Summary

The present work is focused on the investigation of physical and mechanical properties of fine grained soil treated with selected fly ash and lime in order to observe the effects that mixtures prepared with different component proportions induce on the observed behavior.

The experimental investigation was carried out on Speswhite kaolin treated with fly ash coming from fluidized bed combustion and lime. pH measurements, sedimentation tests and oedometer tests were performed in order to understand the mechanisms governing the physical and mechanical behavior of the treated soils.

1. Introduction

Fly ash is a waste material obtained during the energy production in power plants. In countries such as Poland where energy industry is based almost entirely on power plants and thermal power plans operation, the reuse of waste material represents an alternative and economical solution with respect to its disposal. Therefore this involves the need to identify the properties of fly ash originating from a particular power plant, working on raw material mined in a specific location.

Currently fly ash is a worldwide object of interest of scientific units also in terms of its use in geotechnical engineering. Literature describes a beneficial effect of the fly ash addition (also in combination with lime or cement) on fine grained soils properties. These benefits includes among the others decrease of free swelling (Zhang and Cao 2002) and increase of strength and stiffness of the treated soils (Reyes and Pando 2007, Kolias et al. 2005).

The aim of this paper is to show the present stage of an experimental work, concerning the reuse of fly ash, selected from a polish power plant as an alternative solution of ground improvement technique.

2. Materials and procedures

The soil chosen for the present investigation was Speswhite Kaolin, whose properties are summarized in Table 1 and 2. The fluidal fly ash were provided by a power plant placed in Silesia region (Poland).

Chemical composition and grain size distribution of fly ash are given in Table 3 and Figure 1.
Table 1.
Properties of Speswhite kaolinite (http://www.imerys-perfmins.com)

<table>
<thead>
<tr>
<th>pH</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical analysis by X-ray fluorescence</td>
<td></td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>47</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>38</td>
</tr>
</tbody>
</table>

Table 2.
Physical parameters of Speshite kaolinite (Kowalska 2009)

<table>
<thead>
<tr>
<th>Grain size [%]</th>
<th>Plastic limit [%]</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2µm</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>from 2 to 10µm</td>
<td>20%</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plasticity index [%]</th>
<th>44</th>
</tr>
</thead>
</table>

Table 3.
Chemical composition of fly ash from fluidized bed combustion

<table>
<thead>
<tr>
<th>Component</th>
<th>[%]</th>
<th>Component</th>
<th>[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>39.73</td>
<td>MgO</td>
<td>1.75</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>7.52</td>
<td>SO$_3$</td>
<td>4.11</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>20.04</td>
<td>K$_2$O</td>
<td>1.84</td>
</tr>
<tr>
<td>CaO</td>
<td>18.73</td>
<td>Na$_2$O$_3$</td>
<td>0.43</td>
</tr>
<tr>
<td>CaO free</td>
<td>5.24</td>
<td>Cl$^-$</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Fig. 1. Grain size distribution of fly ash from fluidized bed combustion

The experimental program concerned also the investigation of the effects induced by the addition of small amounts of lime on the physical and mechanical behavior of treated soil. The percentages of fly ash and lime added to soil were considered with respect to dry soil weight.

In pH measurements the mixtures were prepared by hand mixing in 100% water content and cured in a closed containers for different time intervals. The measurement was performed according to the standard ASTM D 4972-01 (Knapik et al. 2014).

In order to detect differences in fabric formation between treated and untreated soil, gravitational sedimentation tests were performed. Sedimentation tests included preparation of the mixture of air dried components, mixing solids with amount of water which allows to obtain 100% of water content, closing the container to prevent water loss and storing for 21 hours to obtain appropriate soaking. After this time the mixture was poured into a measuring cylinder and filled with distillate water up to level 1000 ml and mixed by rotating. During test the height of total suspension level and the height of limit between pure water and solid column were measured (Knapik 2014).

Oedometer tests were performed on samples prepared at high water content (w=100%) in order to investigate the influence of additives (fly ash and lime) on compressibility. Tests were performed at 0 day (i.e. after 21 h from addition of fly ash and/or lime) and after 7 days of curing, in order to investigate the effects induced by curing time on the observed behavior.
3. Results

Figure 2 shows the pH measurements over time obtained for different types of mixtures. The pH value tends to increase with increasing fly ash content. The addition of 10% and 20% of fly ash is not able to provide a high alkaline environment, which is necessary for development of long term effects (pozzolanic reactions). pH values decreases rapidly after the first week of curing time.

Fig. 2. The pH changes in time – 100% water content (Knapik et al. 2014)

Figures from 3 to 5 show sedimentation tests results. The addition of fly ash changes pH of pore fluid, inducing a different arrangement between clay particles and consequently different settlement velocities (Fig. 3). Shorter induction period proves that mixtures of soil and fly ash are less dispersed (Knapik 2014).

Fig. 3. Sedimentation test results – kaolinite and fly ash mixtures (Knapik 2014)

The outcomes obtained in Figure 4 and Figure 5 shows that the addition of small amounts of quicklime increases the final height of sediment, highlighting a different particles association types (Knapik 2014).

Fig. 4. Sedimentation test results – kaolinite and 10% fly ash mixtures with (and without) lime (Knapik 2014)
Fig. 5. Sedimentation test results – kaolinite and 20% fly ash mixtures with (and without) lime (Knapik 2014)

Figures from 6 to 11 show compressibility curves obtained for mixtures of soil and fly ash with or without lime at different curing time.

The addition of fly ash induces a slight change of the initial behavior of the treated soils and a decrease of volume strain after 21 hours of curing time (Fig. 6). This effect was investigated over time, in particular after 7 days of curing time (Fig. 7).

Fig. 6. Compressibility curves at 0 day of curing time – soil treated with fly ash

Fig. 7. Compressibility curves after 7 days of curing time – soil treated with fly ash

Figures from 8 to 11 show the influence of small amounts of lime (1% and 2%) on compressibility

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of kaolin treated with fly ash at different curing time. The test results show that for mixtures prepared with 10% of fly ash at 0 day of curing the addition of 1% and 2% of lime results in two different observed behavior. After 7 days of curing time the addition of 1% or 2% of lime has not significant effects on the compressibility behavior of kaolin. Different results were obtained for mixtures prepared with 20% of fly ash. At 0 and 7 days of curing time the addition of 1 and 2% of lime provide no differences in terms of compressibility.

Fig. 8. Compressibility curves at 0 day of curing time – soil treated with 10% fly ash with (and without) lime

Fig. 9. Compressibility curves after 7 days of curing time – soil treated with 10% fly ash with (and without) lime

Fig. 10. Compressibility curves at 0 day of curing time – soil treated with 20% fly ash with (and without) lime
4. Conclusions

The investigation of physical and mechanical properties of kaolin treated with fly ash and lime was performed according to the experimental program here reported:
- pH measurements,
- sedimentation tests,
- oedometer tests.

The results can be summarized as follows:
- increase of pH value: the additives cause the increase of pH from acid (not treated soil – pH value 5.5) to basic, providing favourable environment for the development of long term reactions;
- changes in particles arrangement: additives accelerate sedimentation of solids indicating that mutual interaction between clay particles occur,
- increase of compressibility over time: the addition of fly ash and lime improve the one dimensional stiffness of the treated soil, with a decrease of volume strains; this effect is relevantly dependent on curing time.

Further investigation will be extended to the long term behavior in order to investigate the role of bonding compounds on physical and mechanical properties of treated soils.

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Bibliography

http://www.imerys-perfmins.com