The Physical Properties of Granite Microfines and the Workability of Mortar with Granite Microfines

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Abstract

This paper summarizes the analysis of granite microfines from California for use in portland cement concrete. For reference, the granite microfines were compared to microfines used in previous International Center for Aggregates Research(ICAR) projects. The particle shape characteristics, based on the packing density results, were assessed and apparent clay content, based on the methylene blue value test, was evaluated. Also, the physical properties of the microfines were confirmed in self-consolidating mortar mixtures.

Keywords : Microfines, Packing Density, Methylene Blue Value Test, Particle Size Distribution

1. Introduction

Aggregate generally occupies 70 to 80% of the volume of concrete and can therefore be expected to have an important influence on its properties. Aggregate should also be free of impurities: silt, clay, dirt, or organic matter.

Silt and clay have higher surface area that results in higher water demand of fresh concrete and the higher water demand results in lower strength and higher drying shrinkage of concrete.

When the microfines are not silt or clay but fine powders produced by crushing stone, a certain amount of microfines can be permitted for use in concrete. ASTM C 33 has limited the amount of minus 75 μm fines to 5% for concrete subject to abrasion and 7% for other concrete. Many other countries including Australia, France, India, Spain and UK permit much higher amounts of microfines.

This paper summarizes the analysis of granite microfines from California (herein "CA granite") for use in portland cement concrete.

The analysis was conducted at the International Center for Aggregates Research (ICAR) in The University of Texas at Austin.

For reference, the CA granite microfines were compared to microfines used in previous ICAR projects (ICAR 107 and 108).

Previous ICAR research has shown that microfines should be selected in terms of their particle size distribution (PSD), shape characteristics, and clay content. For the analysis of the CA granite microfines, PSD was evaluated with laser diffraction, shape characteristics were evaluated indirectly with packing density measurements, and the apparent clay content was measured with the methylene blue value test.

2. Test Methods

The CA granite microfines were obtained as settling pond fines and were oven-dried prior to testing. The following test methods were used:

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(1) Density : The oven-dry apparent Density was determined with the gravimetric procedure in ASTM C 128.

(2) Apparent Clay Content: The methylene blue value test was conducted on three separate samples in accordance with AASHTO TP57.

(3) Particle Size Distribution: Laser diffraction measurements were conducted at the National Institute for Standards and Technology. The wet method was used. The specific surface area was calculated based on the assumption of spherical particle shapes and, therefore, reflects only particle size distribution -not particle shape. The span was calculated with the following equation:

$$span = \frac{d(0.9) - d(0.1)}{d(0.5)}$$

where d(0.9) is the diameter with 90 percent passing, d(0.5) is the diameter with 50 percent passing, and d(0.1) is the diameter with 10 percent passing.

(4) Packing Density: The single drop test was performed based on the description of Bigas and Gallias (2003). In the single drop test, a bed of loosely packed microfines is placed in an open dish. A 0.2 ml drop of water is added to the microfines. After approximately 20 seconds, the resulting agglomeration of water and fines is carefully removed with a needle. The test is repeated 15 times on each material. The results of the test are expressed in terms of the packing density (Φ) of the fines in the agglomeration, based on the following equation:

$$\varnothing = \frac{1}{1 + \rho_s \frac{w}{s}}$$

where ρ_s is the density of the powder, w is the mass of water, and s is the mass of the powder.

(5) Mortar Flow Properties : The performance of the microfines was evaluated in self-consolidating mortar mixtures in terms of workability. These mortar mixtures were tested with the procedures used in ICAR Project 108 and were expressed in terms of the HRWRA demand for a constant mini-slump flow and the associated mini-v-funnel flow time. The mini-slump flow and mini-v-funnel test are shown in Figure 1.

