The Use of Non-Commercial Fly Ash in Roller Compacted Concrete Structures

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ABSTRACT

Current beneficial re-use technologies focus mostly on commercial-grade, dry fly ash as a concrete constituent. However, recent project experience with wet, recovered fly ash from old ash ponds as a constituent of roller-compacted concrete (RCC) reveals another option. With careful analysis and adaptable mix designs, non-commercial grade, recovered fly ash may be used as a constituent of RCC to build safe and durable retention structures.

Two of the largest RCC projects in North America, Saluda Dam in South Carolina and Taum Sauk Upper Reservoir in Missouri, were constructed from RCC utilizing fly ash from existing ponds. Saluda Dam with its 1.3 million yd^3 (1million m^3) RCC section effectively recycled 97,500 tons of recovered fly ash. The Taum Sauk Upper Reservoir project with 2.9 million yd^3 (2.2 million m^3) of RCC recycled 150,000 tons of recovered fly ash.

The advantages of using recovered fly ash include reduced cost of construction, as well as the recovery of available volume in existing fly ash impoundments. Recovered fly ash performs well when compared to commercial fly ash and has good chemical and physical properties. There is a large availability of non-commercial fly ash for RCC construction

Using non-commercial recovered fly ash however requires special consideration for non-homogeneity in the quality and characteristics of the ash. This paper proposes to outline the special considerations needed to evaluate ponded fly ash for re-use, in the development of adaptable mix designs using this fly ash, and for monitoring the fly ash and concrete quality during construction to ensure that the construction product meets specifications, and results in a project of the highest quality.

ROLLER COMPACTED CONCRETE

Roller Compacted Concrete (RCC) is a technology that has significant applicability to dams, roads, and foundations. The essential concept is to develop a dry mix that is placed like soil cement, develops the strength of concrete, and does so with much less generated heat.

RCC has essentially the same constituents as conventional concrete, albeit in different ratios, is much drier, and has virtually zero slump. RCC is placed in a manner similar to soil cement using conveyors and dump trucks. It is spread with a bulldozer, and compacted using vibratory rollers. RCC develops a surface that can be walked and driven on immediately upon compaction. This feature, coupled with the low internal heat, allows subsequent lifts to be placed one upon another without delay.

Fly ash is critical to most RCC mix designs because it replaces a certain amount of the total cement needed thus lowering internal heat, and enhances the workability of the concrete.

Workability of the concrete is more of a concern with RCC due to the low moisture and zero-slump characteristics of the mix. As a general rule, up to 50% replacement of portland cement with Class F fly ash can generate a workable mix with excellent strength properties.

The relatively high early strength and low heat generation make RCC ideal for large and massive structures such as dams, allowing for rapid buildup of the structure without the increased heat stress seen on conventional concrete designs.

SALUDA DAM

Saluda Dam is a 207 MW, hydroelectric dam, forming Lake Murray in Columbia, SC. The dam was built in 1927 as an earthen embankment structure, 7,800 (2,377 m) long, and 213 ft (65 m) high. Due to considerations of seismic stability in an earthquake of a magnitude similar to the 1886 Charleston earthquake, the dam was remediated by building a seismically stable structure immediately downstream of the existing dam.

Approximately two thirds of the remediation structure was constructed as a zoned earth embankment. The center third of the structure, due to tight space constraints imposed by the existing powerhouse, was constructed of RCC.

Immediately downstream of Saluda Dam, and sharing facilities, is the McMeekin Station Fossil Plant. McMeekin Station is a two-unit, 250 MW, pulverized coal plant. Baghouses and scrubbers installed in 1991 remove fly ash from the boilers. Prior to 2001, fly ash from the plant was hydraulically conveyed to three fly ash settling ponds and one “polishing” pond, then moved periodically to a large fly ash landfill in the immediate downstream footprint of the existing dam. The fly ash ponds were removed and remediated prior to construction, as they were located in the design footprint of the remediation dam.

