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RESEARCH AND TECHNO-ECONOMIC EVALUATION: USES OF LIMESTONE BYPRODUCTS

PROBLEM STATEMENT

Since 1970, Florida's crushed stone industry has grown from about 40 million tons per year to about 80 millions tons per year of production. Current technology often requires about two tons of stone be mined and delivered to the processing plant per ton of salable product. Of the byproducts that are generated when crushed limestone aggregate is produced, the screenings (minus-3/8" by plus-200 mesh in size) and finer particle sizes represent the greatest under-utilized resource.

OBJECTIVES

The ultimate objective of this research project is to evaluate the nature of byproduct fines production in the state of Florida, with an emphasis on identifying high volume economic uses for these materials which are attractive to coarse aggregate producers in the state. The project was carried out in two parts, with the corresponding specific objectives:

Part I

- estimate the current and future quantity and quality of byproduct resources at selected sites in the state
- characterize the physical and mineralogical characteristics of these byproduct fines presently stockpiled and sold commercially in both state and national markets

Part II

- identify potential economic uses of the byproduct fines characterized in Phase I of the study
- evaluate the economics of processing technologies that would be employed to produce high volume products produced with byproduct fines, emphasizing manufactured aggregates
- evaluate test specimens produced with manufactured aggregates produced from byproduct fines of varying lithology

FINDINGS AND CONCLUSIONS

Researchers first distributed a questionnaire and made visits to selected producers identified by the Florida Department of Transportation (FDOT) as having significant inventories and/or that would be future producers of fines and screenings, in order to quantify both the present and future magnitude of the byproduct fines problem. The questionnaire used was modified after one developed by the International Center for Aggregate Research (ICAR) as part of a national study of byproduct fines production.

For the purpose of this report, fines were defined as either coarse (minus-3/8" by plus-200 mesh) or fine (minus-200 mesh), with the fine category representing the greater waste and storage concern as identifying by aggregate producers in the state. Although the quantity of coarse fines produced annually exceeds that of the fine category, producers tend to sell approximately 78 percent of the coarse category as compared to 34 percent of the fine. As a result, producers identified the need for more research and marketing to be directed at developing products for the minus-200 mesh fines, particularly given that total byproduct fines production is estimated to be 300 million tons over the next ten years.

Researchers then investigated the particle-size distribution (gradation), moisture content, and mineralogy of byproduct fines representing a variety of limestone and dolomitic limestone/dolomite lithologies presently exploited by the aggregate industry. Wet sieve analysis of bulk fines, hydrometer test analysis of minus-200 mesh fraction samples, and x-ray diffraction (XRD) of both bulk fines and the acid insoluble fraction (2N HCl) were undertaken in order to satisfy this goal. Evaluation of the resulting compositional and physical data can be used as input in the development of specifications and test procedures used to evaluate and approve fines for the production of manufactured aggregate materials and in other high volume applications. Furthermore, this data should aid in identifying the most appropriate economic use for fines based on spatial constraints associated with lithologic variation.

Finally, researchers investigated ways to identify potential economic uses for these fine materials, to increase productivity, and to extend the life of an important natural resource based on temporal and spatial variations in composition. A literature review was conducted that focused on the published and unpublished literature on agglomeration and/or compaction of fines, as well as relevant computer programs that relate to the production of manufactured aggregate materials. However, other high volume uses which might be of interest to FDOT (backfill, flowable fill, and direct additives to concrete) were investigated as well.

Four processing methods were investigated for the agglomeration of minus-200 (< 75 µm) limestone fines: drum granulation, pan granulation, roll-press flaking, and roll-press briquetting. These processes form the basis for most fine powder agglomeration found in industry today; they are believed to be useful in providing granules for use as aggregate in concrete. All four processes have been or are currently being used to produce agglomerated limestone for use as agricultural liming agents.

Based on investment cost data developed for limestone granulation and compaction units, the cost for a "wet" granulation process (drum granulation and pan granulation) is slightly higher than for a "dry" compaction unit (roll-press flaking and roll-press briquetting). Most of the cost difference is due to greater costs for instrumentation, piping and ductwork, and auxiliary facilities and buildings. The process equipment cost is essentially the same for both units, because the cost of the compactor and associated equipment for the compaction plant is about equal to the cost of the granulator and drying system in the granulation plant. Most of the peripheral equipment is about the same for each type of unit.

Analysis demonstrated that the conversion costs, including utilities, labor, maintenance, taxes, insurance, and capital recovery, are about 30 % higher for wet granulation than for compaction. Given a yearly production of 78,800 tons, a savings of $488,000 per year would be realized in operating costs with the compaction plant. This would be an ongoing savings in addition to the estimated $296,000 savings in the investment cost for the compaction plant compared to wet granulation.

The key to successfully adapting any of these processes to produce a granule suitable for aggregate use is to identify a binder capable of producing a limestone granule with adequate crush strength for use as concrete aggregate. Samples were ultimately granulated using a wet processing method similar to drum granulation, but using a pug mill, which was found to be more cost effective, mechanically simpler, and more efficient than any of the other wet or dry processing methods investigated. Sodium silicate, Portland cement, and calcium sulfate hemihydrate ($CaSO_4 \cdot ½H_2O$) were investigated as potential binders.

Final granular aggregate products were evaluated in 2"×2" Portland cement concrete (PCC) test cubes with mixed results. Samples prepared with the sodium silicate binder performed poorly, partially in response to unexpected water solubility of the granules, while the samples prepared with Portland cement as the binder performed much better. Quarry H samples with the Portland cement binder performed almost as well as the Ottawa sand standard, possessing a mean 28-day compressive strength value within 250 psi of the Ottawa sand sample. With the results of the quarry H granules, a reevaluation of the binders used in the granulation process, including binder concentrations, might improve granule strength and PCC test results, providing a valuable, high volume application of granulated byproduct fines as a fine aggregate alternative in PCC or ready mixed flowable fill (RFF).

BENEFITS

The stockpiling and disposal of byproduct fines produced by the coarse aggregate industry in Florida is one of the most important problems facing the industry today. Both coarse (minus-3/8" by plus-200 mesh) and fine (minus-200 mesh) fractions of byproduct fines represent highly under-utilized resources suitable to applications in the construction market. This is of particular interest to the Florida Department of Transportation (FDOT), as use of these materials in applications such as engineered backfills, direct addition to concrete mixes as filler (minus-200 mesh), and fine aggregate (minus-3/8" by plus-200 mesh) and agglomeration (minus-200 mesh) for use as a manufactured fine aggregate for flowable fills and concrete offer a means by which the life of a major resource in the state may be extended. Furthermore, the use of these materials in high volume, technically and economically feasible applications will lead to both economic and environmental benefits for the coarse aggregate industry through reduced storage and disposal costs, and increased revenues from the sale of fines.

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