IMPROVING THE PROPERTIES OF FLY ASH BY MIXING WITH DIFFERENT SUBSTANCES

I. Chiricuţă, Eng., I. Rusu, *Dr.Sc., univ.prof.*
Technical University of Moldova

1. GENERAL ASPECTS

Fly ash (FA) are widely used throughout the world in concrete mixtures type road structures. Depending on the coal used to produce them, there are two major categories of ashes applicable in this field: bituminous ash (pozzolanic), originating from burning anthracite or shale coal and sub-bituminous or lignite (self-hardening) from burning lignite (or sub- bituminous coal).

Bituminous ashes are used with a chemical agent or activator (usually lime, Portland cement or blast furnace dust), aggregates and water. For most mixtures using aggregates with sorts precisely set the amount of ash normally varies between 8 and 20%. For sandy aggregates, the amount of ash can be increased from 15 to 30% of weight of the mixture [1].

Sub-bituminous or lignite ash, normally self-hardening, due to the high calcium oxide does not require a chemical agent or an activator but are just mixed with water and aggregate. However, due to the rapid setting of most of these ashes, the ash percentage of the total weight of the mixture may be as low as 5-15%. There are also situations when self-hardening ashes are used for road foundations without addition of aggregate [2].

2. IMPROVING THE FLY ASH

Binders can be used to significantly improve the geotechnical and environmental properties of FA. Even a very small addition of binder (1 – 2 %) as an activator for a dry FA may activate and accelerate the cementation reactions.

The strength development of FA is less the larger the Loss of incineration value (i.e. the noncombustible part of the FA) and the smaller the percentage of CaO in the FA. Even a very small (0,5-1,0 %) addition of active lime significantly improves the cementation [3]. However, there are differences between FA from different sources. (Figure 1) Additionally, it has been shown that the larger the specific surface of a FA the better its strength development [4].

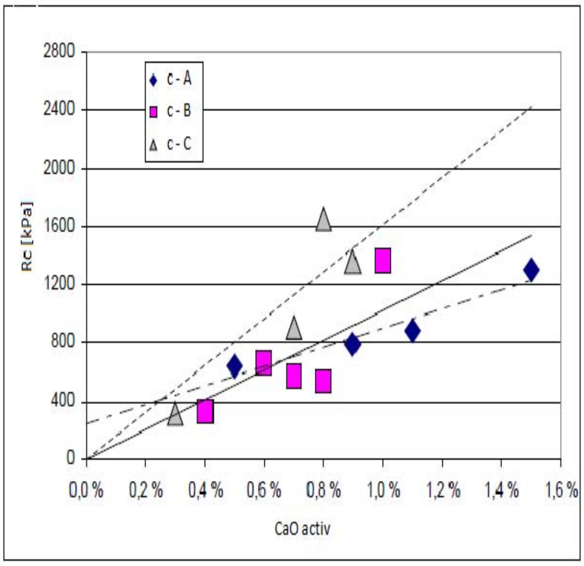

Figure 1. Rc (compression strength) as a function of the content of active CaO for 3 different ashes.

The strength development of a FA will depend considerably on the following factors as well:
- Binder or activator (quality, properties, quantity)
- Water content
- Compaction
- Homogeneity of the mixture
- Efficiency of mixing

The effect of the water content on the strength development and on the compaction of the FA is significant. Most importantly, the farther the water content of the FA is from the optimum water content the lower will be the resultant final strength. Figure 2 shows test results on some FA for the effects of water content on the strength. By using the tests showing the effect of different water contents it is possible to determine the tolerances for changes in water content in practice.

Likewise, it is possible to be determined the minimum relative compaction, D [%], by varying the relative compaction in the laboratory tests. The strength might fall significantly when relative compaction is less than 90-91 %. Therefore, the targeted relative compaction is 91-92 % for most of the FA structures [5].

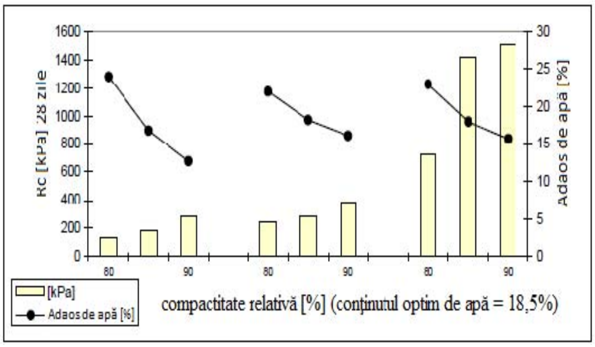

Figure 2. The effects of water content on the strength of some FAs

Binders can be used to significantly improve the geotechnical and environmental properties of FA. Even a very small addition of binder as an activator for a dry FA may activate and accelerate the cementation reactions in the FA. Even 1 – 2 % of activator might multiply the strength of a FA material. To obtain sufficient strength of the material, the required binder quantity is considerably larger in the cases of pile-FA or other originally weakly cementing ashes [6].

