

Tomasz Szczygielski
Polska Unia UPS – Polish CCP Union

Standardization of combustion products for road construction in Poland

Introduction

Utilization of ashes from power generation in road construction in Poland begun in 50-ies, soon after the power plants fired with pulverized coal started their operations. First industrial (branch) standards started to appear in 60-ties and 70-ties, with subsequent revisions. Last major revision of standards regulating the use of ashes in road construction was in the years 1997-98 and these revised standards are still in force. These Polish standards cover a wide range of applications, from using ash in embankments, through ash as soil treatment addition up to aggregates in hydraulically bound mixtures, so called ash concretes. Additionally, the standard PN-S-96035:1997 regulates the characteristics of flyash used for road construction.

Unfortunately all the above mentioned Polish standards cover only ashes from combustion of coal in pulverized fuel boilers – so called conventional boilers. They do not include yet the fluidized bed combustion (FBC) ashes and ashes mixed with the flue gas desulphurization products (FGD).

New European standards covering fly ashes are currently implemented on discretionary basis PN EN (U), and introduce new classification enlarging the areas of application for all types of ashes currently produced in power plants and CHP plants. This opens up a great opportunity for FBC ash.

Main Polish standards for road construction include:

PN-S-06103:1997 – Roads for cars. Subbases from ash concrete, covers the use for construction of subbases of hard coal or lignite ash (conforming to PN-S-96035:1997) in combination with aggregates.

This standard distinguishes the three strength classes of ash concrete:

- class $R_{42}^m = 1,5 \div 3,0$ MPa,
- class $R_{42}^m = 3,0 \div 5,0$ MPa,
- class $R_{42}^m = 5,0 \div 8,0$ MPa.

Class of a subbase is determined by the traffic load category and the location in the road cross-section, in relation to the pavement (principal subbase, auxiliary subbase). Content of ash from hard coal (PK type) in the mixture can be up to 95%.

PN-S-96035:1997 – Roads for cars. Fly ashes, providing classification and specifying required properties of fly ashes useful for road construction. This standard covers ashes from hard coal (PK) and lignite (PB). Additionally, three sub-classes are introduced:

- PK sub-class a – ash as a hydraulic addition to binding materials,
- PK sub-class b – ash as a fine aggregate for mineral mixtures with inadequate granulometry,
- PB sub-class c – ash as a binding material.

This standard is also defining requirements, testing and general guidelines for suitability of ashes for road construction.

PN-S-02205:1998 – Roads for cars. Earth works. Requirements and tests. This standard is allowing amongst others for using fly ash and ash-slag mixtures as materials suitable for construction of road embankments. Ash-slag mixtures should conform with requirements of PN-S-96035:1997. The standard permits using fly ash for bottom layers of embankments, provided that they are used in areas protected from water penetration. The use in upper layers of embankments is conditioned on adding binder to improve the ash. The standard also sets requirements for the different layers of embankments, the same for mineral materials and ashes/ mixtures of ashes and slags.

PN-S-06102:1997 – Roads for cars. Subbases from mechanically stabilized aggregates, where ash may be used as a constituent improving the properties of mixed crushed aggregates. If aggregate mix is not conforming with technical requirements, it can be improved with addition of ash.

PN-S-96012:1997 – Roads for cars. Subbase and grade treated with cement, including using ash for improving granulometry and performance of the treated soil. In this application ash is to provide a better granulometry of the stabilized soil or aggregate.

Technical standards are supplemented by a group of technical agreements. When there is no suitable official Polish standard in operation, a technical agreement (kind of quasi-standard) is required for all building materials and prefabricated products.

