Coal Combustion Products in road construction

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1. 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 fly ash used for road construction. [1]

In Germany, the total amount of ashes used in road construction is small compared to the amount used in Poland. The ashes are mainly used in unbound applications for embankment or dam construction. The long term experiences of hydraulic bound bases with ash were compiled in a research report. The results of hydraulic bound road bases with siliceous and calcareous ash resulted in a proposal to implement the European standard EN 14227-3 into the national regulations for road construction. [2]

Many research project have been performed in Germany demonstrating usage of coal ash for road construction. For example: Suitability of mixtures for hydraulically bound base courses according to European Standards for applications in Germany, Research Project No. FE 08.0181/2004/NGB, Bundesanstalt für Straßenbau (BAST), 2008.

First road construction project with usage approx. 250 000 tons of fly ash in Germany was made in 1982 near Lunen. In 2001-2005 e few road project have been made with wetted fly ash for backfilling, noise barrier, widening of road, parking places and rest areas. [3]

In United Kingdom about 400,000 tonnes per annum goes in fill and road construction applications.

Specification for Highway Works covers all of road construction within the UK. Standards for highway covers all applications including embankments, hydraulically bound materials, etc.. [4]

In Portugal are made pilot projects implementation of coal ash for road construction and national application documents. [5]

In the Netherlands until 2004 the use of fly ash for structural fills was not possible because of environmental regulations. In 1988 a demonstration project was set up to built an embankment around a waste deposit site in the Dutch city of Rotterdam. The project was monitored through a program of laboratory and on-site tests and the results showed that fly
ash is very useful for structural fills and that it has some advantages compared to sand, such as a lower density and good compaction. [8]

In Greece there is no information available about ash in road construction as sub-base or embankments. These types of applications take place occasionally and without keeping records. Greek fly ash is used sporadically for road construction inside the ground plan of power stations and also in pilot applications. EN 13282 as well as the EN 14227 series are legally binding, together with the National Specification concerning the use as fill for reclamation of excavations. [9]

In France was many application of coal ash for road construction. Coal ash was used in mixture with mine stones, siliceous mixed with calcareous fly ashes and subbases were produced with admixture of lime and aggregates. In a past France with its scientific research, experienced road laboratory, technical standards, variety of road products and applications was leading European Country in applications of coal ash for road construction. Unfortunately recent data are unavailable.

Because of environmental roles in many countries usage of coal ash for road construction unfortunately are restricted.

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,
- admixture for subbases and road pavement courses.

<table>
<thead>
<tr>
<th>Wearing course</th>
<th>Road pavement courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonding course</td>
<td></td>
</tr>
<tr>
<td>Principal subbase</td>
<td></td>
</tr>
<tr>
<td>Auxiliary subbase</td>
<td></td>
</tr>
<tr>
<td>Treated grade</td>
<td>Draining layer</td>
</tr>
<tr>
<td></td>
<td>Frost protecting layer</td>
</tr>
<tr>
<td></td>
<td>Strengthening layer</td>
</tr>
<tr>
<td>Natural grade or embankment</td>
<td>Earth works</td>
</tr>
</tbody>
</table>

Parts of a road structure

2. **Fly ashes as binders**

Fly ashes captured in electrostatic precipitators have binding properties and may be used either as self-contained binders, or as addition to other binders. This is possible because of the presence in the ashes of active chemical compounds, similar to those found in cement.

It is interesting, that composition of fly ashes is similar to this of the volcanic ash, used in antiquity by the Romans for construction materials.

It should be borne in mind, that fly ashes have different setting characteristics and lower strength than cements, but have many other advantageous features:
• Can be utilized as coal combustion by-products.
• Allow for savings in CO$_2$ emissions.
• Lower strength levels result in minimal hydration and thermal shrinkage.
• Can be used for stabilizing argillous soils.
• Presence of free CaO is causing chemical and physical bonding of considerable amounts of water. Optimum moisture content in soil is being increased.
• Addition of fly ash changes the structure of soil, increasing its rigidity and consequently its bearing capacity.

