Pavement Subgrade Stabilization and Construction Using Bed and Fly Ash

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INTRODUCTION

The disposal of ash produced from the combustion of solid fuels has been a major subject of research and product development since the early 1900's[1,2]. However, with the onset of modern environmental controls, the technical difficulties of finding suitable markets for such ash are growing ever more difficult[3]. An innovative application has recently been employed by the Jacksonville Electric Authority (JEA) to recycle both the bottom ash and fly ash from two new Circulating Fluidized Bed (CFB) boilers as a stabilizer for non-cohesive sands, which are typical of north Florida. This by-product is currently being marketed under the brand name "EZ-Base™." The results of laboratory testing and numerous field applications in the immediate market area illustrate that this by-product is effective in stabilizing such sandy soils in pavement and roadway construction applications.

BACKGROUND

JEA is the largest community-owned utility in Florida and the eighth largest in the United States. The JEA electric system currently serves more than 360,000 customers in Jacksonville and parts of three adjacent counties. JEA owns and operates three electric generating plants and the associated transmission and distribution facilities. JEA and the Florida Power & Light Company (FPL) also jointly own and operate plants at the St. Johns River Power Park (SJRPP) in Jacksonville and at the Georgia Power Company's coal-fired Robert W. Scherer Plant located in Macon, Georgia. JEA also produces 3.2 megawatts from a methane-fueled generating facility at the Jacksonville, Girvin Road Landfill. All combined, these facilities give JEA a net generating capability of 2,361 megawatts.

In 2001, JEA replaced two 275 megawatt oil/gas fired boilers at it's Northside Generating Station (NSGS) in Jacksonville with 311 megawatt coal and petroleum coke fueled CFB technology by Foster Wheeler Energy Corporation. This upgrade was partially supported by the Department of Energy (DOE) Clean Coal Technology Program. A schematic diagram of the Foster Wheeler CFB

