaction characteristics resulting in strength gains and swelling reduction.
- It has been found that the quantity of lime-fly ash needed to effectively treat a soil to develop increased strength and reduced swelling varies with the type of clay mineral present.

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Author Profile

Dr. Magdi Zumrawi was born in Omdurman, Sudan, 19 May 1963. He received the B.Sc. degree in Civil Engineering and M.Sc. degree in Road Technology from University of Khartoum in 1987 and 1991,

respectively. He achieved Ph.D. in Highway and Railway Engineering, Chang'An University, Xi'an, in Sept. 2000. Now he is Associate Professor in Highway Engineering. His present occupation is Head, Civil Engineering Department, Faculty of Eng., Khartoum University, since Nov. 2014. He is a highway expert working with local and international consultant firms. He has published many articles in local and international journals and attended national and international conferences. He is a member of International Society for Soil Mechanics and Geotechnical Engineering. He is a senior member of the APCBEES.