High Early Strength Fly Ash Concrete for Precast/Prestressed Concrete Products*

by Tarun R. Naik and Bruce W. Ramme

Comments by Ergin Arioğlu and Orhan Manzak, and Authors

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The study by Professor Naik and Mr. Ramme certainly was a remarkable contribution to high early strength concrete containing Class C fly ash for precast/prestressed concrete operations. Thus, the authors are to be congratulated on an interesting paper with some important findings.

The experimental results of the authors provided in Tables 2, 3, 4 and 5 have been analyzed by making use of regression analysis. The main results which can be derived from this analysis are as follows:

- The replacement quantity of cement by Class C fly ash has an obvious effect upon the early strength of concrete. The significance of this effect is shown in Fig. A as a function of the replacement quantity, β, and the observed increase in compressive strength in comparison to the reference concrete (containing only portland cement) for the same curing age.
  As noticed, regardless of curing age, the highest increases in compressive strength for concrete produced at Plant No. 1 were reached in an amount of 25 percent fly ash replacement mixture (Fig. Aa). On the other hand, for Plant No. 2, the picture obtained was quite different. Namely, the highest increases in the strength were observed in 15 percent fly ash replacement level. Indeed, for an equivalent of 25 percent fly ash replacement mixture, regardless of age, there were significant decreases in compressive strength (Fig. Ab). This variation may be due to the fact that the Plant No. 2 concrete was "heated" during the winter months to obtain a concrete placing temperature of about 27°C.
- For the purpose of mix design for normal weight aggregate concrete containing Class C fly ash (high calcium fly ash), a nomograph (Fig. B)[1] was developed utilizing the test results provided by the authors. (Fig. B was based upon a compressive strength at 3 days, i.e., high early strength for precast/prestressed products.) The usage of the design nomograph under consideration is illustrated by means of the following numerical example.

The specified strength is 250 kg/cm^2 (25 MPa) at 3 days, and it is required that no more than one test result in 20 will fall below the specified strength. (The appropriate probability factor is 1.64.) The maximum size of aggregate is 20 mm ($^3/_4$ in.). The slump is about 135 mm ($5^1/_4$ in.) (Plant No. 1).

(a) The required strength is:

$\sigma = 25 + 1.64 \times 3.5 = 30.7 \sim 31$ MPa

in which 3.5 MPa is the standard deviation.

(b) From Fig. B, the estimated water-cement plus fly ash ratio α is about 0.365.

(c) From Fig. B, the mass of total binder (cement M_c plus fly ash M_f) can be found to be 400 kg/m^3.