It is in road construction projects where this possibility of stabilizing clayey soils is especially beneficial. Normally, various types of soils are found under roads and railway tracks, including clayey soils with excess water content.

Currently the use of fly ashes as road binders has been standardized. The PN-EN 14227-4 standard defines required properties of fly ashes, which are presented in Table 1.

Table 1. Properties of fly ashes

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Property</th>
<th>Requirements</th>
<th>Test methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Siliceous fly ashes</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Grain distribution (% passing through mesh opening):</td>
<td>≥ 70%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 0,090 mm</td>
<td>≥ 40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 0,045 mm</td>
<td>EN 451-2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Loss on ignition</td>
<td>≤ 10%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SO3 content</td>
<td>≤ 4%</td>
<td>EN 196-2</td>
</tr>
<tr>
<td>4</td>
<td>Soundness, for mixture of 30% ash and 70% standard cement (if free CaO ≥ 1%)</td>
<td>≤ 10 mm</td>
<td>PN-EN 196-3:2006</td>
</tr>
<tr>
<td>5</td>
<td>Moisture</td>
<td>≤ 1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcareous fly ashes</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Grain distribution (% passing through mesh opening):</td>
<td>≥ 95%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 0,315 mm</td>
<td>≥ 70%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 0,090 mm</td>
<td>PN-EN 196-6 para 3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Soundness, for mixture of 30% ash and 70% standard cement</td>
<td>≤ 10 mm</td>
<td>PN-EN 196-3:2006</td>
</tr>
<tr>
<td>3</td>
<td>CaO reactivity</td>
<td>≥ 5%</td>
<td>PN-EN 197-1</td>
</tr>
<tr>
<td>4</td>
<td>Moisture</td>
<td>≤ 1%</td>
<td></td>
</tr>
</tbody>
</table>

Currently on the market in Poland there are several binders produced either as purely classified fly ashes, or as containing significant content of fly ashes. The most popular include:
• Tefra 15, Tefra 25,
• Tefra Stab,
• Solitex A, B, C
• Lipidur.

3. **What is stabilization with hydraulic binder**

Soil stabilization with hydraulic binder, is a technology involving mixing the soil with the binder, in the presence of water and sometimes also other admixtures, in order to:

- dry up the subgrade,
- correct grain-curve of soil,
- facilitate soil compaction,
- change the structure of soil,
- increase soil resistance to water and frost impact,
- at times to achieve compressive strength capacity.

Combining these factors sometimes results in manifold increasing the soil bearing capacity in comparison to the initial conditions. In soil stabilization practice, a “the worse the better” rule applies, which means, that if the soil is very weak and very watered, then adding fly ashes will raise its bearing capacity several times. However, if the concerned soil is of medium bearing capacity, like e.g. clayey sand, then fly ashes will cause drying of the subgrade, making compaction possible, but bearing capacity increase will be rather small.

Sometimes, only allowing soil to be properly compacted through changing its natural moisture level and increasing its optimum water content, can result in increasing several times its load bearing capacity.

If binders including coarser grains are added to very fine soils, such as clays and silts, then soil grain curve is corrected, making compaction much easier and in many ways increasing the soil’s bearing capacity: through better granulometry, through better compaction and through solidified-bound structure.

Perhaps the most important advantage of stabilization is found in chemically-effected change of the soil structure and binding of its grains. This results in obtaining a rigid working platform, acting as a base for pavement or embankment structures. Cohesive soils, when stabilized with hydraulic binder, do not reach high compressive strength levels, which in many cases is an advantage allowing to avoid the effect of „glass plate on elastic base“. Achieved strength is usually in range of 1 MPa, allowing for a gradual transition from elastic subgrade to rigid layers of the paved structure.

In chemical soil stabilization the following definitions are used:

**Stabilization of soil with binder** – a technological process involving mixing fragmented soil with optimum dose of the binder, and - if necessary – water and other admixtures, followed by compaction of the resulting mixture in order to improve the soil characteristics.

