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16. Abstract

The optimization of aggregates is advantageous for economical and technical reasons; however, the availability of materials and construction operations can dictate the proportions of fine and coarse aggregates. Some general guidelines based on field experience, other investigations and the results of this investigation are presented. Two sets of guidelines were developed. One is intended for users of the ACI 211 method who want to optimize aggregate proportions. The other is intended for eventual users of the Compressible Packing Model. CPM is more complex and requires more testing than ACI 211. As a result, it might not be the preferred procedure for some users. These guidelines are focused on the proportioning and optimization of aggregates; the determination of mixing water, water-to-cement ratio, and cement content is briefly mentioned.

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GUIDELINES FOR PROPORTIONING OPTIMIZED CONCRETE MIXTURES WITH HIGH MICROFINES

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GUIDELINES FOR PROPORTIONING OPTIMIZED CONCRETE MIXTURES WITH HIGH MICROFINES

1.0 INTRODUCTION

The optimization of aggregates is advantageous for economical and technical reasons; however, the availability of materials and construction operations can dictate the proportions of fine and coarse aggregates. Some general guidelines based on field experience, other investigations and the results of this investigation will be made under the assumption that materials are economically available.

For a given slump – or desired level of workability – aggregate blends with high packing density require smaller amounts of paste than blends with low packing density. Therefore, aggregate blends with high packing generally result in less expensive and more durable concrete. High packing density will be attained by means of good grading and well-shaped and smooth particles.

To obtain a good size distribution, the entire range of aggregate size fractions should be viewed as a whole rather than two separate entities, coarse and fine aggregate. The combination of well-graded fine aggregate and well-graded coarse aggregate considered separately does not necessarily result in a well-graded aggregate mix. Furthermore, the combination of sand and coarse aggregate complying with ASTM C 33 grading limits could result in mixtures with poor size distribution.

Aggregates as they come from the pit or quarry do not necessarily have size distributions that result in well-graded blends when combinations of one coarse and one fine aggregate are made. However, the addition of “correcting” aggregates could help to reduce excesses or deficiencies in some sizes. It will generally be essential that concrete plants be able to combine more than two aggregates if optimization is to be achieved.

In general, the goal is not to reach the maximum packing density, since mixtures optimized for maximum packing result in a rocky or harsh mixture and are prone to segregation, but to obtain aggregate blends with proper size distribution that still have a high packing density – just slightly lower than maximum – and possessing good workability. For many applications, proper grading can be obtained by (1) combining the 0.45 power chart and the coarseness chart or (2) by using the Compressible Packing Model [de Larrard, 1999].

2.0 GUIDELINES FOR PROPORTIONING CONCRETE WITH HIGH MICROFINES

Two sets of guidelines were developed. One is intended for users of the ACI 211 method that want to optimize aggregate proportions. The other is intended for eventual users of the Compressible Packing Model (CPM). CPM is more complex and requires more testing than ACI 211. As a result, it might not be the preferred procedure for some users. These guidelines focus on the proportioning and optimization of aggregates; therefore, the determination of mixing water, water-to-cement ratio, and cement content will be mentioned briefly.

Figure 1 presents a flowchart of the proposed methodology for proportioning concrete based on the ACI 211 focused on aggregate with high microfines and aggregate proportions.