One of the early goals on these projects was to use locally generated fly ash in the mix design to reduce the stockpiles on site, and to leave the facility with more fly ash storage volume than the project started with.

EVALUATION OF FLY ASH

Fly ash used in concrete should be Class F (less than 20% CaO). The ash should have a carbon content, measured by the loss on ignition (LOI), of less than 6%. At least 75% of the ash should have a fineness of 45 µm or less[1]. Class C (20% or more CaO content) may also be used in RCC, however doing so further limits the types of aggregate that can be used due to the increased potential for alkali-silica reaction in the cured concrete.

Ash characteristics will vary according to the characteristics of the coal that is being burned. While a dry recovered fly ash can be easily blended and homogenized, doing so with a wet ponded fly ash would be much more difficult. Thus the first step in evaluating a ponded fly ash source is to assess the homogeneity of the resource. A carefully designed and executed sampling and analysis program will provide the designers with depth and areal extent of fly ash zones, and a comprehensive physical and chemical analysis of the fly ash in those zones.

The next step in the process is to determine how much ash is needed and how much is available in the suitable zones. In some cases, zones can be selectively blended or discarded as needed to develop a suitable stockpile. Other factors of the mix design can be adjusted later to optimize the volume of ash used with the quality of the final product.

Ash deemed as suitable will be developed into multiple mix designs during the third stage, and cylinder samples of those mixes will be tested to evaluate the strength properties of the mixes. The final mix designs will be evaluated by building a large-scale test pad, and assessed for ease of placement, quality, and long-term cure strength.

The principle considerations in the evaluation of the ash resource are: physical and chemical characteristics of the ash including moisture content, homogeneity, and accessibility of the resource.

In all cases, the evaluation of the fly ash resource occurs in the context of the larger scope of design that also includes available aggregate, design of the embankment, and the required strength, durability, and permeability of the concrete.

RECOVERING NON-COMMERCIAL FLY ASH

Ponded, non-commercial fly ash must be conditioned and homogenized prior to use in RCC. A typical system uses screening to break lumps and remove debris. A hydraulic classifying system, such as the Econosizer is used to separate particle sizes by decantation to produce fine high quality ash. After processing, the ash is deposited in a sedimentation pond, to be later excavated and placed on the ground for further dewatering[2]. Conditioning the sorted and treated fly ash to a moisture point where it can be accurately fed to a continuous mixing plant generally requires additional handling and spreading. In most cases, the fly ash will drain off excess water if stockpiled and covered. Additional conditioning such as "plowing" the ash with a Rototiller or agricultural disc, and secondary processing through a rotary trommel screen is also effective in bringing moisture to manageable levels.

CONSTRUCTION AND QUALITY CONTROL

Construction phase work with high fly ash content RCC requires a considerable quality control program. This program should include concrete testing parameters of alkali-silica reactivity, compressive strength, modulus of elasticity, moisture content, tensile strength, unit weight, air content, density, and due to the zero-slump characteristic of RCC a vebe (vibrating table) test.[3]

For use of non-commercial grade fly ash, it is also important to consistently verify the physical and chemical properties of the fly ash meet ASTM standards and specific design criteria. Characteristic differences in the recovered fly ash can have an effect on the quality of the concrete. Thus the fly ash, the aggregate, and the mixed concrete are tested throughout the duration of construction, and the mix design modified as needed to optimize for strength and quality.

SUMMARY

Non-commercial grade fly ash can be used in the production of Roller Compacted Concrete. The advantages of using recovered fly ash include reduced cost of construction, as well as the recovery of available volume in existing fly ash impoundments.

Using non-commercial recovered fly ash requires special consideration for non-homogeneity in the quality and characteristics of the ash. With proper conditioning for particle size, moisture and homogeneity, wet ponded fly ash can become a valuable asset and useful construction material.

REFERENCES

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