**Soil-binder mixture** – an optimal mixture of soil, binder and water, and - if necessary - other improving additives.

**Soil stabilized with binder** – a soil-binder mixture, which was compacted and has hardened when binding process finished.
4. Soils to be stabilized

Usually it is assumed, that soils suitable for stabilization with hydraulic binders are cohesive soils characterized in Table 2.

While analyzing the properties of soils suitable for stabilization with hydraulic binders, it may be noted, that except for the compact clays and loams, all types of cohesive soils can be stabilized. But we must remember, that final decision always must be supported with load bearing tests made in situ.

### Table 2. Recommended properties of cohesive soils for stabilization with fly ashes [3]

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Property</th>
<th>Requirement</th>
<th>Test methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grain distribution, % passing through mesh of 0,002 mm opening</td>
<td>≤ 20%</td>
<td>PN-B-04481:1988</td>
</tr>
<tr>
<td>2</td>
<td>Liquidity limit</td>
<td>≤ 40%</td>
<td>PN-B-04481:1988</td>
</tr>
<tr>
<td>3</td>
<td>Elasticity indicator</td>
<td>3 ÷ 20%</td>
<td>PN-B-04481:1988</td>
</tr>
<tr>
<td>4</td>
<td>Organic parts content</td>
<td>≤ 5%</td>
<td>PN-B-04481:1988</td>
</tr>
<tr>
<td>5</td>
<td>Sulfur content, expressed as SO$_3$</td>
<td>≤ 1%</td>
<td>PN-EN 1744-1:2000</td>
</tr>
</tbody>
</table>

Stabilization with a hydraulic binder is sometimes applied in case of single-fraction sands, which are present in the subgrade. Such sands have practically all the grains of uniform size. This prevents any interlocking of grains and filling up voids between larger grains by smaller ones. Additionally, if such sands originate from river beds, their grains are spherical in shape and behave as balls in a bearing, rendering classical compaction methods practically useless. Adding a fine-grained hydraulic binder, acting in this case mainly as a filler, results in the soil grain curve correction, allowing for compaction of soils otherwise un-compactable, and additionally the relatively weak binding action on grains of sand produces a relatively rigid working platform.

5. Designing soil mix stabilized with hydraulic binder

Each soil stabilization project with any hydraulic binder needs a formula developed in the laboratory. Because of a substantial on-site variability of water conditions, especially in case of cohesive soils, the formula from the lab should be tested out on a trial section. In case of greater than assumed variability of water conditions or a change in the weather conditions, the lab formula should be corrected accordingly.

Designing a mixture of soil stabilized with a binder involves:

- determination of natural water content of soil,
- initial determination of binder content,
- calculation of optimal moisture of soil-binder mixture,
- definition of properties of soil stabilized with binder,
- comparison of test results with design assumptions.

The lab formula should include:

- type of soil to be stabilized,
- natural moisture in soil,
- type and amount of binder,
amount of other additives, if any,
optimal moisture of mixture and necessary water amount to be added, if any,
designed properties of mixture.

In technical literature it is possible to find initially recommended amounts of a binder to be used in stabilization of cohesive soils, where most often there is some excess of water and the binder's task is to capture and engage it:

- for \( w_n \leq W_{opt} +2\% \) binder addition \( \leq 3\% \)
- for \( w_n \leq W_{opt} +2+5\% \) binder addition \( 3+5\% \)
- for \( w_n \leq W_{opt} +5+6\% \) binder addition \( 5+7\% \)
- for \( w_n \leq W_{opt} +6+7\% \) binder addition \( 7+10\% \)

Binder amount is not to exceed 15% of dry soil mass.

6. Stabilization technology

6.1. Atmospheric conditions suitable for works

Minimum air temperature during works should be above 0°C. It is recommended to check weather forecasts for several coming days. It is not allowed to place the mixture during intense atmospheric falls. It is not allowed to work on the frozen subgrade.

6.2. Producing soil stabilized with hydraulic binder

Technology of producing the mixture should be the following:

- breaking up of natural soil – required in case of highly cohesive soils,
- possible placement of grain-curve improving material,
- possible spraying of additional water – to achieve optimal moisture,
- placement of binder – in dose according to working formula,
- mixing all constituents to a designed depth.