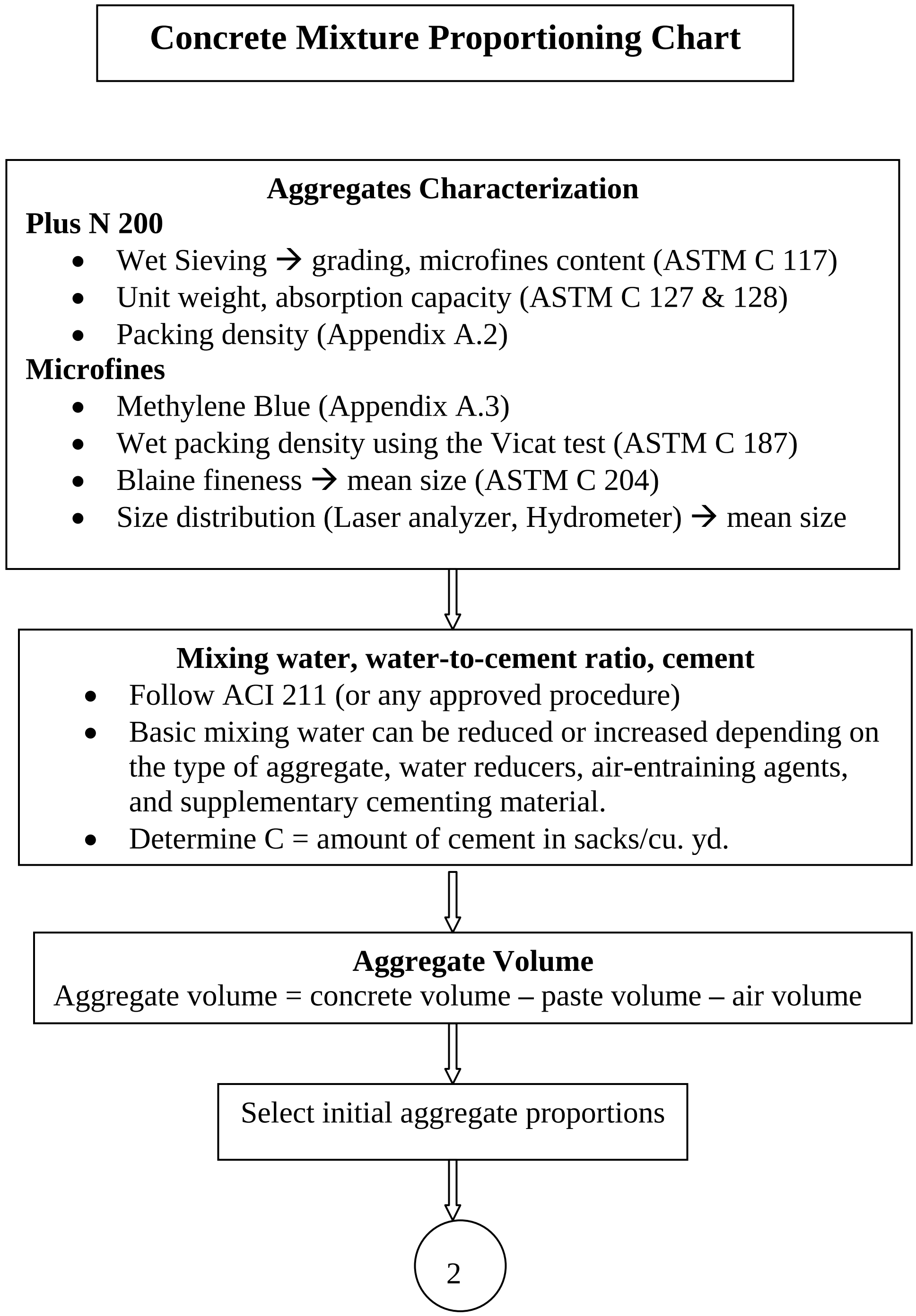

Figure 1 Chart of the Suggested Procedure for Proportioning Concrete Mixtures with High Microfines

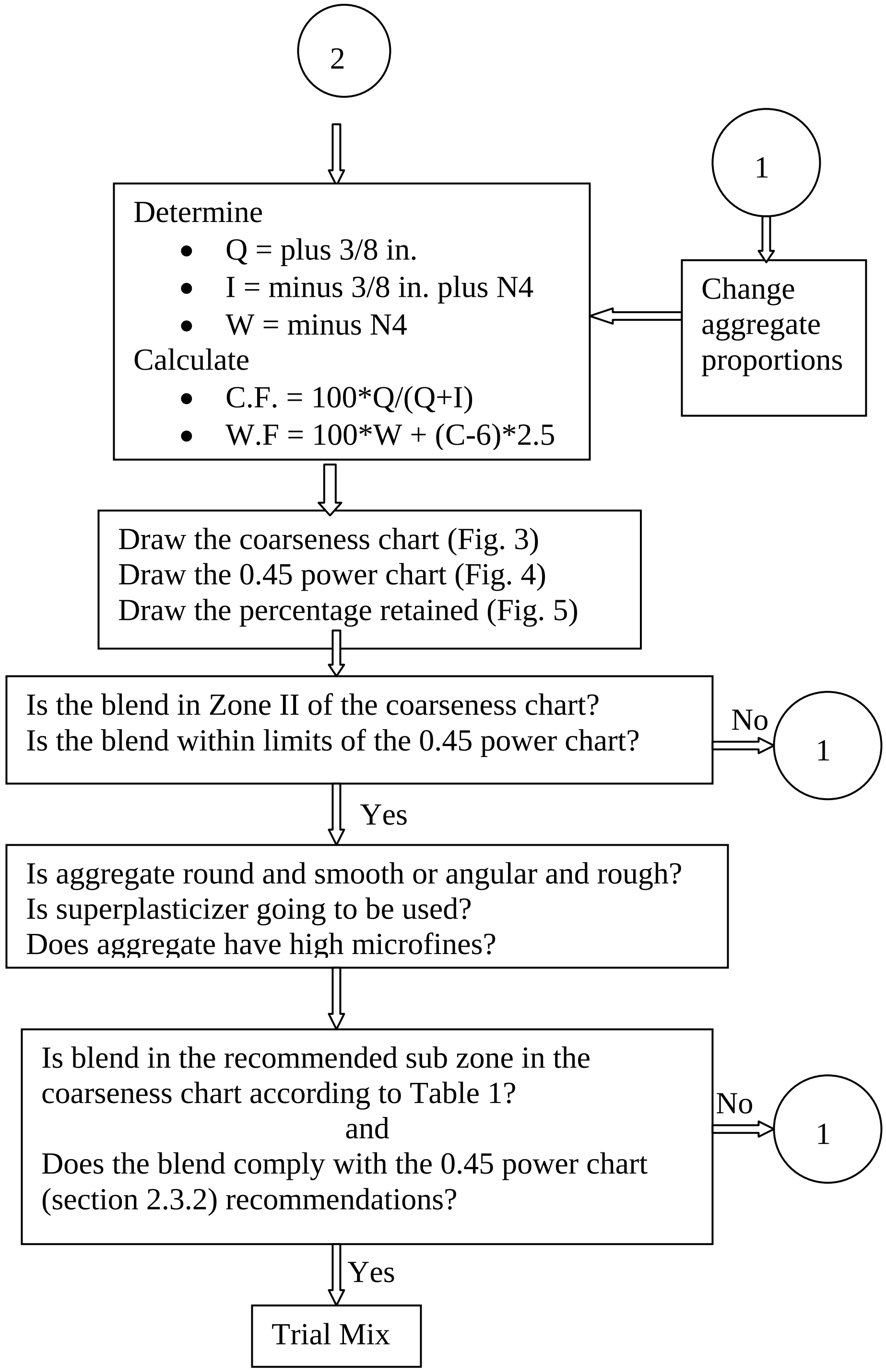

Figure 1 Chart of the Suggested Procedure for Proportioning Concrete Mixtures with High Microfines (cont'd)

2.1 Characterization Tests

For each coarse aggregate source and for each fine aggregate source, aside from the tests required by ACI 211, wet sieving, dry rodded unit weight, unit weight, and absorption capacity, it is recommended to measure both the packing density of the entire aggregate and the packing density of the sieved fractions, particularly if CPM is going to be used. The mean size of the entire coarse aggregate can be determined from the size distribution. Mean size is the size corresponding to 50 percent cumulative passing.