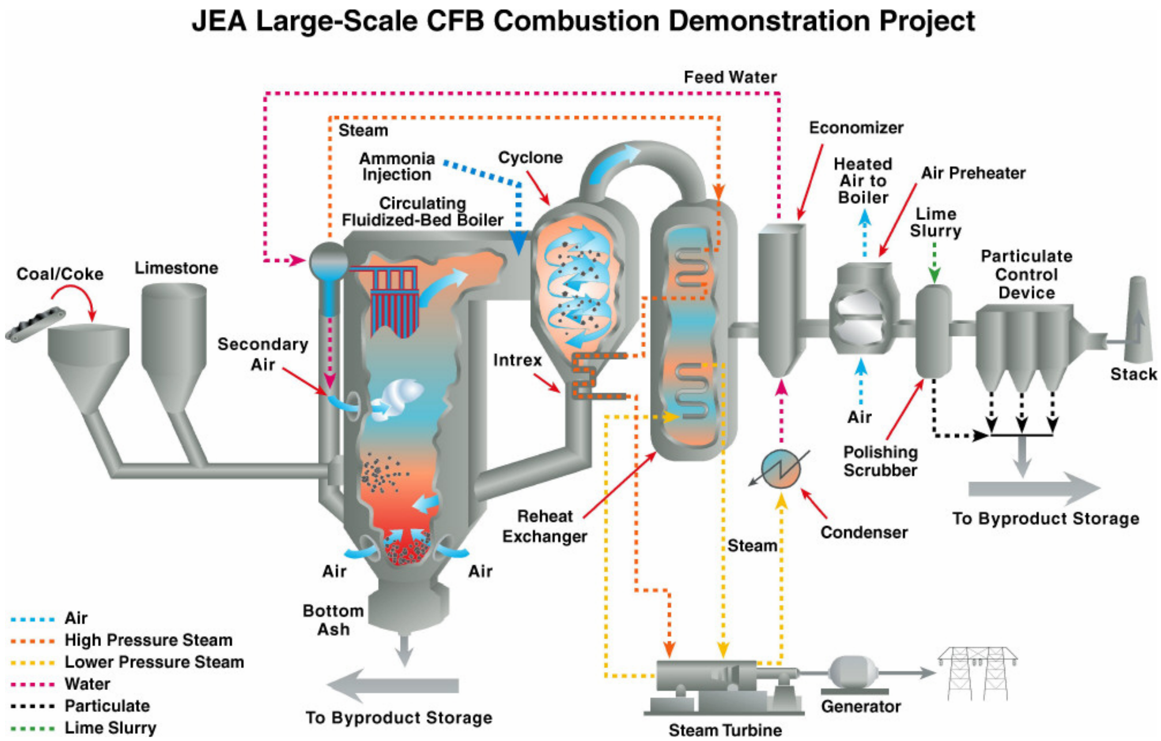

Figure 1. Schematic Diagram of JEA's Foster Wheeler CFB Boiler Units.

boiler units, illustrating, respectively, where the bed ash and fly ash are removed to by-product storage is provided in Figure 1.

JEA's new CFB units produce approximately 700,000 tons of by-product ash material annually. If beneficial uses cannot be found for this by-product ash, it must be landfilled at significant cost to JEA (approximately $25.00 per ton).

BY-PRODUCT COMPOSITION

As shown in Figure 1, coal and petroleum coke are mixed with limestone and burned in the CFB boilers. Limestone is added to create thermal mass for the fluidized bed and to provide a scrubbing medium for removal of sulfurous gases and other impurities. Due to the elevated temperatures during the burning of the fuel mixture, the Calcium Hydroxide in the limestone is partially converted to Calcium Oxide, Calcium Sulfite, and other minor compounds. Due to the efficiency of the CFB boilers and pollution control systems, and the chemistry of fuel burned at the JEA facility, this by-product ash does not meet the American Society for Testing and Materials (ASTM) requirements for conventional and lucrative Portland cement and concrete applications. The general elemental chemical composition by X-Ray Fluorescence (XRF) of this by-product ash is provided in Table 1.

Table 1. Elemental Chemical Composition of JEA By-Product Ash by XRF

Compound Description	Compound	Concentration (%)
Calcium	CaO	59.35
Sulfur	SO_3	32.57
Vanadium	V_2O_5	3.58
Silicon	SiO_2	1.81
Magnesium	MgO	1.11
Iron	Fe_2O_3	0.62
Nickel	NiO	0.30
Phosphorus	P_2O_5	0.29
Aluminum	Al_2O_3	0.19
Strontium	SrO	0.17

The dry bed ash and fly ash components are shown side-by-side in Figure 2. JEA's produces the value-added by-product, EZ-Base™ by hydrating a 50/50 blend of the bed ash and fly ash components with on-site water. When placed and compacted at the proper moisture content, and allowed to cure for a period of three or more days, the EZ-Base™ material undergoes a cementing process due to the hydration of the remaining available free lime (CaO) in the material. The added processing and handling cost of producing EZ-Base™ from the dry ash components is approximately $3.00 to $4.00 per ton.

Figure 2. JEA's CFB By-Product Dry Bed Ash (left) and Dry Fly Ash (right)

BENEFICIAL USE DEMONSTRATION

In 2004, JEA conducted a Beneficial Use Demonstration (BUD) project to assess the stability, leachability and runoff hazards from EZ-Base™. This BUD field testing consisted of constructing five test pads at the NSGS and two test pads at project sites in Jacksonville. These test pads, measuring 12 feet by 50 feet were constructed of compacted EZ-Base™ material, designed to simulate various proposed re-use scenarios. Pre-construction background sampling and analyses were conducted for surface soil and groundwater. Soil samples were collected from around the test pads after installation at various depths. Stormwater samples were collected from the test pads during 11 natural and simulated rain events. Groundwater samples collected from around the test pads monthly, for a period of 8 months. Inter- and intra-pad comparisons were made, and trend analyses were conducted as well.