In case of highly cohesive soils it may be necessary to repeat mixing of all constituents 2 or 3 times in order to get a homogeneous mixture. This may be especially important in case of using agricultural equipment for mixing.

Water. If necessary, water may be dosed by volume or by weight with +10%, -20% tolerance, in order to achieve optimal moisture content.

Binder. Should be dosed by weight according to the working formula – calculated for 1sqm. Particular attention should be paid to the homogeneity of added binder. Accuracy of dosing should stay within \( \pm 0,5\% \).

Used mixing equipment should allow for appropriate mixing of constituents, to a uniform appearance as far as color and graining is concerned. If the homogeneity is not satisfactory, then more passes of the mixing equipment must be applied.

If greater bearing and compressive strength of the base layer must be achieved, or if soil-water conditions are extremely difficult, a staged technology may be used:

- breaking up the soil,
- placement of binder,
- mixing soil with binder to big depth,
• initial compaction of layer,
• placement of new portion of binder,
• possible placement of grain-curve improving material,
• mixing soil with binder to lower depth.

In this case, the first dose of binder is to bring about the optimal moisture of soil, allowing for its proper compaction, while the other is to effect the very binding of soil and achieving its designed compressive strength. Different types of binder and different mixing depths may be used in separate stages.

In case of using stationary mixing plants for stabilization works, all constituents must be delivered to the plant and dosed according to the lab formula.

6.3. **Compaction of soil layer stabilized with hydraulic binder**

After mixing of all constituents, the layer should be compacted by one or two roller passes. After this the surface should be finally leveled out and the final compaction effected. In case of a deep layer, the initial compaction should be done using heavy vibrating or studded rollers. Consecutive compaction should be effected with plain steel rollers or rollers on tires. The necessary number of passes should be established in experimental way, but it should not be less than 4.

The compaction should be commenced at the edge of the layer and continued in parallel trails towards the middle axis of the road. Consecutive trails should overlap by at least 10cm.

Any depressions in the layer showing up during compaction should be immediately leveled out by breaking up the mixture, adding new material and compacting again.

Particular attention should be paid to compacting in the vicinity of work seams and fixtures of other parties.

In case of treated subgrade, compaction should be continued until coefficient indicator value of 1.00 is reached, according to the normal Proctor method (BN-77/8931-12). In case of embankments, compaction should be continued until indicators will reach values defined by the standard PN-S-02205:1998.

6.4. **Work seams**

To make appropriate work seams, day sections and technological trails should be build with an overlap. The longitudinal overlap should not be less than 10cm, and cross overlap not less than 50cm.

6.5. **Curing of soil layer stabilized with ash binder**

Curing should be effected using one of the following methods:

• Spraying the layer with 0.5 to 1.0 kg/sqm of asphalt emulsion.
• Sprinkling with special coating preparations.
• Keeping moistened for at least 3 days by sprinkling water several times a day.
• Covering with plastic sheets for period of 3 days.
• Covering with layer of sand or a thick fabric and keeping moistened for at least 3 days.
• Placing on the base layer a next technical layer of e.g. aggregate. The aggregate should be placed within several hours from mixing the soil with the binder, starting from work
head, using bulldozers or graders, and should be kept without compaction for at least 3 days.

7. Requirements for railroad bases

Railroad base – railway-related earthwork, with adequate securing, protecting and draining appliances, subject to usage impact, climatic impact and impact from subgrade immediately under railroad base and its nearest surrounding (Id 3 Technical Conditions of maintenance of railroad bases).

Railroad base should:

• be sufficiently durable and strong and provide a stable and uniform base for the railway tracks of given class,
• resist any excessive permanent and elastic deformations in given weather and functional conditions, that might impair the traffic safety or necessitate too frequent repairs of tracks.