There are several binders or activators that can be used with FA. The most important binders are different types of lime and cement, as well as industrial residues like slag (especially the blast furnace slag), gypsum, reactive ashes and FGD (flue gas desulphurisation residues). Lime has proved to be a very efficient activator and cement is very versatile [7]. (Figure 3)

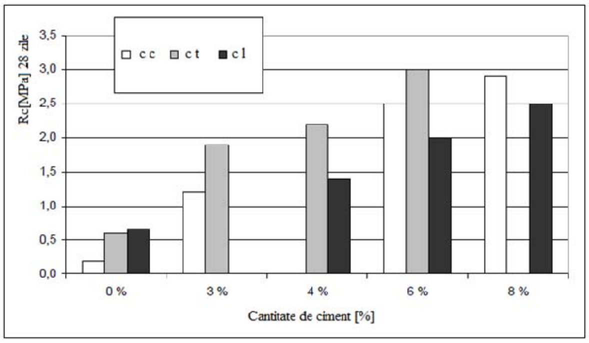

Figure 3. Effect of the quantity of cement on the Rc(compression strength) for 3 types of FA

The use of industrial residues is reasonable because of the environmental and economic benefits that can be obtained, and because it is also technically feasible. The strength of FA will be improved in an almost linear amount with an increasing amount of cement [8].

It is obvious that the effects of binders and binder mixes are different for various FAs.

Each binder has its characteristic reactivity and stabilisation time. Figure 4 indicates that it is worthwhile to test the different binder alternatives because of their significantly different effects. The studies indicate that FAs seem to have relatively good strength development with all types of binders.

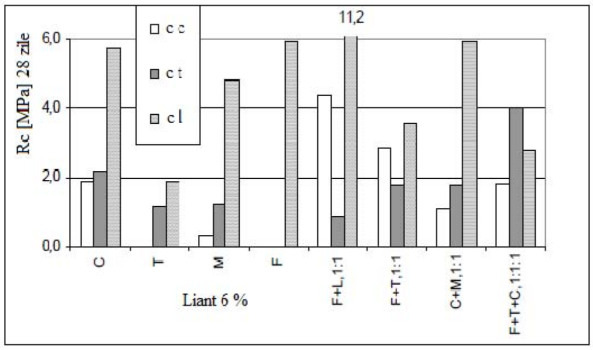

Figure 4. Effect of different binders on the strength of different FA (C= cement, L= lime [CaO], T= hydrated lime, M= blast-furnace slag)

The winter-construction properties of FA can be improved with help of calcium chloride, $CaCl_2$ (CC). The studies have been conducted on the improvement of FA with salt products like CC flakes or solution and the filterwaste (FW) [9]. FW is a byproduct of the production process of CC, and it consists of free lime, gypsum and 20-30 % calcium chloride. Figure 5 shows that the compaction and strength development of FA at – 5 °C will be clearly more effective with an addition of only 2 % FW or 1,2 % CC-solution than without any CC. The actual cementing will start only after the FA structure has thawed, though the compaction has taken place during the frost period [10].

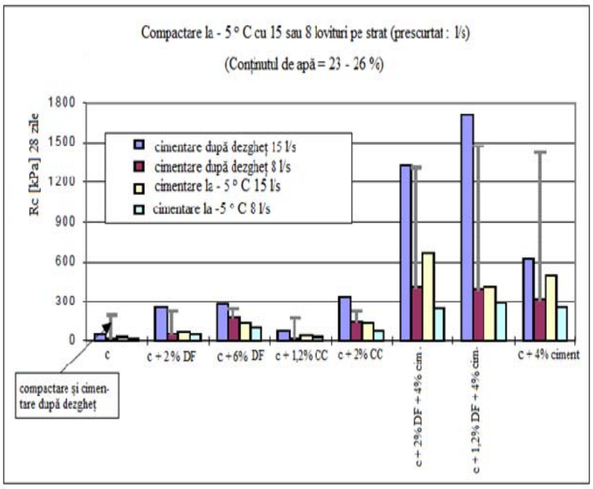

Figure 5. Improvement of FA properties with calcium chloride salt (CC) and filterwaste (FW).

