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APPLICATION OF COAL COMBUSTION BY-PRODUCTS IN LEVEES

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ABSTRACT

Levees are geotechnical structures (among the earth structures of water management structures) built along rivers especially. Embankment dikes require processing of large volume of material, and because of that there is effort to find a suitable replacement for traditionally used materials. One option is the use of Coal Combustion By-Products (CBB). Levees with CBB were built in several quantities in Czech Republic. Realized structures generally with problem-free function are documented. In some cases, relating to flooding during June 2013 there has been a failure. The paper shows some cases of applications of CCB and summarization of the results of usage CBB in earth structures of water management in Czech Republic.

Keywords: Coal Combustion By-Products, Failure, Flood, Levee

I. INTRODUCTION

Floods are a common part of the natural and water cycle in nature. Building of protective structures and the level of protection are arising from public demand and of values of the protected area. Flood protection is technically possible in principle always, the question is economic acceptability. In connection with the floods in recent years (in 1997, 2002, 2013) is given special attention to flood protection dikes or levees that fulfills its function intermittently over a prolonged period of time [1]. These types of levees and the option of using alternative materials is becoming to be in demand, however their building require processing large volumes of materials.

One possibility is the use of solid products of coal combustion, known as Coal Combustion By-Products (i.e. CCB). They include: fly ash, slag, cinder, bottom ash and flue gas desulfurization (FGD) gypsum. For some of these materials, it is necessary prior to their application of the structure to assess susceptibility of unwanted effects. This is especially a relatively small resistance to repeated contact with water and freeze (i.e. frost resistance) reporting volume changes and the risk of failure to meet hygienic and environmental requirements [2]. In addition, alternative materials must exhibit equal or better geomechanical properties than conventional materials.

Most experience of using CCB in earth structures of water management provides building protective dams (dams step-up) on fly ash tailing ponds/storages.

Due to the completion of the recovery of individual blocks of power plants are assumed long-term operation of thermal power plants. It is obvious that the production of CBB in Czech Republic will be still high, so the construction of dikes contains CCB will be in effect in the upcoming years.

II. CCB PROPERTIES

For determining the properties of CCBs are primarily coal qualities, from which the CCB produced, but also the temperature and combustion conditions and the method of separation of coal ash from the flue gas. The temperature of combustion depends on the technical parameters of the combustion device, and determines the emergence of various mineral products. Individual types of CCBs differ in chemical and mineralogical composition and granulometry, which affects their use.

of combustion and desulphurization technologies used in power plants in the Czech Republic formed below CCB:

- at wet limestone scrubber: cinder (in the case of grate boilers), slag (in the case of granulation boilers), ash and gypsum fraction;
- at semidry scrubber : cinder (in the case of grate boiler) slag (in the case of granulation boilers), ash fraction and desulphurization product;
- at fluidized bed combustion: filter ash, bottom ash and to a lesser extent ash from cyclone.

The largest producer of CCB in Czech Republic is company ČEZ, Inc., what is the largest producer of electricity in Czech Republic. The largest producer of electricity from coal in Slovakia is Slovenské elektrárne, a.s. (Slovak Power Plants, Inc.), which operates two thermal power plants Nováky and Vojany. CCB of these plants has potential uses in earth structures of traffic constructions including structures of levees. In Slovakia most of the CCB production is stored in tailing ponds, as alternative material is still not used in levees.

As CCB are also considered treated solid residues after combustion of coal, which are referred to as stabilizate or agglomerate.

As stabilizate we understand the mixture of ash and desulphurisation products or ashes from fluidized bed boilers, which is mixed with water with the addition of additives (lime, cement) to take advantage of the ability of the ash to solidify and harden like for example cement. Some of the stabilizers may lead to the formation of ettringite which causes volume changes. Ettringite formed in the fly ash stabilizate from soluble compounds of Ca, Al and S in a moist alkaline environment.

CCB are usually considered to be waste materials, which contain a higher concentration of contaminants against consentration in standard building materials, such as soil. Therefore, they must comply with the criteria, i.e. the quality of liquor and mass activity Ra_{226}.

CCB is one of the lightweight building masses. Dry bulk density reaches 650 to 900 $kg.m^{-3}$. CCB well compacted with optimum humidity (20-35%), bulk density reaches 1 100-1 200 $kg.m^{-3}$.

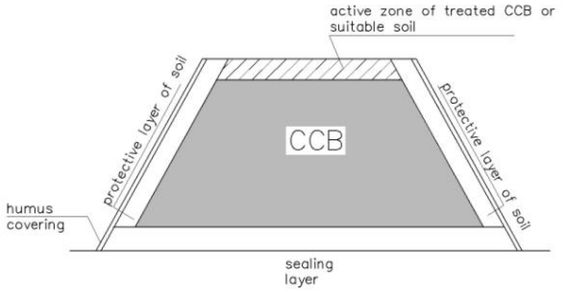
Within the experimental work that was further studied in the Department of Road Structures, Faculty of Civil Engineering in Prague frost resistance and water, including the reporting of volume changes on some fly ash mixtures. Stabilizate is possible in principle to use the construction of levees, but due to the negative results of the cyclic test of resistance stabilizer against freezing and thawing and significant absorbency using certain types of fly ash stabilizer does not seem too promising [3, 4].