2.1.1 Packing Density

The packing density of aggregates with different grading cannot be compared. In fact, a sample of crushed aggregate with a certain size distribution could have higher packing density than a sample of round and smooth aggregate with different grading, and still, the natural aggregate could result in concrete with better workability.

It is recommended to measure the packing density of the sieve fractions of each aggregate and plot the results as shown in Figure 2. Figure 2, based on loose packing density can be used as a reference. A round and smooth aggregate will have packing density, values similar to those shown under "natural," a crushed, poorly shaped and rough aggregate could have a plot similar to line "crushed B" and a crushed aggregate well shaped and not very rough could produce a plot similar to "crushed A."

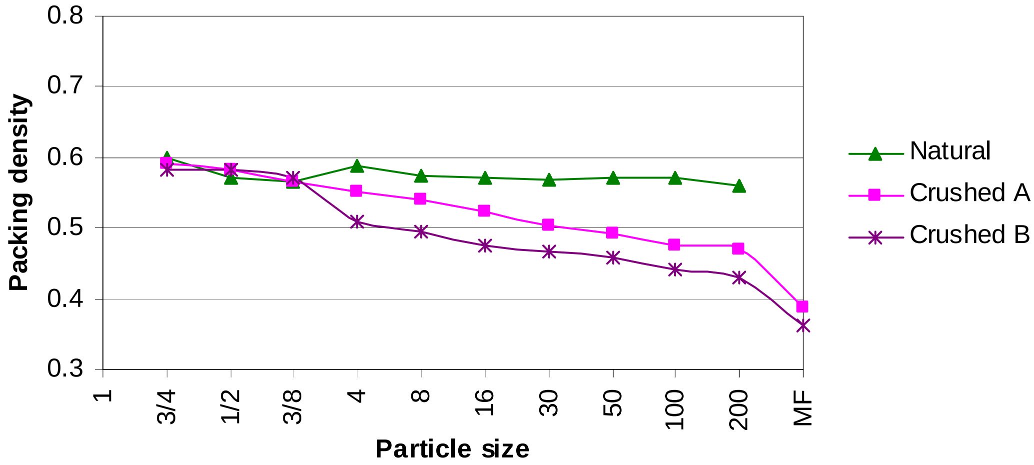

Figure 2 Loose Packing Density of Natural Aggregate, Well-Shaped Crushed Aggregate and Poorly Shaped Crushed Aggregate

2.1.2 The Methylene Blue Test (for microfines)

It is recommended to perform the methylene blue test using the Ohio DOT standard (Appendix A.1) on microfines. A High MBV usually indicates a high probability of claylike and harmful particles. Microfines with MBV higher than 6 must be further evaluated using petrographic examination or chemical analysis.

2.1.3 Wet Packing Density (for microfines and cementing materials)

For microfines and cementing materials the packing density has to be obtained in saturated conditions. The Vicat test (ASTM C 187) is recommended for that purpose. The packing density from this test is required for CPM. Even if CPM is not going to be used, wet packing density values provide a comparison of different types of microfines and gives an indication of the effect of microfines on concrete water demand. The wet packing density can be determined by means of Equation 1.

$$\phi = \frac{V_{solids}}{V_{total}} = \frac{1}{1 + \frac{W_w}{W_{mf}} SG_{mf}} \qquad (1)$$

where:

W_w = weight of water

W_{mf} = weight of microfines or powder

SG_{mf} = Specific gravity of microfines or powder

For fly ash, the wet packing density of the combination of cement and fly ash in the proportions that are going to be used in the actual mixture should be determined. This recommendation arises from the fact that fly ash, particularly class C, alone results in a flash set. The packing density from this test is required for CPM, and the wet packing can be determined by means of Equation 1. Even if CPM is not going to be used, wet packing density values can be used to compare different types of cementitious materials and gives an indication of the effect on water demand.

Preliminary information from ongoing research at The University of Texas at Austin (UT) shows that the flow table (the test used for mortar) can be used as an alternative for the Vicat test to determine the water demand or the packing density of microfines and cementing materials

2.1.4 Laser Analyzer Size Distribution and Blaine Surface Area

This option can be used to determine the mean size of microfines and cementing materials for CPM. Blaine fineness surface area can also be used to determine the mean size of microfines. Equation 2 gives a suggested relationship based on preliminary information:

$$D = 75 - 163B \quad (2)$$

where : D = mean diameter in μm

B = Blaine fineness in m^2/g

There is an ongoing project at UT from which a more reliable relationship can be obtained.

2.2 Determination of Water and Cement Amounts (For ACI 211)

The determination of mixing water, water-to-cement ratio, and cement content is based on different criteria such as desired slump, strength, and durability. ACI 211 has guidelines that can be followed for an initial determination of these quantities. Other agencies have their own criteria that could also be used. ACI 211 values are based on crushed aggregate that is well shaped, like “crushed A” in Figure 2. As a result, a water decrease of 30 lb/cu. yd. is suggested by ACI 211 for natural round and smooth aggregate. For aggregate with very low packing density like “crushed B” in Figure 2 an increase of water is required.

2.3 Aggregate Proportions Using the Coarseness and the 0.45 Power Charts

Once the amounts of water and cement have been determined, the volume of total aggregate can be calculated by subtracting the water, cement, and air volumes. The percentages of coarse and fine aggregate can be determined with the help of the coarseness, the 0.45 power and the size distribution charts.

