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BORAL RESOURCES

Proportioning FLY ASH CONCRETE MIXES

The American Concrete Institute's ACI 211 standard sets forth a series of steps through which values are selected for the following:

- cementitious materials content
- air content
- water content
- coarse aggregate size and content

Proportioning fly ash concrete mixes is slightly more complicated than proportioning plain cement concrete mixes. The same solid volume proportioning techniques described in ACI 211 are employed, as are used with conventional concrete mixes.

These ingredients are converted into solid volumes. The difference between the sum of the total volumes and 27 cubic feet will determine the necessary volume of sand. Sand weight is then calculated to complete the trial mix proportions. The accuracy of this mix must be checked by physically preparing a sample of the proportioned ingredients and testing the mixture for yield.

While fly ash is a cementitious material that greatly benefits concrete, the proportioning of concrete containing fly ash requires adjustments because of the physical properties of the ash. Viewed microscopically, fly ash particles are spherical in shape. Because of this and other physical attributes of fly ash, one can expect the following:

- The ball bearing shape significantly aids the workability of concrete. This allows for lower sand content than conventional mixes while handling remains similar. As the proportion of sand is reduced, all performance aspects of the concrete are enhanced.
- Again, because of fly ash's spherical particle shape, less water is required to achieve the same level of slump as in the control concrete. The addition of fly ash in conventional mixtures typically reduces the water needed by 5% to 10% over plain concrete (depending upon the quantity of fly ash), and this reduction can be further increased where high levels of fly ash are used.
- The specific gravity of fly ash is much lower than that of portland cement; therefore, 100 lbs. of fly ash has a much greater solid volume than the same weight of portland cement. Past practice has dictated a cement reduction when water-reducing admixtures are used; however, in fly ash concrete, the cementitious materials

For more information or answers to questions about the use of fly ash in specific applications, contact your nearest Boral Resources Technical Sales Representative or call 1-770-684-0102

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(cement and fly ash) volume is higher, not lower. This higher quantity of cementitious materials greatly assists in the finishing process.

- Air entrainment is not affected adversely with high quality fly ash supplied by Boral. Boral has developed a proprietary foam index test that allows us to better control fly ash quality with respect to air entrainment in concrete. A slight increase in admixture dosage can be expected because of the increased solid volume of cementitious fines, but performance should be uniform. This increase in dosage typically amounts to less than 0.25 ounces per 100# of cementitious materials.
- The use of water-reducing admixtures is encouraged with fly ash concrete mixtures; however, certain factors must be considered:
  1. During warm temperatures, a normal dosage of water-reducing admixture is calculated on the combined weight of cement plus fly ash.
  2. During periods of low temperatures, it is advisable to use a conservative dosage of normal set time water-reducing admixture calculating the dosage based only on the weight of cement. Under cool temperatures, normal setting water-reducing admixtures may cause retarded concrete set. Reducing the dosage utilized during cool conditions can help maintain proper concrete set times.

Determination of Fly Ash Content

Several methods exist for the selection of the fly ash content in a mixture.

Specification. The specifications for a particular project may define a required fly ash content. The percentage of fly ash required may range from as little as 10% to as high as 50% or 60%, depending upon the intention of the engineer. Failure to adhere to the specified level of fly ash may result in concrete of substandard properties and may not be suitable for the intended purpose.

Optimum Ash Curves. In this method, a control curve is first generated by testing mixes with cement contents which vary from a low of 300# to a high of 700# per cubic yard in increments of 100#. All mixes should be of identical lump and yield. Plot cement contents on the abscissa (X axis), plot comprehensive strength on the ordinate (Y axis). A separate curve will be generated for each age of test. A family of optimum ash curves will be generated for each age of test. A family of optimum ash curves is then derived in the following manner:

For each point on the control curve, a series of mixes should be tested with fly ash contents varying between 10% and 30% of total cementitious material (by weight) in increments of 10%. Plot these results on the same charts as the control mixture. These curves can then be utilized to choose the appropriate proportions of cementitious materials for any requirements.

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Water/Cementitious Materials Ratio Curves. In this method, the Abrams law of water to cement ratio is utilized. As this law is applicable to plain cement concrete, so is it applicable to fly ash concrete. The objective is to construct a family of curves which are plotted together, with each curve indicating a specific percentage of fly ash by weight of total cementitious materials (typically 0%, 10%, 20%, 30%, etc.). This method is particularly useful where specifications require a maximum water/cementitious materials ratio.*

Do not be surprised to find that for a fly ash mixture to be equivalent in strength to a plain cement mixture, the W/(C+FA) must be lower than the W/C. This is acceptable due to the fact that fly ash acts like a water reducer. Where cement is replaced by an equivalent weight of fly ash and the strengths are equal, they both have the same weight of cementitious materials but the fly ash mix will have a lower water demand.

Replacement Method. Another successful method of designing fly ash concrete is by replacement. This involves selecting a conventional mix which has demonstrated an adequate performance level. Replacement tests should be run on a series of mixes containing fly ash in amounts ranging from 10% to 30% or more. To obtain 28-day strengths equal to the straight cement mix, it may be necessary to replace cement at a ratio exceeding 1:1. This can be determined by experimenting with mixes designed with replacement ratios of 1:1, 1:1.1, 1:1.2, etc. As in the other methods, specification factors will influence the selection of the optimum replacement percentage and ratio.

For detailed explanations of the testing programs mentioned above, the following references are available:

1. Cannon, R. W., “Proportioning Fly Ash Concrete Mixes For Strength And Economy”, *Journal of The American Concrete Institute*; V. 65; No. 11; November 1968.
2. Lovewell, C. E. and Hyland, Edward J., “Proportioning Concrete Mixes - A Method of Proportioning Structural Concrete Mixtures With Fly Ash And Other Pozzolans”, American Concrete Institute Publication SP-46-8.
3. Lovewell, C. E. and Washa, G. W., “Proportioning Concrete Mixes Using Fly Ash”, *Journal of The American Concrete Institute*; V. 54; No. 12; June 1958.

***Note** - The American Concrete Institute now defines that water to cement ratio is equivalent to water to cementitious materials ratio. This means that fly ash is counted by weight the same as portland cement in this calculation. The importance of this to the concrete designer is the water reducing capability of fly ash. Where plain cement concrete may require 300# of water to provide the necessary degree of workability, fly ash concrete will use significantly less water, and may only require 90% of this, or 270# of water. If a max W/C of 0.5 is specified, the plain mix would need 600# of cement, while the fly ash mix would only need 540# of cementitious materials. The economic benefits are obvious.