Selected Technical Agreements:

EPO Spółka z o. o.:

1. Technical Agreement issued by IBDiM (Research Institute for Roads and Bridges) Nr AT/2006-03-2009 for Concrete Mixture EPO-BET for construction of principal and auxiliary subbases, as well as for strengthening layers and grade bases for road embankments.
2. Technical Agreement IBDiM Nr AT/2005-03-1932 for Hydraulic road binder EPO-MIX for traffic engineering applications,
3. Technical Agreement IBDiM Nr AT/200-04-1820 for Lightweight crushed aggregate EPO from boiler slag for road construction, as base aggregate, as grain distribution improvement addition, and as filling or locking aggregate.

UTEX Spółka z o. o.:

AT/2004-04-1651	Furnace slag aggregate UTEX
AT/2004-04-1749	Soil improvement binder Solitex
AT/2005-04-1827	Concrete mixture with ash and slag
AT/2005-03-1866	Hydraulic road binder Solitex

European Standards relating to CCPs in Road Construction

European Standards EN regulating the use of CCPs in road construction are prepared by the Technical Committee TC 227 of CEN:

EN 14227-3:2007 – Hydraulically bound mixtures – Requirements; Part 3: Mixtures bound with flyash, contains requirements for mixtures stabilized with ashes, acting either as part of the binder or as the main aggregate constituent.

EN 14227-4: 2005 – Hydraulically bound mixtures – Part 4: Fly ash for hydraulically stabilized mixtures, contains characteristics of and requirements set for ashes.

EN 14227-1 – Specifications for unbound and hydraulically bound mixtures. Part 1: Mixtures bound with cement, for construction of load bearing and subbase layers, for the construction and maintenance of load bearing layers and subbases of roads, airfields and other trafficated areas.

EN 14227-5 – Hydraulically bound mixtures - Part 2: Mixtures stabilized with road binders, this standard provides a definition of „mixtures stabilized with a road binder” used for the construction of roads, airfields and other trafficated pavements, and is defining recommendations for constituents, mix composition and laboratory testing.

The current state of standardization in Poland and Europe regarding the utilization of coal combustion byproducts allows for a wide range of applications of ash and slag as autonomous materials for road construction or in combination with mineral materials in technologies involving stabilization with cement.

Depending on the type of application in the road structure these may be:

- mixtures for earth works substituting mineral soils,
- mixtures treated and stabilized with hydraulic binders.

Wearing course	Road pavement courses	
Bonding course		
Principal subbase		
Auxiliary subbase		
Treated grade	Draining layer	Earth works
	Frost protecting layer	
	Strengthening layer	
Natural grade or embankment		

Fig. 1. Parts of a road structure

Characteristics of fly ash in PN EN 14227-4 standard

The recent standard PN EN 14227-4 relates to fly ash for hydraulically bound mixtures and covers a wide range of possibilities. Fly ash in hydraulically bound mixtures may act as:

- aggregate admixture improving the granulometry of the mixture (up to 20% ash content),
- pozzolanic admixture or even autonomous binder (3 to 20% ash content),
- principal constituent of ash mixtures – ash concretes (ash content to 97%).

Ashes conforming with PN EN 14227-4 are also used for treating soils in order to increase their suitability for construction according to EN 14227-14. Fly ash act as a dehumidifying agent, increasing bearing properties of soils, or as a hydraulic or pozzolanic agent causing binding of soils and producing a quality of resistance to compression and freezing.

In the standard PN EN 14227-4, a new classification of ashes was adopted, departing from the one used so far. Only two types of ash are named: siliceous and calcareous. It should be noted, that the standard is neither limiting the combustion technology nor the type of coal. It means, that the standard will cover all types of ash, from both hard coal and lignite, burnt in power installations employing various combustion and flue gas desulphurization technologies. Separate sets of tests apply for each type of ash. Type of ash should be determined by analyzing the composition of oxides in given ash.

Tables 1 and 2 present the testing programs for each type of ash according to the standard PN EN 14227-4.