For the coarseness chart, divide aggregate in three fractions: large, Q; intermediate, I; and fine, W. Large aggregate is composed by the plus 3/8 in. (9.5 mm) sieve particles; intermediate is composed by the minus 3/8 in. and plus N4; and fine is composed of the minus N4 sieve particles. The coarseness chart gives the relationship between the modified workability factor (W.F.) and the coarseness factor (C.F.). These factors can be calculated with Equations 3 and 4.

$$W.F.\ (\%) = W \times 100 + (C-6) \times 2.5 \qquad (3)$$

where W = minus N8 sieve particles

C is the amount of cement in sacks per cubic yard of concrete

$$C.F.(\%) = 100 \times Q/(Q+I) \qquad (4)$$

where Q = Plus 3/8-in. sieve particles

I = Minus 3/8 in. and plus N8 sieve particles

2.3.1 The Coarseness Chart

According to Figure 3, in the coarseness chart the desirable zone is II. Zone II is further divided in three sub zones, II-a, II-b, and II-c. Table 1 presents suggested desirable zones depending on the amount of microfines, on the addition of superplasticizers and on the shape of plus N 200 particles. Generally mixtures in Zone II-c tend to be dry and stiff when no superplasticizers are used and mixtures in Zone II-a tend to segregate when superplasticizers are used.

Table 1 Suggested Desirable Zones in the Coarseness Chart

Type of Aggregate	No Super	With Super
Natural (no microfines)	II-a, II-b, II-c	II-c
Crushed (15% microfines)	II-a, II-b	II-b, II-c

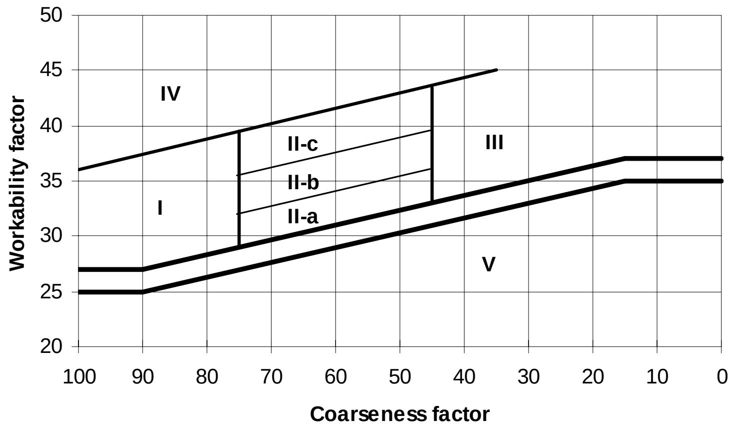

Figure 3 Coarseness Chart for Desirable Mixtures

2.3.2 The 0.45 Power Chart

Using the 0.45 power chart, the goal is to be close to the 0.45 power line. It is not recommended to have blends all above the straight line, since they will tend to be stiff and will require high dosages of superplasticizer. Blends far below the straight line are too coarse and are prone to segregation. Figure 4 shows examples of some acceptable and one not recommended size distributions for aggregate blends.

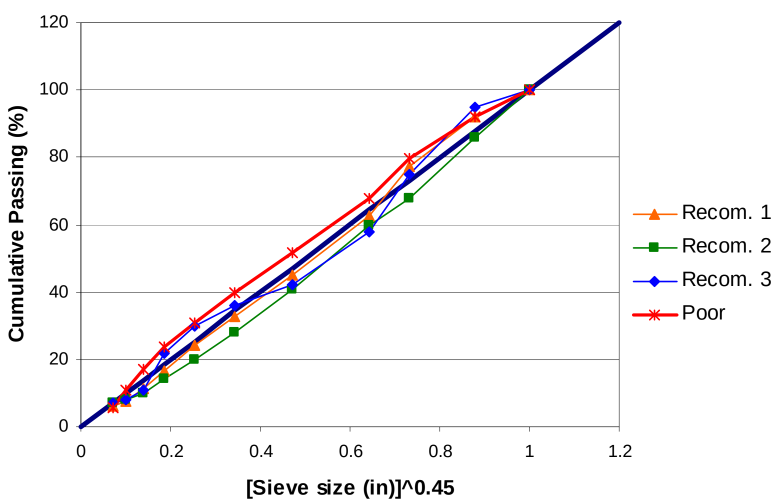

Figure 4 The 0.45 Power Chart Examples. The Poor Blending has too Many Fines

2.4 Percentage-Retained Size-Distribution Charts

Figure 5 shows the percentage retained size distribution charts corresponding to the examples presented in the 0.45 power chart. The size distribution diagrams show that desirable mixtures are mostly within the traditional "18-8" limits and that, except for microfines, amounts retained decrease with size for particles passing the N8 sieve. It can also be seen that as compared to recommended blends, the poor blend has relatively high percentages of No. 50, No. 100 and No. 200 particles and consequently has a deficit of coarse particles from ½ in. to No. 8.

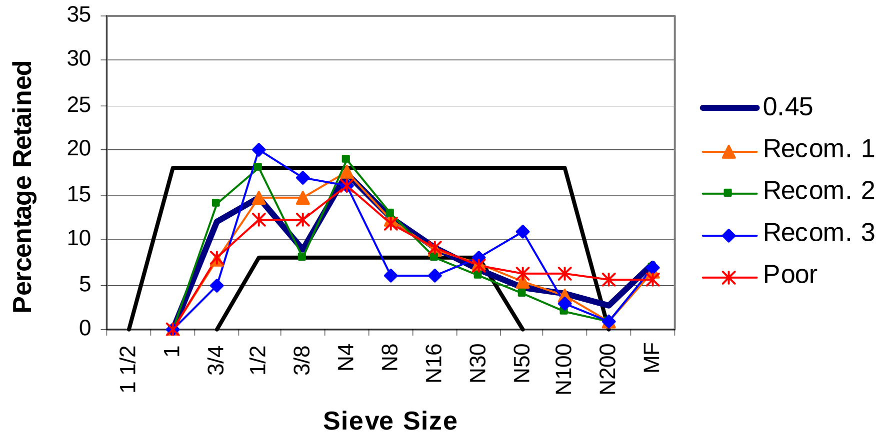

Figure 5 Size Distribution Examples. The Poor Blending has too Many Fines

2.5 Size Distribution for High Microfines Contents as Compared to Size Distributions for no Microfines.

Examples of optimum blends with and without microfines as well as the 0.45 power blend are presented in Figure 6. These examples based on several tests performed at The University of Texas [ICAR report 104] show that compared to aggregate with no microfines, a good grading for manufactured aggregate with high microfines content requires little more coarse particles (i.e. less fine particles, except for microfines). As a result, the modified workability factor for manufactured aggregate should be lower than for natural aggregate as indicated in Table 1.