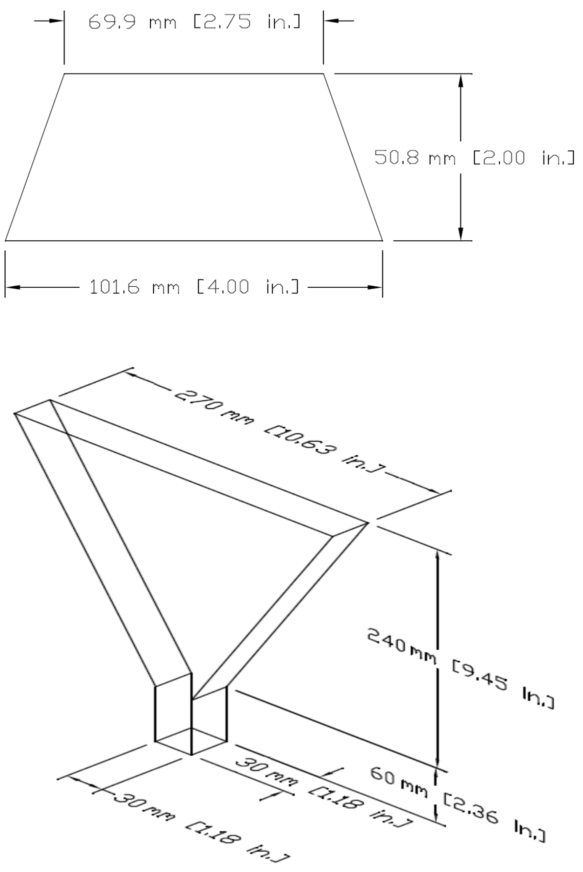

Figure 1. Mortar Workability Test Equipment

3. Results and Discussion

The physical properties of the CA granite microfines are shown in Table 1. The properties of the microfines used in ICAR Projects 107 and 108 are also shown for reference. The oven-dry apparent density of the CA granite microfines was determined to be 2.70g/cm^3.

3.1 Particle Size Distribution

ICAR research has shown that the combined PSD of all powders should be considered—including cement, cementitious materials, and mineral fillers. The PSD of the microfines should generally not overlap those of the other powder materials so that the overall powder PSD is improved by the addition of microfines.

Accordingly, microfines should generally be finer than cement and should have a broad range of sizes.

Table 1. Physical Properties of CA Granite Microfines and Microfines from Previous ICAR Research

Microfines ID	Span	Specific Surface Area (m^2/g)	Packing Density	Methylene Blue Value (mg/g)
CA_GR	2.913	0.766	0.572	17.5
ICAR 107 Materials				
DL-01		0.948	0.794	0.75
GR-01		0.703	0.771	0.94
GR-02		0.359	0.752	1.75
GR-03		0.423	0.662	6.88
HG-01		0.632	0.783	2.75
LS-01		0.930	0.756	1.08
LS-02		0.752	0.752	1.88
MA-01		0.286	0.789	2.17
NS-01		0.366	0.762	1.25
PF-01		0.456	0.810	0.50
TR-01		0.468	0.690	6.25
TR-02		1.544	0.747	2.92
ICAR 108 Materials				
DL-01	2.638	0.965	0.701	3.38
LS-02	6.673	1.394	0.678	1.63
LS-05	3.042	1.214	0.698	1.00
LS-06	4.688	1.806	0.665	2.25
GR-01	2.192	0.467	0.592	0.63
TR-01	3.302	1.243	0.637	7.88
Cement (Type I/II)	2.990	1.729	0.631	n/a
Fly Ash (Class F)	6.113	1.706	0.849	n/a
Note:Microfines IDs for ICAR 107 and 108 don't correspond.				

The PSD of the CA granite microfines is compared in Figure 2 to those of the microfines and the Type I/II cement used in ICAR Project 108.

The CA granite microfines were slightly coarser than the reference cement shown in Figure 2. The optimal PSD of microfines depends on the other powder materials used in the mixture.

The PSD measurements are further compared in Table 1 in terms of span and specific surface area. The span reflects the spread of sizes and the specific surface area reflects fineness. Laser diffraction measurements of PSD are based on the assumption of spherical particles and do not reflect particle shape.