Figure 6 shows the improvement of the compaction results of a certain FA (not frozen) when mixed with different salt products.

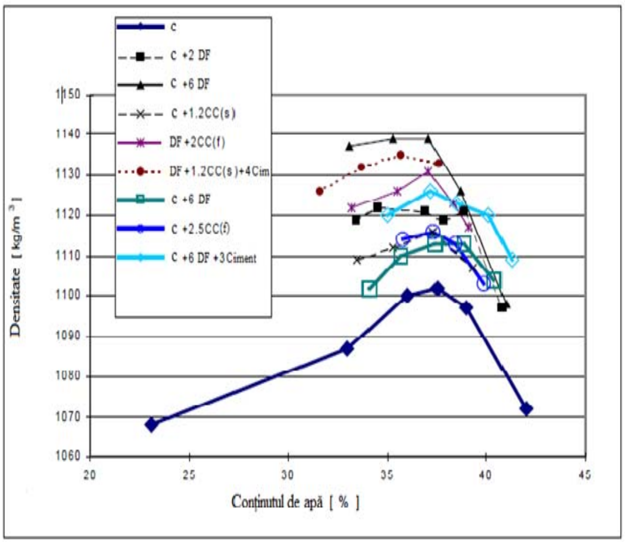

Figure 6. Bulk density depending on water content.

We can improve the compaction of a certain FA (not frozen) by mixing it with different salt products. The salt products also decrease the frost heave of frost susceptible materials. The most effective additive is 2 % of CC flakes. Research concluded that frost susceptible FA can be improved with a small addition of CC. However, these findings can be improved by additional research.

Binders can also be used to improve the environmental behaviour of FA. The effect of different binders on the solubility of heavy metals from a stabilised FA is significant. For example, the blast furnace slag significantly reduces the leaching of several heavy metals. A test was made in 1991 on a coal ash using the EP Tox Test that is designed to simulate leaching under natural disposal conditions. The leaching medium was diluted acetic acid.

3. CONCLUSIONS / RECOMMENDATIONS

1. The properties of FA can be significantly improved by adding different substances, like binders, salts etc. This way, FA becomes a quite valuable material for many road construction applications.

2. There is a significant variation in the quality of FAs from different power plants, despite the use of similar fuels or fuels from same supply source. FA quality variations among peat combusting plants is larger than variations among coal combusting plants. Accordingly, separate FA batches from individual power plants may differ considerably from each other. Therefore, it is important to have continuous control of the geotechnical quality parameters of FA.

3. During open-air pile storage of FA, a large part of the inherent and important geotechnical properties of FA will be lost because of excess moisture. A pile-FA cannot be recycled for use in as many applications as a dry FA, and the properties of a pile-FA application will be of lower quality than with a dry FA. Therefore, adequate dry storage arrangements for FA will be an essential precondition for the development of a controlled recycling system. This is also necessary because most FA is produced during the coldest season, when there are very little on-going road construction projects.

References

1. *Use of Peat Ash in Road and Street Construction Report no. 25/1989.*

2. ***Kauppinen J.*** *Use of a Stabilised Peat Ash in Road Construction M.Sc dissertation for the Civil Engineering Department of the University of Oulu. 1993.*

3. *National Lime Association. Lime Stabilization Construction Manual, Bulletin 326, Arlington, Va, 1991.*

4. ***Kim A.G., Kazonich G.*** *Mass Release of Trace Element from Coal Combustion By-Products. A paper for the International Ash Utilization Symposium. Lexington. 1999.*

5. *SGT studies (1990-2000) on the properties of diverse industrial residues. Unpublished reports that include relevant data from project clients like FinnRa, diverse paper manufacturers, Outokumpu Polarit Oy, and Kemira Chemicals in Finland.*

6. *Use of Peat Ash in Road and Street Construction Report no. 25/1989.*

7. ***Lockhart J.*** *Pennsylvania Turnpike Reconstruction - Part III: Lime- Pozzolan Meets the Reconstruction Challenge. Pennsylvania Asphalt Pavement Association, Website, Harrisburg, Pa. Sept 2001.*

8. *Utilisation of Ashes - project (1996-1998) reports on binder development, test construction and follow-up tests.*

9. *Report on the utilisation of filterwaste and calciumchloride in soil construction. Laboratory investigations and full-scale test construction. SCC Viatek Oy/SGT for Kemira Chemicals in 2000.*

10. ***Chang W.F., Mantell M.I.*** *Engineering Properties and Construction Applications of Phosphogypsum. Phosphate Research Institute, University of Miami, U.S.A., 1990.*

Recommended for publication: 05.09.2014.