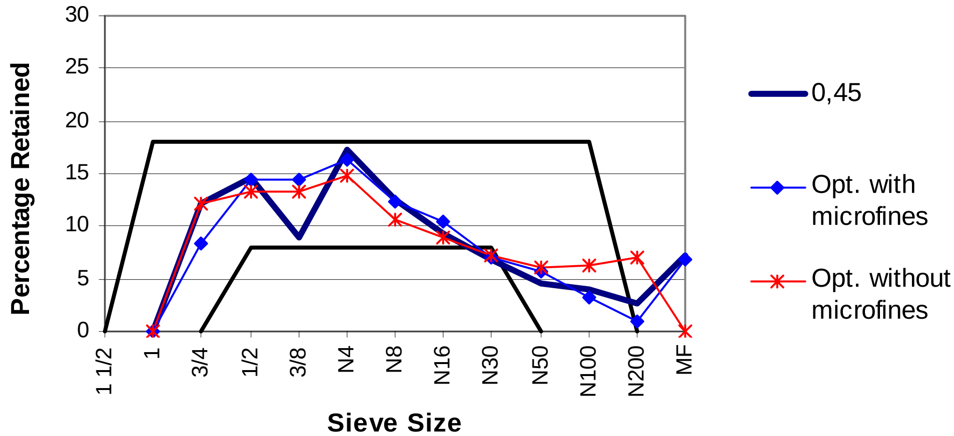

Figure 6 Comparison of Optimized Blends with and without Microfines

2.6 Determination of Water and Cement Amounts (for CPM Users)

Criteria that limit mixing water, water-to-cement factor, and cement content has to be followed. ACI 211 or some other guidelines could be used as an initial approach. Depending on the packing density of aggregates and cementitious materials as well as the grading, water and cement contents can be varied to reach the desired properties such as slump, strength, yield stress, and plastic viscosity.

2.7 Aggregate Proportions Using CPM

Figures 7 and 8 show suggested ideal aggregate-only filling diagrams for blends without microfines and blends with high microfines. It can be seen that without microfines the ideal filling diagram is uniform as suggested by de Larrard [1999], while for mixtures with high microfines it is suggested that the amounts of material passing the N 8 sieve decrease with the sieve size, as shown in Figure 8. This figure also shows the filling diagram of the 0.45 power mixture. All these mixtures are within the limits of the 0.45 power chart and in Zone II of the coarseness chart.

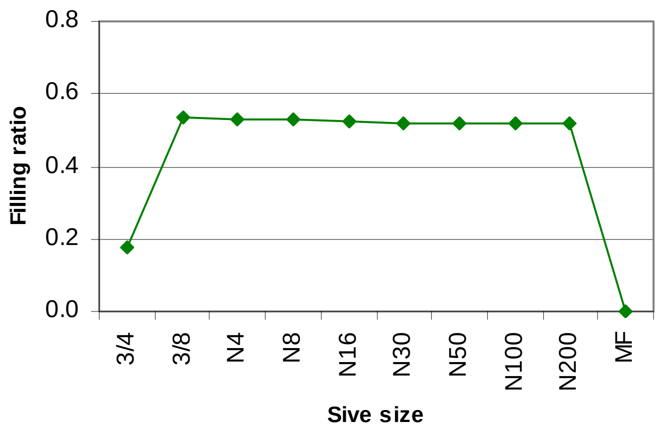

Figure 7 Ideal Filling Diagram for Mixtures without Microfines

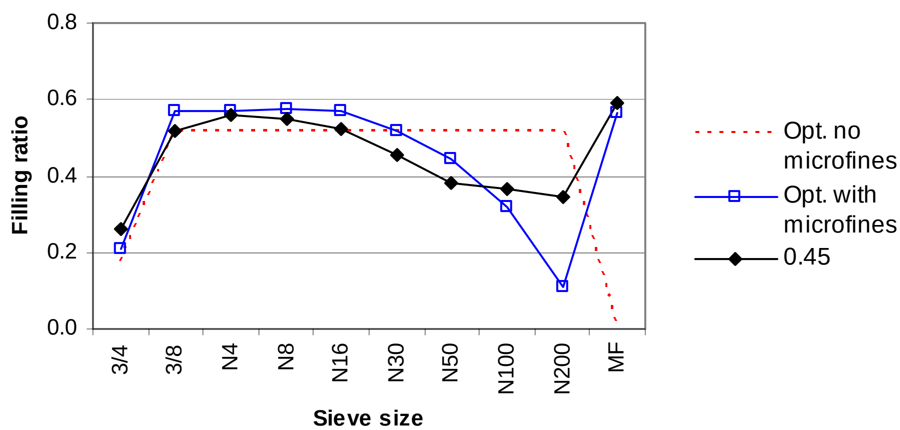

Figure 8 Filling Diagram for a Recommended Mixture with High Microfines (The Filling Diagram of the 0.45 Power Mixture is Shown for Comparison)

2.8 Example

A concrete mixture is to be made with traprock aggregate with the following characteristics:

- Coarse aggregate, A-1: Bulk specific gravity (SSD) = 3.1; absorption capacity = 1.5%; total moisture content = 1.0%; dry-rodded unit weight = 110 lb/cu. ft.
- Coarse aggregate, A-2: Bulk specific gravity (SSD) = 3.0; absorption capacity = 1.5%; total moisture content = 1.0%; dry-rodded unit weight = 110 lb/cu. ft.
- Fine aggregate, A-3: Bulk specific gravity (SSD) = 2.9; absorption capacity = 2.5%; total moisture content = 3.5%; microfines content 14%; fineness modulus = 2.9.