Table1 Testing program for siliceous fly ash according to EN 14227-4

Ref.	Type of test	Test procedure according to standard:
		siliceous ash
1.	Granulometry (grains passing 90 and 45 μm mesh)	EN 451-2
2.	Loss on ignition	PN EN 196-2
3.	Determination of $-\text{SO}_3$	PN EN 196-2
4.	Determination of free lime and soundness ^{*)}	EN 451-1
5.	Moisture content	-
6.	Pozzolanic activity (when required)	Compressive strength measurement
7	^{*)} Soundness (required if free CaO>1%)	PN EN 196-2

Table 2 Testing program for calcareous flyash according to EN 14227-4

Ref.	Type of test	Test procedure according to Standard:
		calcareous ash
1.	Granulometry (grains passing 90 and 315 μm mesh)	PN EN 196-6
2.	Soundness	PN EN 196-3
3.	Reactive calcium oxide	PN EN 197-1
4.	Water content	-
5.	Hydraulic activity (when required)	Compressive strength measurement

The number of features tested according to the new standard is substantially smaller in comparison with the old Polish standard PN-S-96035, which is making the plant production control much simpler. Type of ash may be determined on the basis of chemical composition, which is tested in each power plant producing ash. The new standard is not including any testing of natural radioactivity, because numerous past research has proven beyond doubt, that the radioactivity of fly ashes conforms with the requirements defined for building materials. Also other features haven't been included in the new standard, such as: uncompacted density, content of external impurities, general CaO content and SiO_2 .

The standard PN EN 14227-4 defines the scope of testing and requirements for each type of ash separately. For example, in case of calcareous ashes no testing of SO_3 or loss on ignition is required, which opens possibilities for utilizing FBC ashes and ashes with FGD products, which generally contain more SO_3 than in conventional ashes. Testing of soundness is demonstrating, how given ash will perform in a hydraulically bound mixture.

Two new features of ashes found their place in the standard: the **pozzolanic activity** and **hydraulic activity**. From the point of view of classification of ashes these are very important parameters,

indicating the potential properties, which the mixture made with given fly ash will be achieving. The pozzolanic and hydraulic activity is determined by testing the strength of a mixture of tested ash with standard aggregate (and lime as an activating agent while determining the pozzolanic activity).

Fly ashes conforming with PN EN 14227-4 are used for hydraulically bound ash-containing mixtures according to PN EN 14227-3. Bound mixtures in strength classes ranging from 0.5 to 36 MPa are used in road subbases. The standard PN EN 14227-3 distinguishes 5 types of mixtures, named: FABM 1÷5 (**Fly Ash Bound Mixtures**).

Type of the mixture depends first of all on the composition and grain distribution profile of the mixture. The standard is providing grain distribution ranges and sets limit curves. Generally, the ash mixtures may be divided into three kinds:

- Mixtures FABM 1÷3 – composed first of all from fine aggregates or coarse aggregates with addition of ashes and binders,
- FABM 4 – mixtures of declared composition, granulometry and performance characteristics.
- FABM 5 – mixtures made basically from ashes with addition of binders.

Benefits of using materials derived from coal combustion by-products:

- ✓ Economic, durable and versatile material,
- ✓ Material of low specific density (ranging after compaction 1.1-1.3 kg/dm³), which reduces the cost of transport by up to 40%,
- ✓ Country-wide availability,
- ✓ Significant strength and frost resistance,
- ✓ Their use preserves natural resources.

Conclusions

Adoption of a new classification of ashes according to PN EN 14227-4 is favorable in the aspect of opening up new possibilities of utilizing a much wider range of fly ashes than before.

The new classification includes all types of ashes in terms of coal combustion and flue gas desulphurization technologies, even those earlier not conforming with the requirements of the standard PN-S-96035.

According to the new classification system, regardless of the type of burnt coal, FBC ashes will be classified as calcareous ashes.

The new classification system and testing program according to PN EN 14227-4 is much simpler and more unambiguous than the previous one.

Calcareous and siliceous ashes conforming with PN EN 14227-4 can be used in hydraulically bound mixtures according to PN EN 14227-3.

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