According to Id 3, railroad base should fulfill the following requirements:

• for newly built and modernized tracks 80 ÷ 120 MPa
• for tracks in use (when assessed as requiring strengthening) 40 ÷ 80 MPa

Durability of the upper part of railroad base is provided by using the materials which are:

1. Sufficiently durable: resistant to water, inorganic (Iom ≤ 0,2%), with content of SO3 ≤ 0,2%.
2. With good grain-curve and withstanding separation under vibration.
3. Resistant to frost-heaving
4. Mechanically stable at layers interface (not mixing); this is not required in case of stabilized soils.
5. Adequately permeable to water:
   • ≥ 10⁻⁴ m/s if soil must drain rain water,
   • < 10⁻⁶ m/s if it is necessary to prevent rainwater infiltration (railroad base must be adequately profiled.

Protective layers are also applied in railroad base. Their depth, depending on the type of soil should be 30-50 cm. These can be constructed using stabilization of soil with binders.

Homogeneity of railroad base has big importance on entire track lines and station groups.

Entire railway track and railroad base should provide for frost-resistance of the structure. Total depth of all layers should be within 54 to 132 cm range, depending on the region of Poland.

8. Requirements for road bases

A Catalogue of Typical Susceptible and Semi-rigid Pavements gives a requirement of obtaining a load bearing capacity immediately under the pavement structure:

• for traffic KR1 and KR2 100 MPa
• for traffic heavier than KR2 120 MPa

The same requirements are given in the standard PN-S-02205:1998.
According to the above references, the required bearing capacity may be effected in several ways:

- exchanging soil,
- placing draining or frost-resistant layer,
- stabilizing soil,
- placing a mattress made from geo-fabric and aggregate,
- making depth reinforcement (piles, columns),
- combination of any above techniques.

If we compare requirements described in points 7 and 8 we can see, that they are analogous concerning bearing capacity of road base and railroad base.

9. Examples of application

9.1. Experimental section at LCS Nasielsk, Poland

On September 9, 2009 at grounds of LCS Nasielsk, in Świercze, Poland, on track line 2, between km points 69+850 and 70+250 an experimental section was made, involving strengthening of railroad base with hydraulic binder.

Subgrade of the track line included cohesive soils: clays and sandy clays. They were waterlogged and not-compactable to achieve the adequate load bearing capacity.

Load bearing tests made immediately on the railroad base site gave values between 11 and 14 MPa. Given this bearing capacity, placing thick layers of railroad base would not guarantee its adequate bearing capacity. Another problem was of course presented by adequate compaction of natural grade and subsequently also the railroad base.

Applying approx. 35kg/sqm of hydraulic binder and mixing it with the soil to 35cm depth, caused drying of subgrade and making it compactable.

Load bearing test made after 4 days from stabilization gave test readings from 80 to 140 MPa.

Such results show, that well-executed stabilization of the subgrade may successfully provide a self-contained railroad base without any additional layers of aggregates.

9.2. Construction of ring road in Słupsk, Poland

On many sections of a ring road in Słupsk in Northern Poland, softly elastic cohesive soils are found immediately under pavement layers or embankments. In several cases their improvement was effected by applying calcareous ashes.

The natural subgrade had load bearing capacity of 10 to 20 MPa.

After effecting the stabilization, the bearing capacity was 55 to 80 MPa. Such a grade bearing stability ensured reaching the required capacity of 120 MPa immediately under the paving layers.

10. Production of readymade ash mixtures

Several firms around the country are producing readymade ash mixtures, in which the active calcareous fly ashes are combined with inert ashes of various origin.

stabilization, for using large volumes of other anthropogenic materials, namely fly ash, slag, burnt shale, and other. For technical reasons, these mixtures can be produced both in-place, which is usually more economical, or in-plant. The latter is more often used in case of mixtures containing large amounts of secondary materials. In this case the mixtures are produced where these anthropogenic materials occur, and then transported in placement site.

It’s worth showing what requirements for readymade mixes are given by the standard [4], since some of them are defined differently than in the standard [5], which is otherwise most often used and generally known.