The size distribution of the three aggregates is shown in Table 2

Table 2 Size Distribution of Aggregates (Percent Retained)

Size	A-1	A-2	A-3
1 in.	1.3	0.0	0.0
¾ in.	31.2	0.0	0.0
½ in.	46.9	14.4	0.0
3/8 in.	17.2	78.0	0.0
N 4	2.4	7.5	21.2
N 8	1.0	0.1	31.1
N 16	0.0	0.0	16.5
N 30	0.0	0.0	8.7
N 50	0.0	0.0	6.0
N 100	0.0	0.0	4.1
N 200	0.0	0.0	2.3
MF	0.0	0.0	14.0

For the required slump, strength and durability the following values were determined using ACI 211: mixing water = 340 lb/cu. yd., w/c = 0.41, cement content = 768 lb/cu. yd. = 8.3 sacks/cu. yd., expected air content = 2 percent. Determine the amounts of the three aggregate sizes.

1. Aggregate volume:

   Agg volume = 1 – water volume – cement volume – air volume

   Agg volume = 1 – 340/ (62.4 × 27) – 768/ (3.15 × 62.4x27) – 0.02 = 0.633

2. Initial aggregate proportions:

   Based on ACI 211 the following proportions were selected for A-1, 55%, and for A-3, 45%. Table 3 shows the resulting proportions.

3. Parameters for coarseness factor

   C = 8.3 (sacks of cement per cu. yd.)

Table 3 Size Distribution of Blend (Percent Retained)

Size	A-1 55%	A-2 0%	A-3 45%	Blend
1 in.	1.3	0.0	0.0	0.0
¾ in.	31.2	0.0	0.0	17.9
½ in.	46.9	14.4	0.0	25.8
3/8 in.	17.2	78.0	0.0	9.5
N 4	2.4	7.5	21.2	3.6
N 8	1.0	0.1	31.1	12.8
N 16	0.0	0.0	16.5	7.4
N 30	0.0	0.0	8.7	3.9
N 50	0.0	0.0	6.0	5.0
N 100	0.0	0.0	4.1	4.2
N 200	0.0	0.0	2.3	3.7
MF	0.0	0.0	14.0	6.3

Q = 17.9 + 25.8 + 9.5 = 53.1%

I = 3.6 + 12.8 = 16.4%

W = 100 – 53.1 – 16.4 = 30.5%

C.F. = 100 × 0.531/ (0.531 + 0.164) = 76.5

W.F = 100 × 0.305 + (8.3 – 6) × 2.5 = 36.3

4. Coarseness chart and the 0.45 power chart

   Figure 9 shows that mixture is in Zone I, out of the desired Zone II. Figure 10 shows that grading is far out of the limits in the 0.45 power chart. This mixture is probably going to be rocky and prone to segregation. Additionally the size distribution is shown with the “18-8” limits in Figure 11, which shows that there is excess of ¾ in. and ½ in. particles and deficit of No. 4 and No. 30.

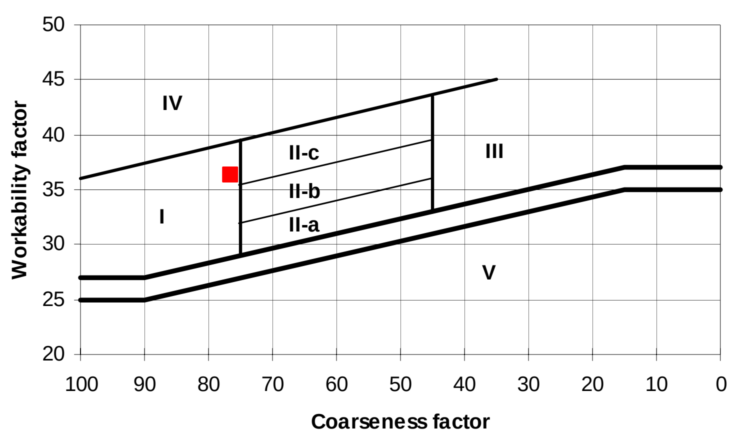

Figure 9 Coarseness Chart for the Initial Mixture

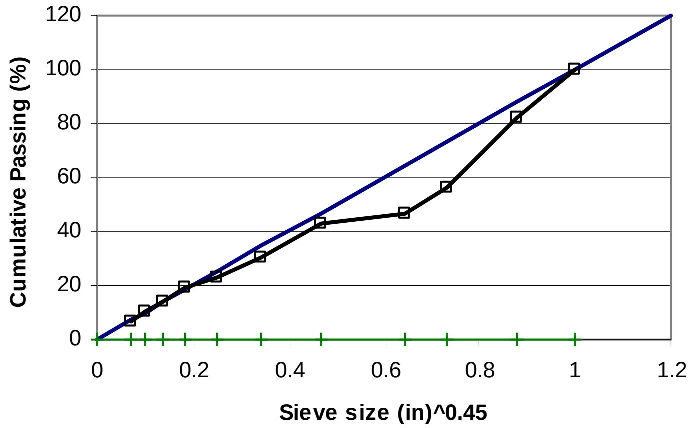

Figure 10 The 0.45 Power Chart for the Initial Mixture

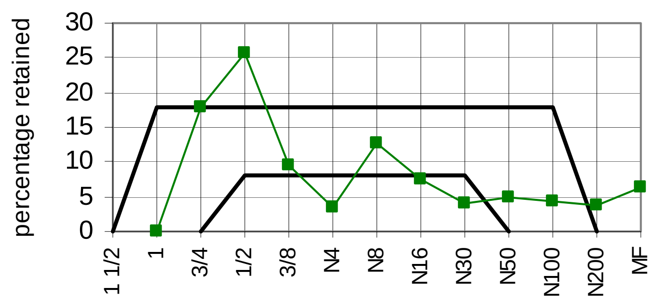

Figure 11 Size Distribution for Initial Mixture

5. Change proportions.

   After some trials the following proportions resulted: A-1, 28%, A-2, 26%, and A-3, 46%. The corresponding charts are shown in Figures 12 to 14. The resulting blend is mostly within the suggested limits and is expected to perform better than the initial one. Since it is in Zone II-c it will probably be stiff and dry without water reducer; as a result, the addition of superplasticizer is probably required. If material could be sieved and recombined, or if a "correcting" aggregate could be used, further optimization could be performed.