The groundwater, soil and stormwater runoff data clearly demonstrated that the EZ-Base™ byproduct does not pose significant risk to the environment, and demonstrated that the environmental fate of analyses in the byproduct is very similar to the other commonly used products in similar applications (e.g., concrete, limerock, asphalt). As a result of these findings, a variety of potential risk-based reuse scenarios were proposed to the Florida Department of Environmental Protection (FDEP), the state environmental regulatory agency on the basis of human health and ecological considerations. These included soil stabilization in environmental remediation applications, road bed and road surface projects, commercial/industrial site paving projects, and road right-of-way application. Toxicological, risk and engineering questions were satisfactorily addressed and approvals were granted for reuse of the CFB byproduct on a broad scale.

APPROVED APPLICATIONS

Based on the previously described BUD, the FDEP approved the use of EZ-Base™ for the following applications:

1) Final top surface for roads, parking lots, lay down yards and similar industrial and commercial applications using compacted EZ-Base™ either alone or with stone (such as granite or limestone) or asphalt millings rolled into the top surface;
2) Compacted as a base course for civil applications in accordance with Florida Department of Transportation (FDOT), where the EZ-Base™ will be covered with a friction surface (final top surface) such as asphalt or concrete or compacted EZ-Base™;
3) Stabilized base course (meeting compaction requirements) for civil applications, where a final top surface such as asphalt or concrete or compacted EZ-Base™ will be used;

4) Mixed with existing limestone base for civil applications, where a final top surface such as asphalt or concrete or compacted EZ-Base™ will be used; and
5) Used in stabilization processes for remedial projects where access controls are in place and where the remedial project has been reviewed and approved by the Department (FDEP).

It is important to note that this approval is based solely on environmental performance and does not address the performance, or engineering properties of the material in such applications.

ENGINEERING PROPERTIES

The engineering properties of pavement materials are commonly monitored with respect to specific laboratory tests including: moisture content, dry density, and bearing ratio. In the state of Florida, the Limerock Bearing Ratio (LBR) as determined by Florida Method FM 5-515 is the common property specified during design, while dry density, as determined by the modified Proctor compaction method (AASHTO T-180) is used for acceptance purposes during construction. Typical dry density and LBR curves for the neat EZ-Base™ material, with respect to moisture content are shown in Figures 3 and 4. The optimum dry density for the neat EZ-Base™ material typically ranges from about 83 to 85 pounds per cubic foot (pcf) and the optimum moisture content typically ranges from about 27 to 29 percent, by dry weight. The maximum LBR of the neat EZ-Base™ typically exceeds a value of 100, as shown in Figure 4.