### Table 3. Required properties of stabilized mixture according to PN-S-06103:1997

<table>
<thead>
<tr>
<th>Type of layer</th>
<th>Compressive strength</th>
<th>Strength after 14 cycles of freezing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R_3^1$</td>
<td>$R_{14}^m$</td>
</tr>
<tr>
<td>Upper layer of road base for heavy and very heavy traffic</td>
<td>5 ( \div ) 8</td>
<td>( \geq ) 2,5</td>
</tr>
<tr>
<td>Upper layer of road base for light and medium traffic, and lower layer of road base for heavy and very heavy traffic</td>
<td>3 ( \div ) 5</td>
<td>( \geq ) 1,5</td>
</tr>
<tr>
<td>Lower layer of road base for light and medium traffic</td>
<td>1,5 ( \div ) 3</td>
<td>( \geq ) 1</td>
</tr>
</tbody>
</table>

As may be seen in Table 3, the mixtures of ash concrete can be produced in 3 strength classes. The top one roughly corresponds with the strength of yet another mixture popular in road construction – lean concrete (compressive strength 6÷9 MPa). Two other classes correspond to the requirements for classical stabilization with cement, according to PN-S-96012:1997.

It’s worth though paying attention to several details:

- Because in this mixture instead of cement active ashes are used, compressive strength is determined after 42 days of samples storage. This means of course much longer period of on-site inactivity, but lower costs of mixture manufacture usually outweigh this time loss.

- In order to be able to assess the suitability of the mixture in a short period of time, a quick test method was provided in the standard, allowing for having conclusive results already after 3 days form producing the mixture and forming test samples.

- Interim strength requirements after 14 days are not so rigorously stated as in the case of stabilization with cement. Only lower limits are given here, which allows for more leeway in selection of constituents, and especially in binder dosage.

- Frost resistance of the mixture is defined by compressive strength after 14 cycles of freeze-thaw. Only lower limit of strength is given here, which again gives more freedom in selecting the mixture constituents.

But also difficulties should be highlighted here, which are mainly the result of inadequate knowledge or experience of engineers. Most commonly used in road construction is of course stabilization with cement. Comparing the required properties for stabilization with cement and requirements for ash concrete we see that the differences are rather cosmetic in
nature. The requirements are expressed in different way, rather then actually be different. But unfortunately for many people this equals to changing of technical specification, meaning changing of contractual terms, and procedural difficulties start mounting, not technical arguments.

This type of mixtures should be used more and more often because of:

- economic considerations – use of alternative materials is usually cheaper;
- environmental considerations – savings in use of new materials, especially binders, and reduction in otherwise landfilling of anthropogenic materials.

It is worth reminding here, that currently European Union law is obliging us to consider possibilities of using anthropogenic materials before applying typical mineral materials.

As an example, a road binder for drying and treatment of soil TEFRA 15 produced by Ekotech Ltd according to the standard EN 14227-3 /4, having a Plant Production Control Certificate Nr 92/ZKP/09 issued by the Research and Development Centre for Concrete Industry „CEBET”, as well as Hygienic Attest nr NR/B/1701/01/2008 from the National Institute for Public Health – State Hygiene Department. On demand a Declaration of Conformity with Standard is also provided to the Client.

11. Technical standard vs technical approval

Technical Approvals are issued for materials not conforming to all standard requirements. They give a chance of using non-standard materials, which nevertheless effectively provide the core performance defined for standard materials. A practice of issuing technical approvals for materials conforming to standard requirements is reprehensible. This brought about in Poland a deleterious practice of viewing materials with a technical approval as superior to standard materials, even those with CE marking. General Directorate for National Roads and Motorways, designers, project engineers and contractors should be constantly informed about this, and project specifications as well as tender documents should conform with EU rules, especially in the aspect of fair competition.

Conclusions

Coal ash is as a good alternative product as structural fill. From a civil engineering point of view it is a better product than sand. It can be use as a mixture fly ash and slag or with admixture of sand. It can be also river/see sand easy accessible in many places.

Most likely in Poland coal ash is most broadly in Europe used for road and railway construction in variety applications and technologies. Recently ca. 3-4 mln tonnes of coal ash per annum goes to road construction in variety of products.

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

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

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