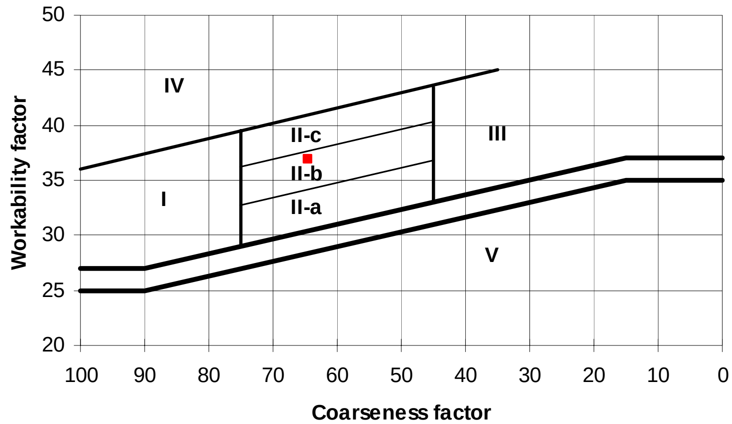

Figure 12 Coarseness Chart for the Optimized Mixture

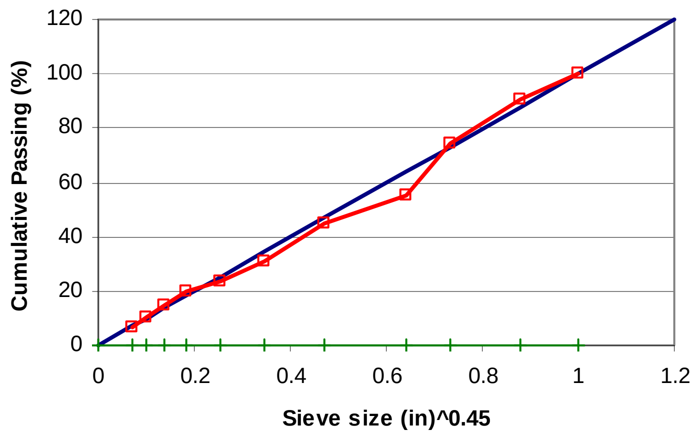

Figure 13 The 0.45 Power Chart for the Optimized Mixture

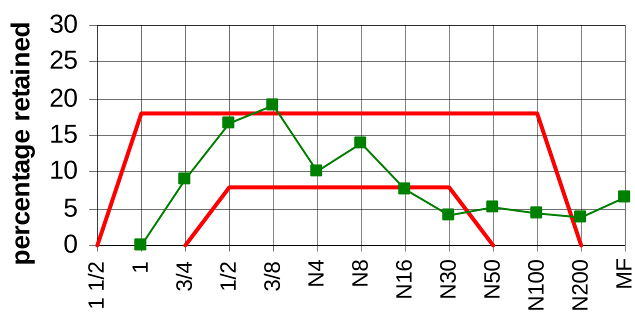

Figure 14 Size Distribution for the Optimized Mixture

6. Aggregate amounts (SSD)

   Weight aggregate A-1 = 0.28 $\times$ 0.633 x (3.1 $\times$ 62.4 x 27) = 926 lb/cu. yd.

   Weight aggregate A-2 = 0.26 $\times$ 0.633 x (3.0 $\times$ 62.4 x 27) = 832 lb/cu. yd.

   Weight aggregate A-3 = 0.46 $\times$ 0.633 x (2.9 $\times$ 62.4 x 27) = 1423 lb/cu. yd.

REFERENCES

Quiroga, P. and D. Fowler, "The Effects of Aggregate Characteristics on the Performance of Portland Cement Concrete," ICAR 104-1F, 2004.

De Larrard, F., "Concrete Mixture Proportioning: a Scientific Approach," London, 1999.

APPENDIX
NON ASTM METHODS

A.1 WET PACKING DENSITY OF MICROFINES AND CEMENTITIOUS MATERIALS

The wet packing density of material passing the N 200 sieve can be determined by means of the Vicat test and the "thick paste" test. The last one is described and recommended by de Larrard [1999]. However, both methods yielded similar results and the "thick paste" state for microfines is difficult to define. For that reason the Vicat test was used in the study.

The recommended procedure is the ASTM C 187 "Standard Method for Normal Consistency of Hydraulic Cement," except that cement is replacement by the powder that is going to be tested. With the amount of water from the test, the packing density is calculated with Equation A.1

$$\phi = \frac{V_{solids}}{V_{total}} = \frac{1}{1 + \frac{W_w}{W_{mf}} SG_{mf}} \qquad \text{(A.1)}$$

where: W_w = weight of water

W_{mf} = weight of microfines or powder

SG_{mf} = Specific gravity of microfines or powder

A.2 PACKING DENSITY OF AGGREGATES

Dry packing density of aggregates should be performed either in representative samples of the material or in fractions that have been previously washed. The packing density depends on the method of compaction. Dewar [1999] suggests using the loose packing density for the Theory of Particle Mixtures (TPM), de Larrard [1999] suggests using the vibrated-plus-pressure packing density for the Compressible Packing Model (CPM), and Andersen [1993] suggests using the rodded packing density according to ASTM C 29.