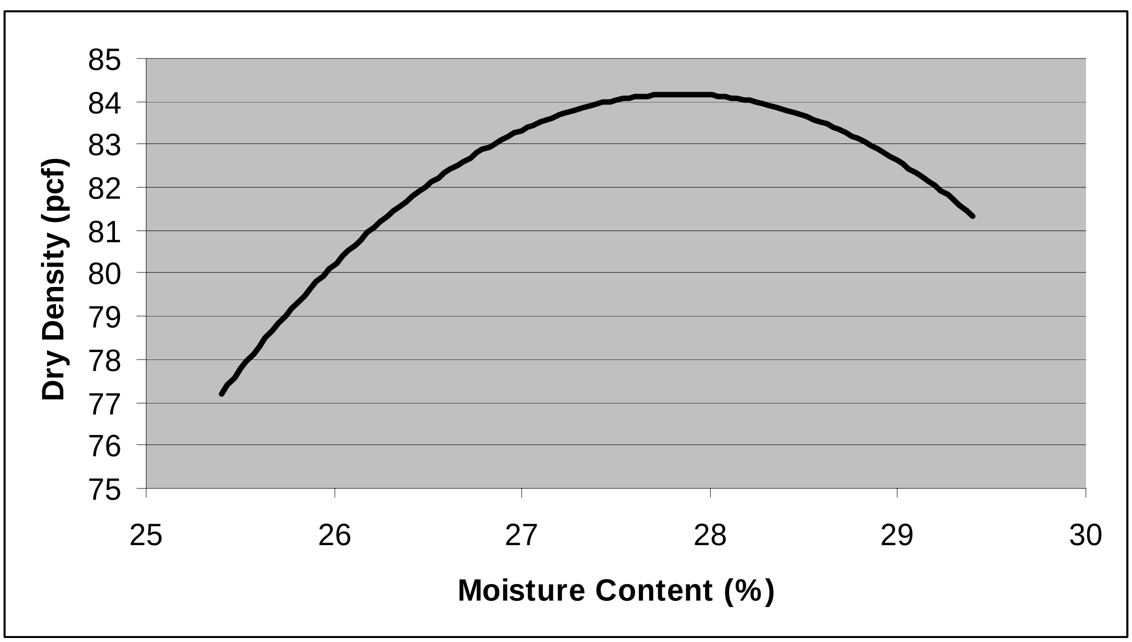

Figure 3. Typical Curve Showing Dry Density versus Moisture Content for Neat EZ-Base™ Material

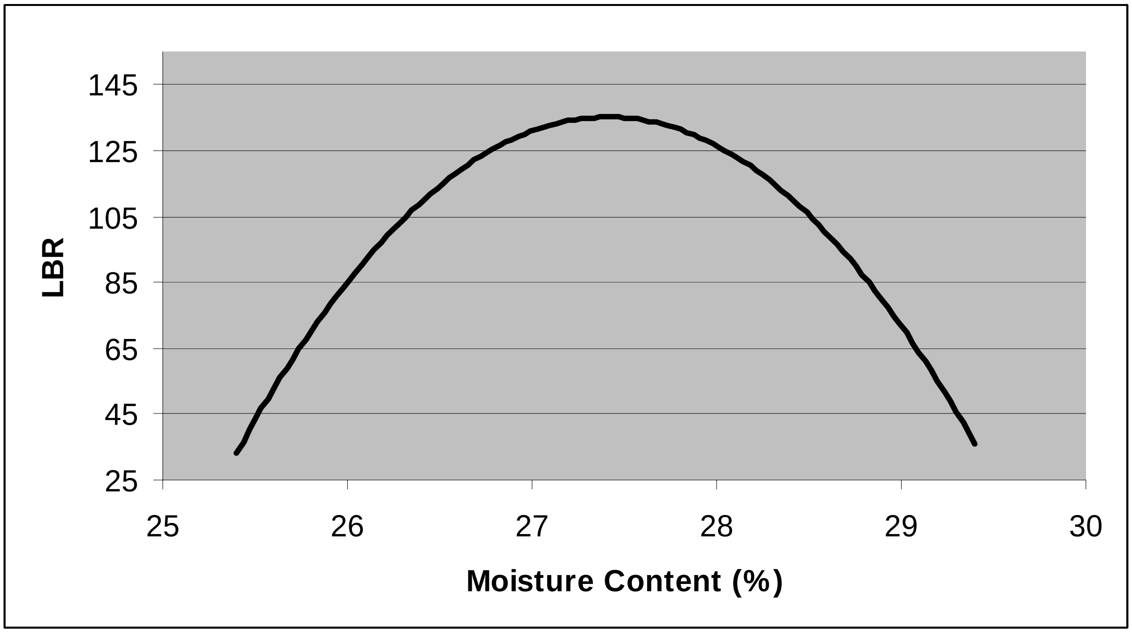

Figure 4. Typical Curve showing LBR versus Moisture Content for Neat EZ-Base™ Material