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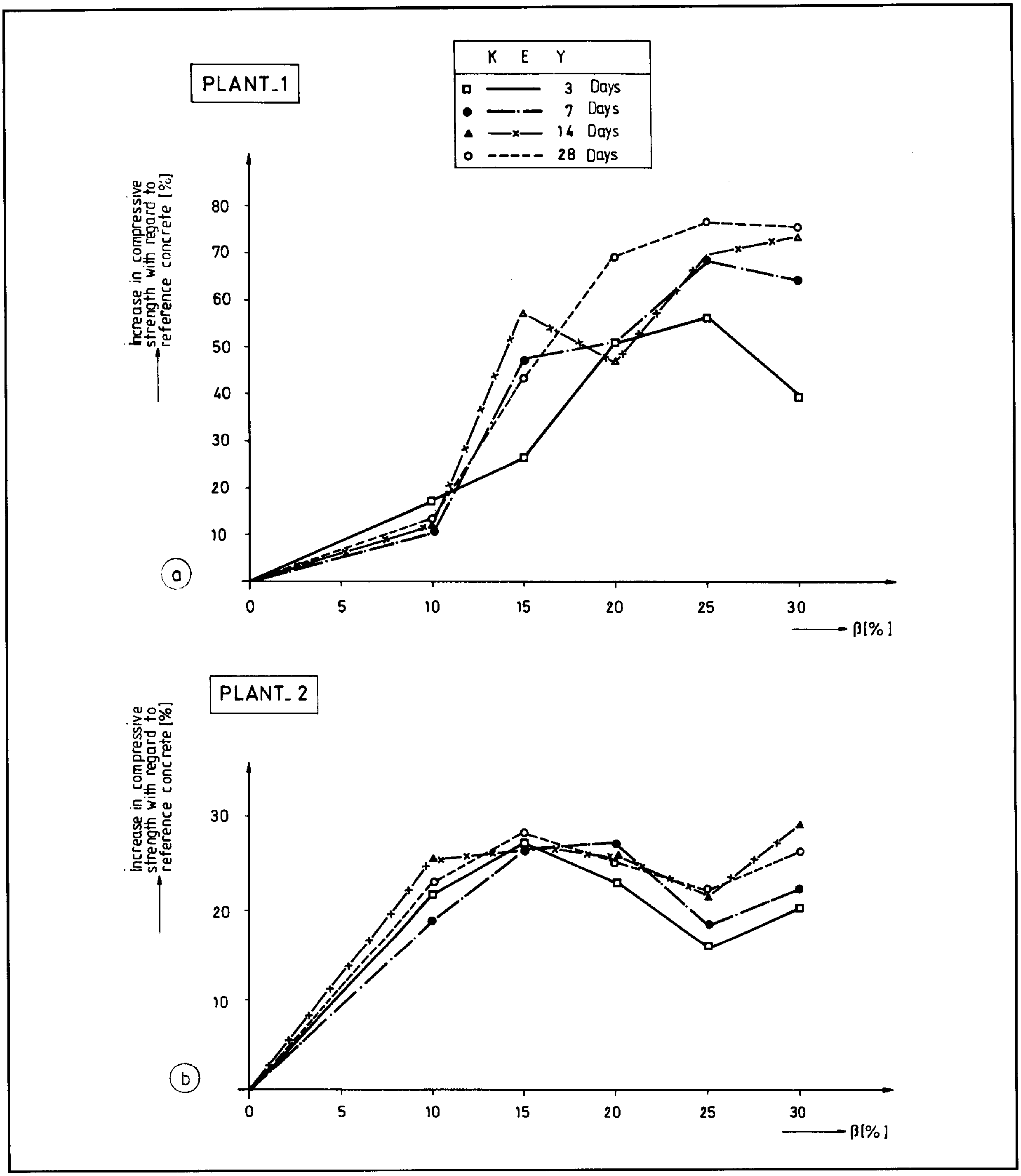

Fig. A. Relation between increase in compressive strength with regard to reference concrete containing only portland cement and fly ash (Class C) replacement level (by weight) β.

(d) The other quantities in kg per cubic meter of concrete can be computed as follows:

$$\alpha = \frac{M_w}{M_c + M_f} = 0.365$$

Mixing water:
$M_w = 0.365\ (M_c + M_f) = 0.365 \times 400 = 146\ kg/m^3$

By using the mass of mixing water ($M_w = 146\ kg/m^3$) from the nomograph, the amount of fly ash replacement β is about 20 percent.