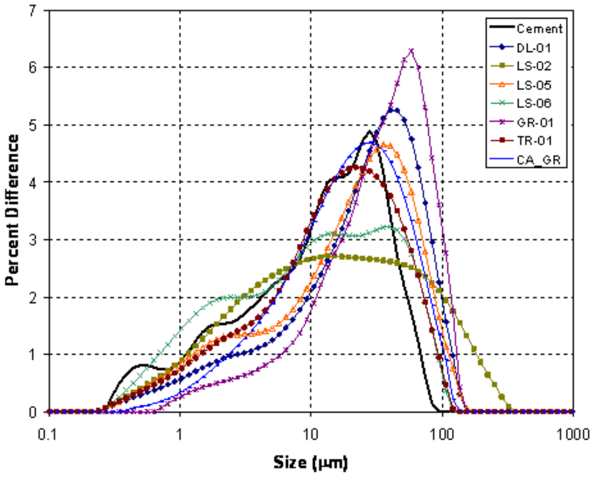

Figure 2. Comparison of Laser Diffraction Results

3.2 Packing Density

Packing density reflects the PSD and shape characteristics of the powder. The packing densities of microfines are typically greater than those of cement (angular shape) and less than those of fly ash (spherical shape). Powders with higher packing densities generally result in better workability(Kwan & Fung, 2009); however, packing density is not sufficient to predict workability because it does not fully account for PSD and shape.

Single drop test for the packing density is shone in Figure 3 and Table 1 shows that the packing density of the CA granite microfines was lower than those of all other microfines tested in ICAR Projects 107 and 108.

Figure 3. Single Drop Test

The packing density; however, was similar to that of the Type I/II cement used in ICAR 108. The low packing density of the CA granite microfines likely reflected poor shape characteristics because the particle size distribution was similar to those of several of the other microfines.

3.3 Methylene Blue Value (MBV)

The methylene blue test is a system for determining how much of a solution made from water and methylene blue will adhere to the microfines, which gives an indication of their surface area. The methylene blue value test is shown in Figure 4.

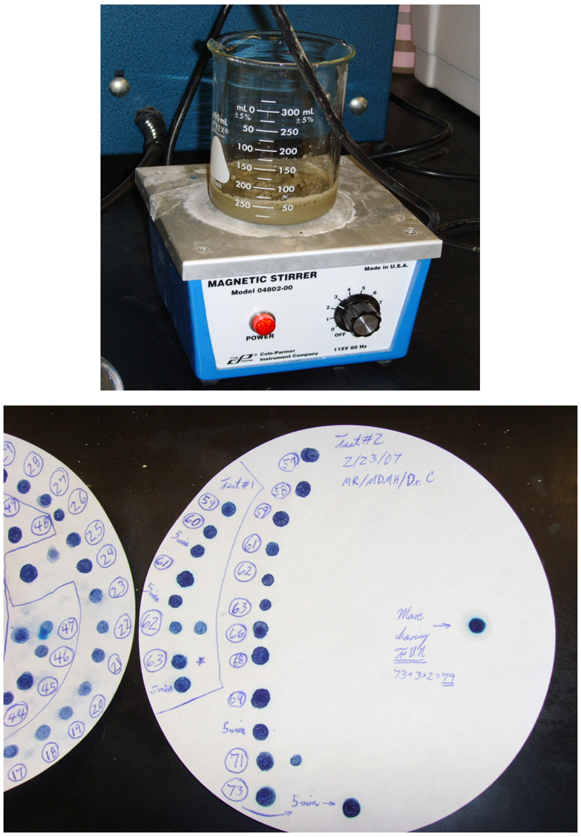

Figure 4. Methylene Blue Value Test

The methylene blue value indicates the apparent clay content. Clays are undesirable because they increase water and water-reducer demand for a constant workability level and can adversely interact with polycarboxylate-based high-range water-reducing admixtures (HRWRA). The extent to which clays are problematic depends on the specific type of clay.

The methylene blue value of the CA granite microfines was significantly higher than most of the other microfines tested in ICAR 107 and ICAR 108.

3.4 Mortar Mixtures

Self-consolidating mortar mixtures were tested to evaluate the flow property of mortar with the CA granite microfines.

