Effects of Particle Size Distribution on Performance in Cementitious Systems

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Particle Size Distribution in Cement

- Particle size distribution, uniformity factor and specific surface area (SSA) are important physical parameters affecting cement service properties.

- These parameters define the proportion of fine and coarse particles in the cement.

- Particle size distribution can be measured with automatic or manual sieves.
Particle Size Distribution in Cement

- The most frequently followed parameters in the cement are 45 and 90 micron sieve residue and blaine (specific surface area) values.
- Blaine value is a numerical value of the area covered by 1g material.
- It is impossible to interpret about performance of cement with these two values.
- For this reason, particle size distribution is performed with automatic devices via distribution curves.
The effect of cement particle size distribution on performance is also influenced by the grain size of the mineral admixtures. It is an important parameter that must be taken into consideration during cement selection since all the components of a cementitious material can have different particle size distribution.
The grain size distribution curve for the cement needs to be 'S' shape.

The meaning of 'S' is that the particles are distributed homogeneously in different dimensions within the sample.

While investigating properties of cement grain not only the size but also the shape parameter is important because these two variables are essential to determine total surface area.
Particle Size Distribution in Cement

Main cement properties affected by particle size distribution:

- Strength
- Setting Time
- Permeability
- Hydration Temperature
- Water Demand and
- Microstructure
Particle Size Distribution in Cement

- The most important parameter in particle size distribution is homogeneity which is expressed as 'n'.
- The high value of n means that the grain size distribution occurs in a narrower range. On the other hand, low value of it demonstrates that it has a wider particle size distribution.
Particle Size Distribution in Cement

- n value is critical for cement performance. Small n values; in other words wider particle size distribution decreases water demand and increases packing density.

- On the other hand; a narrower particle size distribution gives higher hydration rates for equal specific surface area and increases water demand.
When the samples have equal specific surface area, the uniformity factor make a positive contribution towards strength improvement because of a rapid hydration rate due to the narrow size distribution.

- There is no linear relationship between strength of cement mortar and (n) value.
- n value is calculated as $n = \frac{D_{60}}{D_{10}}$
- n=1 represents unit homogeneity value.
Particle Size Distribution in Cement

n = uniformity factor, is specified in devices that measure particle size distribution and this value shows particle size distribution of substance and whether it is homogeneous or not when considering surface area of the sample.
Particle Size Distribution in Cement

- As seen in figure, when samples spread homogeneously in a narrow size area in other words when n value increases, it is possible to see increase in early age strength values especially.
As can be seen in figure, increasing the percentage of 3 – 32 μm fraction resulted in higher strength values.

But, the most important outcome of this graph is that sample only contains 3 – 32 μm particle has the highest strength value. This indicates that the distribution should be uniform and narrow.
Similar results are obtained for samples with increased amounts of the 5-20 μm fraction. It is clear once again narrower distributions give higher strength.
 According to the above graphs following conclusions can be deduced:

- Especially, fineness has a great effect on 2 days strength. In late ages, strength is affected more by the amount of coarse particles rather than fines.

- When the amount of 3-32 μm fraction in the PC 42.5 R sample is increased by 20%, a 13% improvement in 28 days strength is obtained.

- Although decrease in the total surface area and blaine values, with the addition of the 5-20 μm fraction into PC 42.5 R, early strength increases compared with PC 42.5 R due to improved homogeneity of size distribution.
Particle Size Distribution in Cement - Conclusions

- The fine and coarse tails in the beginning and at the end of the particle size distribution curve have different effects on strength.

- If both ends are minimized and the distribution is made more uniform, high strength values can be obtained.

- Considering water demand and setting characteristics, higher strength products can be achieved with optimization for both ends.
Increasing the amount of water required to reach the standard consistency of the cement paste means that there is more space between the cement particles. This situation is an outcome of narrow grain size distribution.

Increase in water demand in fine cement particles may be related to surface area but actually main reason is that limestone dehydration is lower and therefore the amount of dissolved and available SO₃ is low.

Disadvantage of increased water demand in cement can be eliminated by adding at a certain amount of dehydrated limestone to the cement.