SUBGRADE STABILIZATION CRITERIA

Subgrade stabilization may be accomplished by mixing EZ-Base™ with existing subgrade or embankment soils in the design/prescribed proportions, as determined from laboratory trial mixes. In Florida, subgrade stabilization materials are specified by FDOT in Section 914 of the FDOT Standard Specifications for Road and Bridge Construction[4]. The JEA EZ-Base™ material generally meets the requirements of Section 914-3.2, Local Materials. Section 914-3.2 requires that at least 97% by weight of the total material shall pass a 3 ½ inch [90 mm] sieve, and that material having a plasticity index greater than ten or a liquid limit greater than 40 shall not be used as a stabilizer. The JEA EZ-Base™ by-product meets both of these criteria, with 100 percent passing the 3 ½ inch [90 mm] sieve and negligible plasticity.

The required thickness and design strength of the stabilization are typically shown on the roadway plans. An example of such is provided in Figure 5. As shown, a 12-inch thick layer of Type B stabilization (LBR=40) is commonly specified below the base layer for paved roadways in Florida[5]. The density requirement for acceptance during construction, as specified in Section 160-7.2.3 of the FDOT Standard Specifications for Road and Bridge Construction[4] is a minimum of 98 percent of the optimum dry density, as determined by the modified Proctor compaction method (AASHTO T-180).

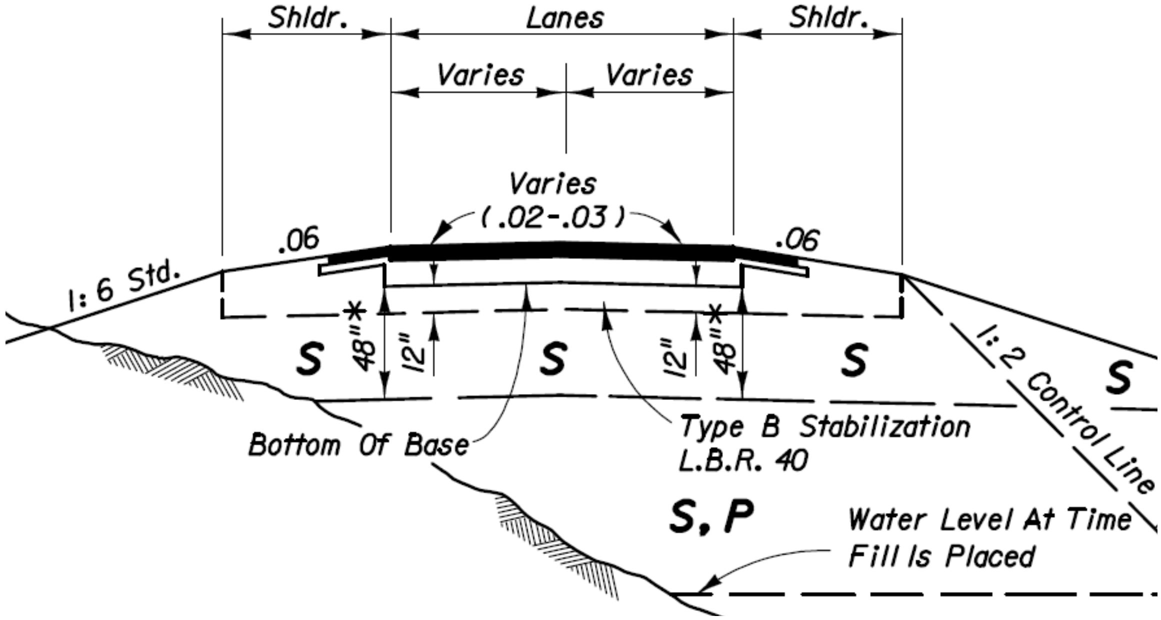

Figure 5. FDOT Embankment Utilization Plan, Showing Typical 12-inches of Type B Stabilization (LBR=40)[5].

