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ENERGY CONSERVATION POTENTIAL
OF PORTLAND CEMENT
PARTICLE SIZE DISTRIBUTION CONTROL -- PHASE III
IMPROVED CONTROL OF THE FINISH GRINDING PROCESS
IN CEMENT MANUFACTURE

CTL Contract No. CR7913/4330

QUARTERLY REPORT
January 1, 1986 to March 31, 1986

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Technical Progress Report
January 1, 1986 - March 31, 1986

Energy Conservation Potential of Portland Cement
Particle Size Distribution Control
Phase III

Improved Control of the Finish Grinding Process in Cement Manufacture

I. OBJECTIVE AND SCOPE

The main objective of Phase III is to develop practical economic methods of controlling the particle size distribution of portland cements using existing or modified mill circuits with the principal aim of reducing electrical energy requirements for cement manufacturing.

The work of Phase III, because of its scope, will be carried out in 10 main tasks, some of which will be handled simultaneously.

Task 1 will acquire suitable clinker and gypsum, characterize both materials, and deliver 40-50 tons clinker and 2-3 tons gypsum to each of two subcontractors, Allis-Chalmers (A-C) Corporation at Oak Creek, WI, and Kennedy Van Saun (KVS) at Danville, PA. Half of the clinker and gypsum delivered to Allis-Chalmers will be crushed to -10 mesh and delivered to Construction Technology Laboratories (CTL) at Skokie, IL, for use in subsequent tasks.

Task 2 will utilize the crushed clinker and gypsum in the CTL closed circuit pilot ball mill to establish baseline conditions. This task will provide matrix and test plans for the subsequent tasks involving grinding operations at CTL, A-C, and KVS. Instruments and feeders will be calibrated and checked.

Task 3 will utilize the CTL pilot ball mill to determine if changes in mill operating parameters can effect particle size distribution so as to produce a controlled cement that will save grinding energy and also provide good performance.

Task 4 will study the performance of a high efficiency air classifier relative to production of the kind of controlled particle size distribution cement that was developed in Phases I
and II of this project. This task includes purchase and erection of specified classifier equipment.

**Task 5** will study the effects of gypsum on the performance of the grinding operation and particularly its effects on air classification.

**Task 6** will study use of semi-air swept grinding technology to arrive at some optimum set of operating parameters that will produce a controlled particle size distribution cement.

**Task 7** will handle data developed by prior tasks and will integrate the information into a mathematical model designed to establish operating parameters which will lead to particle size distribution control and energy savings.

**Task 8** involves the A-C pilot roller mill which will develop data leading to optimum operating conditions required to produce controlled particle size distribution cements.

**Task 9** will select cement samples from the most promising operations and perform standard cement and mortar tests.

**Task 10** manages the project and provides required reports and technology transfer.

### II. SUMMARY OF PROGRESS

**Task 1**

Task 1 is complete.

**Task 2**

Task 2 is complete.

**Task 3**

Task 3 is complete.

**Task 4**

The dust collector, fan, air discharge duct, air flow measuring device, and classifier modification are installed. The system is operative and is being used for the prescribed series of tests.
Task 5
Initial work of preparing the ground gypsum/clinker mixture has been completed representing over half the task.

Task 6
Work on Task 6, semi-air swept milling is complete except for a small amount of re-testing and the final report.

Task 8
Task 8 is complete. A specific cement produced from the roller mill series of runs was selected by CTL by means of particle size distribution analysis, cube strength performance, and workability. A large quantity of this cement was produced in the roller mill for concrete tests as a future part of this project. A final report was submitted by the subcontractor.

III. DETAILED PROGRESS

January 1 to March 31, 1986

Task 4: Performance of High Efficiency Classifier

Subtask 4(a): During the FY1986 II Quarter, all modifications to the classifier and milling system were complete. A number of modifications had to be made after the contractor completed his work. The present classifier is a modification to a 30-in. Raymond Air Classifier, which was the originally installed equipment. The modification represents a new development by C-E Raymond, Inc., who is currently marketing such a retrofit to the existing Raymond classifiers in the field. However, our modification is the first of the 30-in. series totally operating in a continuing closed circuit which has meant that several operating problems had to be solved and learning had to be accomplished. Presently, the classifier is working very well and represents a considerable jump in technology.

Subtask 4(b): Test Matrix: complete.
Subtask 4(c): Grinding runs were conducted with the improved separator as installed. It was found that the air volumes generated by the blower were about 50% higher than required, preventing the system from producing a product finer than about 2000 cm$^2$/g. The pulleys and belts on the fan were replaced. Preliminary tests showed that, with the modifications made by CTL, the mill system was capable of producing cements of the appropriate finenesses.

Task 4 is on schedule and is expected to be complete by April 15, the Milestone date.

Task 5: Separate Grinding and Mixing of Gypsum

Previous work by ourselves and others has strongly suggested that gypsum agglomerates in the grinding process, coating grinding media and mill liners, and also agglomerates within the cement. These agglomerates not only inhibit efficient comminution by cushioning grinding media and liners, but also provide false, large particles presented to the classifier which separates principally on size. Therefore, it is likely that large agglomerates made up of fine particles of gypsum will be rejected by the classifier and returned to the mill as tails. This situation will presumably decrease grinding efficiency by further coating mill internals and by regrinding particles that are already fine enough.

