Simple Particle Packing

Material: Recycled Glass

Issue: *When mixing granular materials with bonding agents (e.g. cement with aggregate), it is sometimes critical to achieve the highest possible "particle pack," that is, the combination of materials and gradations that has the greatest density when blended dry. Finding the highest particle pack can significantly improve strengths of bonded materials by increasing bonded surface area per weight of material. It also reduces liquid requirements for wetting mixtures.*

Best Practice: Given two granular materials, one coarse and one fine, each different percentage combination of the two materials will have a different density, measured in grams per cubic centimeter. The maximum particle pack is the combination of the two gradations that has the highest density. This is a description of a quick and easy way to determine the maximum particle pack for two materials, or three if one material has a pre-defined percentage in the mixture.

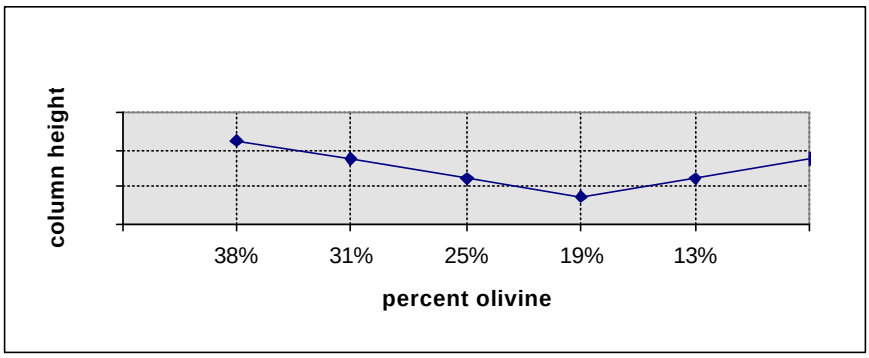
1. Obtain a one-inch inside diameter glass tube, called the "packing tube," at least three feet long, a flexible plastic or cloth centimeter scale, a gram weight scale, and a supply of the two granular materials to be packed, as they are to be delivered for production. A glass or Pyrex tube is better than plastic because it stays straight and will not scratch as quickly.
2. Plug one end of the tube and tape the centimeter scale to the tube so that zero starts at the plugged end.
3. Weigh out a combination of the two granular materials, recording the weight of each, for a total of 400 grams. Mix the two (or three) granular materials thoroughly outside of the packing tube and pour them, through a funnel, into the packing tube.
4. Tap the bottom of the packing tube a defined number of times on a cushioned surface. A piece of all-weather carpeting works well. 200 taps may be sufficient. The number of taps must be such that no discernible packing is occurring after an additional 10 taps. For large percentages of very fine materials, even a large number of taps may not settle the material. That can be disregarded. Large percentages of fines cannot be as efficiently packed as combinations of coarse and fine.
5. Record the height of the tapped column, empty the mixed materials, mix new materials at different percentages, and begin again. Continue until the point of minimum column height is found. That is the maximum particle pack.

Example:

Assume that a maximum particle pack is needed for three granular materials, with one of the materials being cement, to be combined in a 3:1 ratio with two aggregates. By repeating steps 3-5 above, the following table is created:

grams cement	grams copper slag	grams olivine	total grams	column height
100	150	150	400	46.5
100	175	125	400	45.5
100	200	100	400	44.5
100	**225**	**75**	**400**	**43.5**
100	250	50	400	44.5
100	275	25	400	45.5

Graphed, the table above looks like this:



Therefore, the maximum particle pack for a 3:1 aggregate:cement mixture is achieved with

25% cement
19% olivine 120 mesh
56% copper slag 16x30 mesh

It is also possible to perform the same type of analysis with three variable aggregates, but a three-dimensional graphing surface is necessary and the number of iterations can be daunting.

Implementation: This kind of analysis can be performed in a shop environment in a few minutes. Records should always be kept of past results. Any time a new source of granular material is received, new tests should be run, even if the gradation analysis is the same as one previously used. This is because different processing equipment generates differently shaped grains, resulting in surprisingly different particle packs.

Benefits: Optimizing particle packing when combining aggregates with binders can dramatically increase the strength of the composition material and decrease shrinkage during curing.

Application Sites: Small businesses, shops, and laboratories.

Contact: For more information about this Best Practice, contact CWC (206) 443-7746, e-mail info@cwc.org.

References: Most ceramics texts treat the characteristics of particle packing, including

Grimshaw, Rex W., *The Chemistry and Physics of Clays and Other Ceramic Materials*, Wiley-Interscience, 1971, pp 407ff.

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