CONSTRUCTION METHODS

Transportation and Delivery: EZ-Base™ is typically transported to the project site via haul truck, slightly below optimum moisture content. The material is delivered and dumped in the vicinity of the point of use, as shown in Figure 6.

Spreading: The material is then evenly spread, using conventional construction grading equipment to the prescribed mixing thickness, as shown in Figure 7.

Mixing: After spreading the material evenly throughout the limits of the roadway construction, the material is mixed, as described in Section 160-5.3 of the FDOT Standard Specifications for Road and Bridge Construction. Mixing is performed using rotary tillers or similar equipment meeting the approval of the Engineer. The area to be stabilized is thoroughly mixed throughout the entire depth and width of the stabilizing limits. The mixing operation is shown in Figure 8.

Compaction: Upon completion of the mixing operation, the materials are compacted to a minimum of 98 percent of the optimum dry density in accordance with FDOT Section 160-7.2.3. If the moisture content of the material is improper for attaining the specified density, carefully add water until reaching the proper moisture content for the specified compaction. The addition of water before mixing has been found to be beneficial if the material is known to be significantly dry of optimum prior to mixing. Based on experience, compaction is best obtained with a pneumatic tired roller, as shown in Figure 9.

Figure 6. Delivery of EZ-Base™ to the Project Location.

Figure 7. Spreading of EZ-Base™ to the Prescribed Mixing Thickness.

Figure 8. Mixing of EZ-Base™ Using a Typical Rotary Tiller/Mixer.

Figure 9. Compaction of EZ-Base™ Using a Pneumatic Tired Roller.

Acceptance Testing: Density measurements are typically obtained using a nuclear density device, as shown in Figure 10. However, due to the presence of bound water and traces of residual carbon in the byproduct ash, the moisture content of the compacted surface cannot be accurately measured with the nuclear device, thus the Speedy moisture gage must be used, as shown in Figure 11.

PRECAUTIONARY NOTES

EZ-Base™ is specifically well-suited for the stabilization of non-cohesive sands that do not achieve a laboratory LBR value of 40 without the addition of an approved stabilizing material. This material is approved only for applications above the wet-season ground water table and must not be placed in or adjacent to wetlands and/or waterways. As shown in Table 1, EZ-Base™ contains sulfates. Some Portland cement concretes are known to experience secondary expansive reactions in the presence of sulfates. Thus, EZ-Base™ should not be used in direct contact with concrete or recycled concrete, where precautions against sulfate attack have not been employed. Similarly, EZ-Base™ should not be inadvertently mixed with any recycled materials, without consideration of the potential chemical reactions that may result.

The constructability and curing of EZ-Base™ is sensitive to moisture content. Thus, care must be taken when adding water on the jobsite for compaction purposes. Excessive water will affect the curing process and performance of the material. Light to moderate rain events will not adversely affect the placement and performance of EZ-Base™. However, if heavy rains are expected during placement, it is recommended that placement be re-scheduled.

CURRENT DISPOSITION OF MATERIAL

JEA currently produces approximately 700,000 tons of the subject ash annually. Approximately 60 percent of this material is now being beneficially re-used, while about 40 percent is still being disposed of in area landfills. With increased exposure and documented successes in the roadway markets, it is anticipated that 100 percent will be diverted to beneficial uses in the near future.

CONCLUSIONS

An innovative application is currently being employed by JEA to recycle both the bottom ash and fly ash from CFB boilers as a stabilizer for non-cohesive sands, in north Florida. This by-product is currently being marketed under the brand name EZ-Base™. The results of laboratory testing and numerous field applications in the immediate market area demonstrate that this by-product is environmentally friendly and technically sound in stabilizing sandy soils in pavement and roadway construction applications.

Figure 10. In-Situ Density Testing with the Nuclear Density Device.

Figure 11. Moisture Content Testing with the Speedy Moisture Content Gage.

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