III. CCB APPLICATION POSSIBILITIES AND EXAMPLES OF USAGE IN EARTH STRUCTURES OF WATER MANAGEMENT STRUCTURES

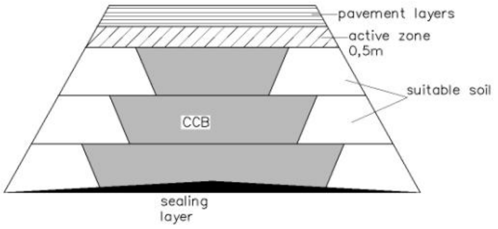
Ash stabilizates or other types of CCB can be used in dikes by several ways (Fig. 1). Alternative material can form a homogeneous body of the dam with protective side stir (levees Vrdy) where compacted CCB provides a stabilizing and sealing function, or can serve as a sealing core dikes (levees Pardubice), or the CCB used only to base layer structural layers of the road (Vrbno near Melnik).

Natural protective side stir are necessary for the protection of the fly ash material from direct contact with water, which readily undergoes erosion.

Application CCB allows building protective earth dams in areas with poor soil bearing capacity, which is common in flood plains, which cover consists of fluvial sediments.



a) use CCB in simple body structure levees (sealing and stabilizing function)



b) the internal compozition of the dam construction used as a traffic road (roads, cycling)

Figure 1: Possible applications of CCB in levees, including road construction on the dam crest

3.1 Examples of use CCB

In the village Rohatec near Hodonin levees were built along the Morava River protecting the village against flooding (Fig. 2). Dam crest is headed 0.5m above the water level at the centennial water on the Morava River (Q_{IOO}). The height of the dam corresponds to similar dams (Skalická) on the Slovak side of the river. The dam is 1.271 meters long, inclined slope of 1:2 and a dam crest has width of 4 m. On the dam crest is built a lightweight construction of road (bike trail), width of 3.0 m with 0.5 m verge. The dam is designed as a continuous liner body with an inner solid core and the slopes of soil. Until the dam was applied to fly ash stabilizate REHAS EHO from near Hodonin power plant. Is the ash mortar, i.e. moistened mixture of bottom ash and fly ash (from fluidized bed combustion technology). The total volume of embankments amounts to 20.670 cubic meters.

Figure 2: Levee with asphalt bicycle trail near the village Rohatec in the Hodonín http://standa1977.rajce.idnes.cz)

In the town of Hradec Kralove protective levees were implemented protecting the southern and southeastern part of the built-up area of the village before the flows in the river eagle until Q100. The total length of the dam is 530 m, height of about 1.20 to 1.80 meters. The investor of structure is the "Elbe River Basin", state office (Fig. 3).

Figure 3: Completed levee near the village Nepasice (http://reka-orlice.sije.cz/trebechovice-hradec-kralove)

Ash from the Heating Plant Malešice in Prague was used in the construction of levees in Rohanský ostrov (Rohan Island) in Karlín, part of Prague. Wold before the levee was later sprinkled up to the crest in order to increase the vertical alignment of the ground above flood flows, so it is no longer a barrier in the ground so evident.

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In Pardubice construction of the dam was used to seal the core of the CCB from a nearby power plant Opatovice. After the dam crest is led by asphalt road. The core of the dam is protected side stir. The amount of stored fly ash stabilizer amounted to 52.500 tons (Fig. 4).

a) levee during construction **b) levee after construction**

Figure 4: The levee with bicycle path using CCB in Pardubice (Power Plant Opatovice, 2014)

After previous experiences of urbanizated area of town Vrdy near Čáslav there was built levee in 2012, whose body is made up from ash stabilizate (Fig. 5). The dam has used 2.000 tons of fly ash stabilizate. In 2013, it successfully passed the river Doubrava spill and protect the village from flooding.

Figure 5: Vrdy - Construction of Levee Using CCB (Power Plant Opatovice, 2014)

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3.2 Causes of Hydraulic Failure

Earth dikes can exhibit a wide range of hydraulic failures. Fault conditions associated with crossing one of the limiting states. Breach of the dam may be due to loss of stability, overtopping the dam, filtration deformities, erosive action of water and sabotage, war and terrorism [5, 6].

Most of the failures of earth dikes in the Czech Republic are due to overflow of the crest of dike during the floods (40%), when there is a failure of the body of the dike, or even to its rupture. Embankment dikes are rarely designed as a spillway dam and their resistance to failure surface erosion is limited. While at low dikes constructed on a low flood flows with a higher frequency of repetition is the probability of exceeding the design flow higher. Increase the safety of the dike can be achieved by appropriate technical measures (site assessment and appropriate controlled spillway dike construction solutions in these areas). It is important to draw up emergency plans and warning system. A necessary condition for increasing the safety of dikes, is their monitoring and ongoing maintenance [6].