Even though self-consolidating concrete is not used widely at this time, extensive self-consolidating mortar data was available from ICAR 108, allowing a comparison of the CA granite microfines to a wide range of other microfines.

Microfines that perform relatively well in self-consolidating concrete are likely to perform well in concretes with other workability levels.

The mortar mixture proportions are shown in Table 2 and the mortar mixtures test results are shown in Table 3. It should be noted that the paste volume and powder volume increase and the water/powder ratio decreases when microfines are added. The same sand, cement, fly ash, and polycarboxylate-based HRWRA used in ICAR 108 were used in the evaluation of the CA granite microfines. The dosage of HRWRA to achieve a mini-slump flow of 9-inches and the associated mini-v-funnel time were determined.

Table 2. Mortar Mixture Proportions

Mix	w/cm[1]	w/p[2]	Absolute Volume (%)				
			Water	Cement	Fly Ash	Sand[3]	Microfines
Control	0.35	1.013	22.9	15.6	7.0	54.5	0
15% Microfines[4]	0.35	0.744	22.9	15.6	7.0	46.3	8.2

[1] Expressed by mass
[2] Expressedy by volume
[3] The fine aggregate, excluding microfines, was LS-02-F for all mixtures
[4] Percentage of microfines expressed as volume of sand

Table 3. Comparison of Mortar Mixture Test Results (15% Microfines)

	HRWRA Demand (ml/l)	Mini-V-Funnel Time (s)
Control (no microfines)	1.28	6.6
CA Granite	6.40	11.4
GR-01	2.68	12.5
GR-01 (repeat)	2.50	13.9
TR-01	3.00	8.6
LS-02	1.93	6.3
DL-01	2.78	8.1
LS-05	1.93	7.4
LS-06	1.50	5.1

The GR-01 mortar was repeated when the CA granite microfines were tested. All other results are from ICAR 108.

The mini-v-funnel time was determined by filling the mini-v-funnel in one lift, pausing for 60 seconds, opening the gate at the bottom of the mini-v-funnel, and recording the time for mortar to discharge from the funnel. The ICAR research indicated that the HRWRA demand is related to yield stress and the mini-v-funnel time is related to plastic viscosity.

The mixtures were evaluated in terms of HRWRA demand for a 9-inch mini-slump flow—which is related to yield stress and reflects the PSD, shape characteristics, and clay content—and mini-v-funnel time—which is related to plastic viscosity and reflects PSD and shape characteristics.

The HRWRA demand for the mortar mixture with CA granite was significantly higher than the other mortar mixtures due primarily to the high apparent clay content. It is well-known that polycarboxylate-based HRWRA interact with clay, resulting in significantly increased dosages for a constant workability. The clays adsorb the HRWRA polymer, such that additional HRWRA must be added to disperse the powder materials.

Once sufficient HRWRA is provided to offset the effects of the clay, the workability is otherwise unaffected.

The mini-v-funnel time was comparable to the other source of granite microfines tested in ICAR 108, likely reflecting the similar PSD and shape characteristics. These two granite microfines, however, compared poorly in terms of mini-v-funnel time to the other microfines, likely reflecting the poor shape characteristics of the two granite microfines.

4. Conclusions

Previous ICAR research has shown that microfines should be selected in terms of particle size distribution, shape characteristics, and clay content. The CA granite microfines, which the particle size distribution was similar to many of the other microfines tested in ICAR research, exhibited the following properties in reference to the microfines testing in previous ICAR research:

(1) The particle shape characteristics, based on the packing density results, were poor and the apparent clay content was extremely high.

(2) The physical properties of the microfines were confirmed in self-consolidating mortar mixtures. The mixture required high HRWRA dosage, reflecting the extremely high clay content of the microfines. The mini-v-funnel time, which is related to plastic viscosity, was also high, reflecting the poor shape characteristics of the microfines.

(3) The particle shape characteristics and clay content of the CA granite microfines are compared poorly to the other microfines tested previously in ICAR research.

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