Fly ash (Class C):
$M_f = \beta\ (M_c + M_f) = 0.20 \times 400 = 80\ kg/m^3$

Cement:
$M_c + M_f = 400\ kg/m^3$
$M_c = 400 - 80 = 320\ kg/m^3$

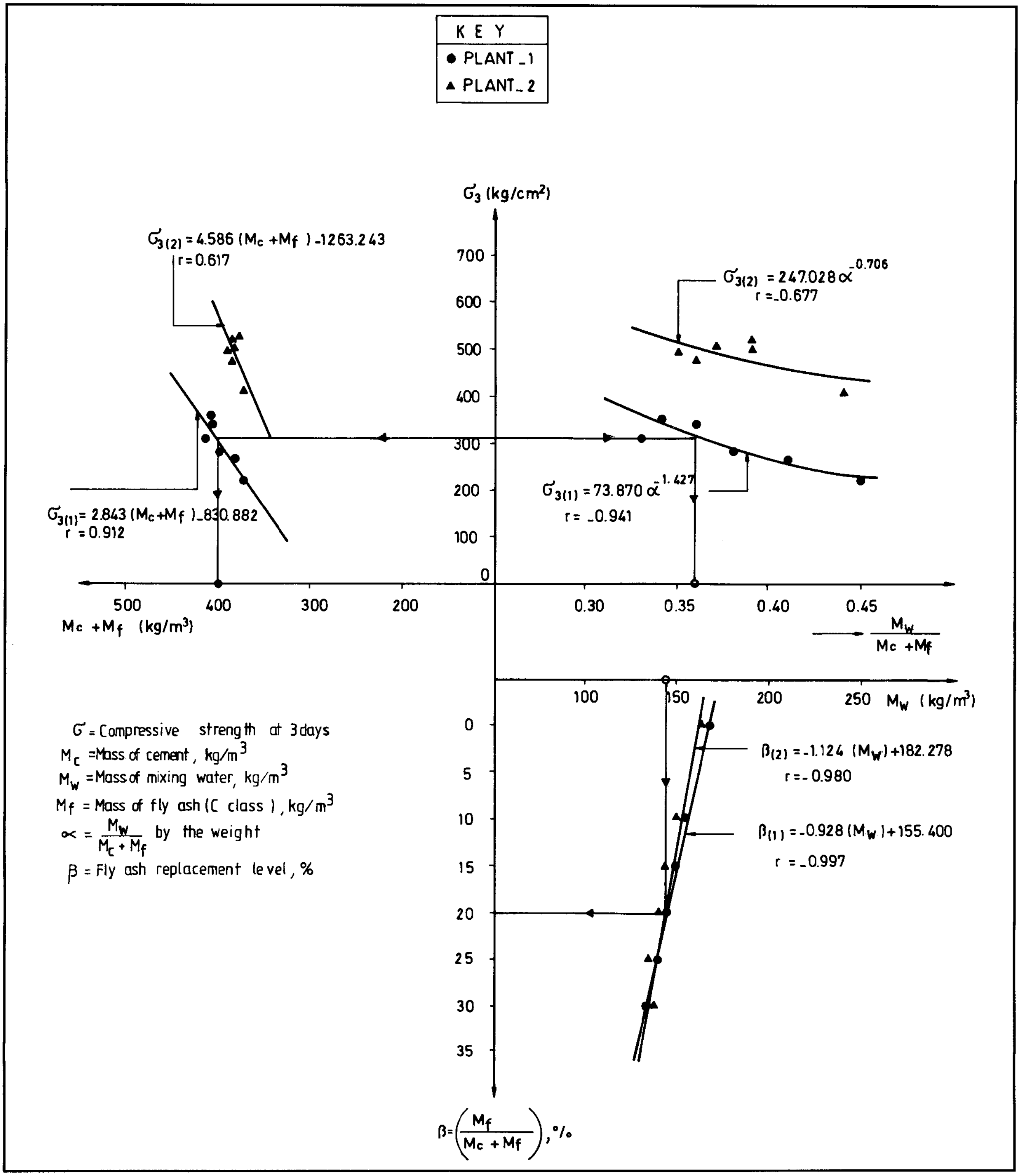

Fig. B. Nomograph for concrete mixtures containing Class C fly ash (high calcium content) utilizing test data of Naik-Ramme.

Employing the first estimate of density of concrete γ, the mass of total aggregate per unit volume of concrete can be calculated:

$$\gamma = M_c + M_f + M_w + \sum M_a \cong 2440 \text{ kg/m}^3$$

$$\sum M_a = 2440 - [320 + 80 + 146] = 1894 \text{ kg/m}^3$$

Needless to say, the mix proportions in the above expressions should be checked by producing trial mixtures, taking into account the required compressive strength and workability of concrete.

REFERENCE

1. "Fly Ash Utilization," Research Report, Yapi Merkezi, Camlica, Istanbul, Turkey, January 1992, 65 pp.

AUTHORS' CLOSURE by TARUN R. NAIK* and BRUCE W. RAMME†

The authors would like to express their sincere thanks to Professor Arioğlu and Mr. Manzak for their applied interest and continued development on this topic. The nomograph developed for helping to select mixture proportions based on 3-day compressive strength requirements of concrete is very practical and useful.

We agree that trial mixtures with specific materials from the site are very important in developing concrete mixtures. It is also important to obtain performance knowledge of one's specific source of fly ash and portland cement combinations, since there are many different varieties and qualities of both materials available that yield a wide range of results.

The fly ash used at both precast/prestressed plants in this study was a high quality ASTM C618, Class C fly ash. Each plant used a different brand of ASTM C150, Type I, portland cement. The authors believe that the difference between the two brands of cement used had a significant effect on the optimum replacement levels at each plant based on prior experience with these materials.

We also recognize that this specific study concentrated on mixture proportioning, workability and compressive strength results. It is also important to perform testing on other concrete properties that may be critical for specific applications.

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DISCUSSION NOTE

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