3.3 Failure of Protective Dikes

An example of the use of CCB, albeit to a limited extent, is also a dike near the village Vrbno near Melnik on the left bank of the Vltava near the confluence of the Vltava, Labe and navigation channel “Vraňansko-hořínský” (Fig. 6) [3]. Its primary function is partial protection of agriculturally managed area. The dike is about 2200 m long, at the highest point of the dike is about 3 m high.

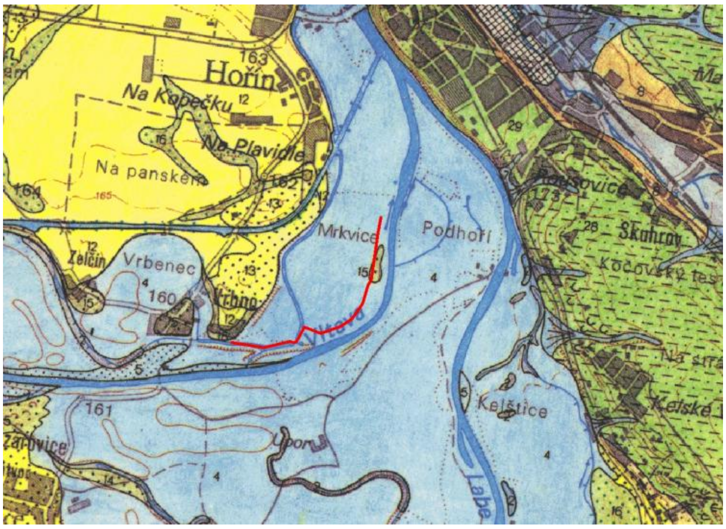

Figure 6: Location of levee in the geological map 1:50 000, sheet Mělník 12-22

In 2009-2010 it was built cycle path Horní Počáply-Vliněves-Zelčín a length of 18.6 km, which partially runs along the crest of the levee. During the construction has been found weak subsoil for the bike path on large parts of the structure including the levee. To improve the bearing capacity of the subsoil of asphalt pavement was used special stabilizate in the form of a mixture of fly ash and cement clinker from a nearby power station in Mělník [7].

During the floods in 2013 there has been a breach this levee by overflow when exceeding of the design flow rate in the Vltava River. Water overspill violated in erosive action of downstream face of the dam (Fig. 7). In several places there was a shearing failure and landslide of the downstream face. Slide surface at the greatest failures to hit below the crest of the dam, respectively under construction layer of asphalt bike trail. The total number of failures dam reached 90, but most were minor disturbances. On the slide surfaces is apparent that is different resistance against shearing failure in fly ash stabilizer (higher) compared with the soil layers when saturated with water.

a) the greatest of the many failures of downstream face of the levees in the length of approximately 25 m

c) detail of exposed interior of the levee, including layers from fly ash stabilizate

Figure 7: Failure of levee because of overtopping during the flood in 2013 (Mráz, 2013)

During the flood in 2013 there was overtopping of dikes and other places in the watershed of Vltava and Labe, respectively traffic roads using CCB as construction material (Fig. 8). There was no significant failures occurred, however. The difference between levee in Mělník and other structures consisted in using fly ash stabilizate greater extent, i.e. layers min. 40 cm or more. Layer of CCB at levee in Mělník is to maximal thickness of 25 cm.

Figure 8: Flooding of base layer of still unfinished cycle paths from CCB during flooding (ČEZ a.s., 2013)

IV. CONCLUSION

In the Czech Republic there are already a large number of examples of successful use of coal combustion by-products in embankments and dikes. At the same time, however, there has been documented cases where some construction problems occurred. It can say that is a clear causal ignorance of some specifics CCB or their understatement.

Using CCB to earth structures of water management can achieve their substantial price reduction. From the properties CCB used in the presented examples that the geotechnical properties can be better compared with soil especially in case of the shear strength, unconfined compressive strength and also the overall settlement of the dam crest. CCB advantage is the possibility of storage even at low temperatures.

The limiting factor for the use of certain types of CCB is a relatively small resistance to repeated contact with water and frost and reporting volume changes. Failures of constructions often stem from not detecting these properties due to neglect perform the required laboratory tests. Rarely does the problem of the possibility of leaching of toxic substances such as heavy metals.

Use CCB in earth structure of water management while reaching geotechnical and other desired properties can be recommended. Emphasis must be placed on the quality of the design which should be based on laboratory tests, the particular material used, or from in situ measurements on test sections.

The annual production of CCB is so high that it is still necessary to seek alternative ways of their use. The main advantage of using CCB is the replacement of natural raw materials (stone, natural gypsum, clinker partially), which has a positive impact on the environment, and lower, eventually zero costs for storing CCB as waste.

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