This task investigates two potential solutions to the problem, both of which seek to keep gypsum out of the mill. Our work involved grinding, in a batch, various mixtures of clinker and gypsum to determine the largest proportion of gypsum in the blend which could be ground without causing problems. This turned out to be a 50/50 blend of clinker and gypsum ground to a Blaine specific surface area of approximately 5000 cm$^2$/g. The Blaine value reflects very finely ground gypsum and coarsely ground clinker which is the natural result of grinding two disimilar materials together which have widely disparate grindabilities. Since the batch mill represents only the first step in this grinding approach, the clinker can be relatively coarse since it will either be a small part of the whole cement or alternately will be reground in the closed circuit mill.
In the first alternate method, the ground 50/50 clinker/gypsum mixture was blended into a ground clinker (no gypsum) of proper fineness which was produced in Task 2. Particle size distribution was determined and is shown in Figure 1. Physical tests were started on the resultant cement. In the second alternate method, yet to be run, the closed circuit mill will be fed clinker only and the classifier will be fed concurrently with the 50/50 clinker/gypsum mixture. Since the classifier is now a high efficiency classifier, it is expected that good separation will take place and that a much smaller amount of gypsum will return to the mill, thus lowering to a considerable extent the amount of gypsum in the mill. This should lead to further cement grinding efficiencies. Power readings on batch mill grinding as well as closed circuit mill grinding will be accurately accounted for to determine if a net savings of energy has been achieved.

Task 6: Semi-Air Swept Milling

Clinker was ground in a two-foot diameter batch mill using 40 x 50 mesh feed material to estimate the effect of clinker aging on breakage parameters. Results of this test were plotted against breakage parameters obtained from fresh clinker of the same lot seven months previous. Figure 2 shows that the size distribution of progeny fragments are different. Computer simulations showed that S values, i.e. breakage rates, were also different.

Successful prediction of the breakage of a 140 x 200 mesh clinker sample was accomplished from the parameters of fast breakage of a 40 x 50 mesh feed.

Experimental results indicate that the particle size for which the maximum S value occurs is proportional to the diameter of the balls and that B values, i.e. characterization of progeny fragment sizes, do not depend on ball size. This suggests that B values may be controlled by a combination of variables.

Equations for modeling air-swept mills were developed. Based on the models, size distribution and flow rate equations for the closed
circuit arrangements have been calculated, and a specific cement clinker simulator is currently being prepared to include the foregoing formulations.

All pilot mill test work is complete, as is the laboratory scale work.

**Task 7: Optimize Ball Mill Circuits by Mathematical Modeling**

Some data from Tasks 2, 3, 4, and 8 have been sent to Dr. L. G. Austin. Compilation of complete data is underway with full delivery expected by the end of June.

**Task 10: Physical Testing, Administration, and Final Report**

Physical tests of cements from various tasks have been started.

Tasks appear to be on schedule after shutdown of the project and rescheduling Milestones.

The project was temporarily halted November 15, 1985, by mutual agreement due to depletion of allocated funds. Amendment A006 was received, signed, and returned by January 31, 1986, providing the remaining funds for the project. A new Milestone log was submitted in February and approved which took into account re-scheduling of staff and other work; this new Milestone plan is submitted with this report. Work on the project did not recommence until February 15, 1986, so that rearrangement of work schedules could be accomplished. A reestimate of the effects of the 3 month shutdown on project costs is underway.

**IV. FUTURE WORK**

**Task 4: Performance of High Efficiency Classifier**

Grinding runs outlined in the test matrix will be performed. Since mill speed was found to have little effect on product fineness, only one mill rotational speed will be used. Also, due to a shortage
of material, one ball volume loading will be used in Task 4. Because the U.S. cement industry tends to use about 35% ball loading, and since the pilot mill system attains maximum production at that loading, 35% will be the ball loading used in Task 4.

Task 5: Separate Grinding of Gypsum

The second alternative (see Task 5 under Detailed Progress Report) will be run, and power readings taken of batch and closed circuit mills. Particle size analysis and performance tests will be done on the resulting cement. It is expected that the whole of Task 5 will be completed on schedule.

Task 6: Semi Air-Swept Milling

A few laboratory tests to check earlier work will be completed and the remainder of work on modeling will be finished. Since very little remains to be done on this task, it is expected that all work will be accomplished within the schedule.

Task 7: Optimize Ball Mill Circuits by Mathematical Modeling

The immediate work of tabulating and arranging raw data will be carried out by CTL staff. As soon as the tabulations are complete, data will be sent to L. G. Austin for use in mill circuit modeling. The task remains on schedule.

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PARTICLE SIZE DISTRIBUTION

Density  g/cc  Viscosity  cp

DATE

BY

TEMPERATURE °C

RATE START DIA.

160
93

Figure 1

TASK 5

50/50 Clinker/Gypsum Blend
Combined with Task 2 Ground Clinker

Equivalent Spherical Diameter, \( \mu \) m
Figure 2. Size distributions for new and old 40 x 50 mesh Cement Clinker. 0.196 m (8 inch) mill; U = 0.75; J = 0.30; 1 inch balls.