Material can be in oven-dry or in saturated surface-dry material condition. Packing can be determined in a 0.10-ft^3 container for fine aggregate and material passing the 3/8-in. sieve, and in a 0.25-ft^3 container for both coarse aggregate and material retained in the 3/8-in. sieve and for fine aggregate and material passing the N4 sieve. The container should be rigid and should have an inside diameter at least five times the maximum size of aggregate.

The packing density, α, is defined as the volume of solids in a unit volume. If a weight W of aggregate with specific gravity, SG, fills a container of volume Vc, α is:

$$\alpha = \frac{V_s}{V_c} = \frac{W}{V_c SG} \tag{A.2}$$

The “wall effect” correction is made by means of Equation A.3 [de Larrard, 1999]

$$\alpha' = [1 - (1 - k_w)V_p]\alpha \tag{A.3}$$

where α' = packing corrected for wall effect

α = measured packing

V_p = disturbed volume by the wall effect

k_w = constant that depends on particle angularity.

k_w = 0.88 for rounded particles

k_w = 0.73 for crushed particles

Vp is calculated under the assumption that due to the wall loosening effect, the packing density is affected within a distance of d/2 from the wall, where d = mean diameter of particles. Then

$$Vp = \pi/4\ [D^2H - (D-d)^2\ (H-d/2)] \quad \text{(A.4)}$$

where D = Interior diameter of the container

H = Interior height of the container

Additionally, for the Compressible Packing Model, the virtual packing, ϕ, is calculated as:

$$\phi = \alpha'\ (1+1/K)$$

where: K = index of compaction = 9 for vibrated-plus-pressure packing

Compaction Methods

Loose Packing

The loose packing of coarse and fine aggregate can be determined following the BSI 812: Part 2, "Testing Aggregates: Methods of Determination of Density." The relevant portions of the standard are the following:

Fill the container with the aggregate by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 50 mm (2 in.) above the top of the container. Take care to prevent, as far as is possible, segregation of the particle sizes of which the sample is composed. Fill the container to overflowing and remove the surplus aggregate by rolling a 16 mm (5/8-in.) rod across and in contact with the top of the container; any aggregate which impedes its progress should be removed by hand, and add aggregate to fill any obvious depressions. For 6 mm (N 4) aggregate or smaller, the surface may be struck off, using the rod as a straight edge. Then determine the mass of the aggregate in the container. Make two tests.

Vibration-Plus-Pressure Packing

A mass of dry aggregate is put in a cylinder having a diameter more than five times the maximum size of aggregate. A piston is introduced into the cylinder, applying a pressure of 10 kPa (1.42 psi) on the surface of the specimen. Then the cylinder is fixed on a vibrating table and submitted to vibration for 2 min.

Rodded Packing

Following ASTM C 29, three layers of material are compacted with a 5/8-in. rod 25 times each.

A.3 THE METHYLENE BLUE ADSORPTION TEST [OHIO DOT, 1995]

1. Scope

This supplement covers the procedure for measuring the amount of potentially harmful fine material (including clay and organic material) present in an aggregate.

2. Equipment

This test shall be performed in a Level 2 laboratory, containing the following additional equipment:

- Amber colored burette, mounted on a titration stand, with sufficient capacity to completely perform the test

- 3 suitable glass beakers or flasks
- Magnetic mixer with stir bar
- Balance, sensitive to 0.01 gram, of sufficient capacity to perform the test
- 250 mm glass rod with an 8 mm diameter
- Laboratory timer or stop watch
- 75 µm (no. 200) sieve and pan
- 1000 ml volumetric flask
- Whatman No. 2 filter paper

3. Reagents

- Methylene blue, reagent grade, dated and stored for no more than 4 months in a brown bottle wrapped with foil in a dark cabinet, at lab temperature
- Distilled or deionized water at lab temperature

4. Procedure

This test shall be performed on a sample(s) of material passing the 75 µm (No. 200) sieve, taken from the washed gradation of a 2000 g sample of the individual or combined materials (as required). The washed sample is dried to a constant weight and mixed thoroughly. Three separate samples of 10 g (± 0.05g) each are taken. Each of these samples is combined with 30 g of distilled water in a beaker by stirring with the magnetic stirrer until thoroughly wet and dispersed.

One gram of methylene blue is dissolved in enough distilled water to make up a 200 ml solution, with each 1 ml of solution containing 5 mg of methylene blue. This methylene blue solution is titrated stepwise in 0.5 ml aliquotes from the burette into the beakers containing the fine aggregate solution, while continually stirring the fine aggregate solution, keeping the fine aggregate in suspension. After each addition of the methylene blue solution, stirring is continued for 1 minute. After this time, a small drop of the aggregate suspension is removed and placed on the filter paper with the glass rod.

Successive additions of the methylene blue solution are repeated until the end point is reached. Initially, a well-defined circle of methylene blue-stained dust is formed and is surrounded with an outer ring or corona of clear water. The end point is reached when a permanent light blue coloration or “halo” is observed in this ring of clear water. When the initial end point is reached, stirring is continued for five minutes and the test repeated to ascertain the permanent end point. Small additions of methylene blue solution are continued until the 5-minute permanent end point is reached. The number of milligrams of methylene blue is calculated by multiplying the number of milliliters of methylene blue (MB) by 5 mg/ml (ml MB × 5 mg/ml = mg MB).

The methylene blue value (MBV) is reported as milligrams of methylene blue solution per gram of fine aggregate (e.g. MBV = 55 mg/10g or 5.5 mg/g). Multiple tests should be reported separately.

5. Notes

- Certain clays will give poor results with this test. If so, soak the 75 µm (No. 200) sieve material in the distilled water at 90 °C for three hours while stirring. Allow to cool to lab temperature before proceeding with titration.
- With experience, the person performing the test can reach the end point more quickly by skipping early aliquotes.