July 1984

CRI TECHNOLOGY DIGEST

CEMENT RESEARCH INSTITUTE OF INDIA

RAPID METHOD OF CONCRETE MIX DESIGN

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INTRODUCTION

That concrete is the most widely used man-made construction material is due to the ease with which its properties can be 'tailored' to meet different requirements of application, eg, adequate strength, workability, serviceability, durability, aesthetics, economy, etc. The proportions in a concrete mix can be determined to meet either one or more of the above-mentioned requirements. However, in majority of cases, adequate workability in fresh state and the 28-day compressive strength dictate the choice of mix proportions. These can be arrived at either by 'nominal mix' or 'design mix' basis. Between these two approaches, 'design mix' concrete is always preferable, as it ensures rational use of materials and leads to considerable savings in the consumption of cement. This Technology Digest presents a method of rapid adjustments in concrete mix design, evolved at the Cement Research Institute of India (CRI), to take into account the variability in the strength characteristics of cement.

This rapid method has been adopted at the Cement Research Institute of India with very encouraging results, both for OPC and blended cements. CRI will assist in its adoption in various construction projects in the country.

APPROACH TO CONCRETE MIX DESIGN

There are a number of methods of designing concrete mixes. Indian Standards Institution is also in the process of formulating its own guidelines. The basic approach in concrete mix design in all such methods is that the water-cement ratio is chosen for the required 28-day compressive strength of concrete from generalised relationship between strength and water-cement ratio of concrete (*See* Fig 1) and the water content in the mix is adopted for the required workability and the type of aggregates available. From these two, the quantities of cement and water in the mix are known; the balance is the quantity of aggregates, the coarse and fine fractions of which are selected in suitable proportions.

In view of considerable variability in the strength characteristics of cements that one may encounter, it is questionable whether a single

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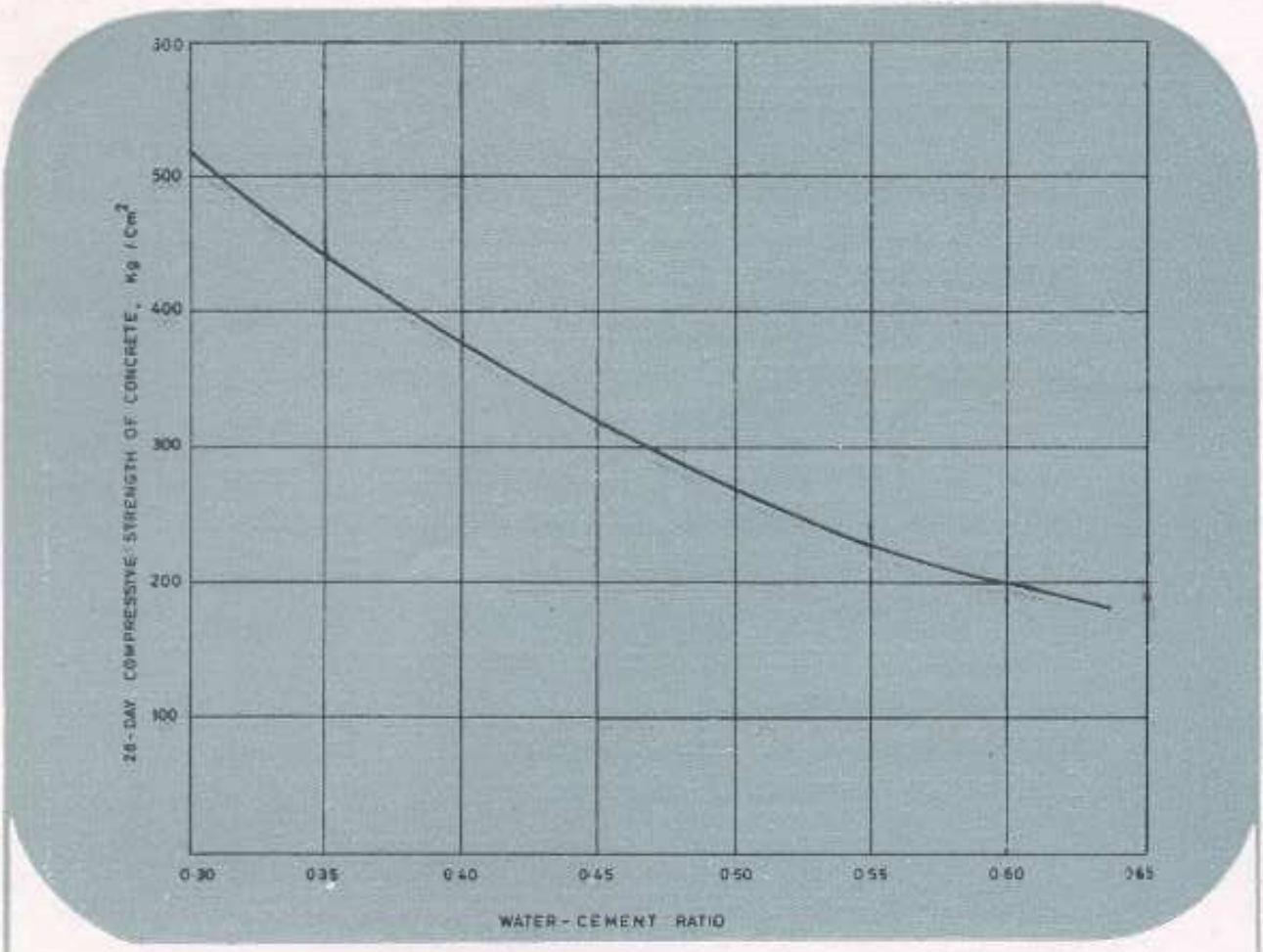

Fig 1 Generalised relation between water-cement ratio and compressive strength of concrete

strength *vs* w/c ratio curve of the nature of Fig 1 will always lead to the correct mix proportions in the first instance and in fact, a number of trials are necessary. This problem has been studied in great details at the Cement Research Institute of India. As a result, a series of strength *vs* w/c ratio curves have been developed, each applicable for cements having different strengths at 7 or 28 days, when tested as per IS: 4031-1968. Between the two ages, the one specifying cement strength at 28 days is preferable, as the 28-day concrete strength is better correlated with the 28-day strength of cement rather than the 7 days', especially in case of blended cements like PPC or portland slag cements. Such a relationship is shown in Fig 2. Once the 28-day strength of cement is known, the required w/c ratio is picked up from the appropriate curve in Fig 2 and mix proportioning becomes much more direct. The adjustments necessitated due to variations in aggregate characteristics can be accomplished by tests on workability of fresh concrete, immediately after mixing the trial batch.

RAPID METHOD

This approach will need a minimum of 28 days to test the strength of cement and another 28-days for the trial mix of concrete, ie, a total of 56 days. This brings out a major difficulty in adoption of design mix concrete in our country. In view of shortage of cement and interrupted supplies, once cement is received at the construction sites, there is a tendency to straightway use it without waiting for trial mixes. Unless one is in a position to procure adequate quantities of cement and aggregates well in advance, pre-test and store them at the site, it will be difficult to expect the site-engineer to wait for the completion of the trial mixes, before using cement in constructions.

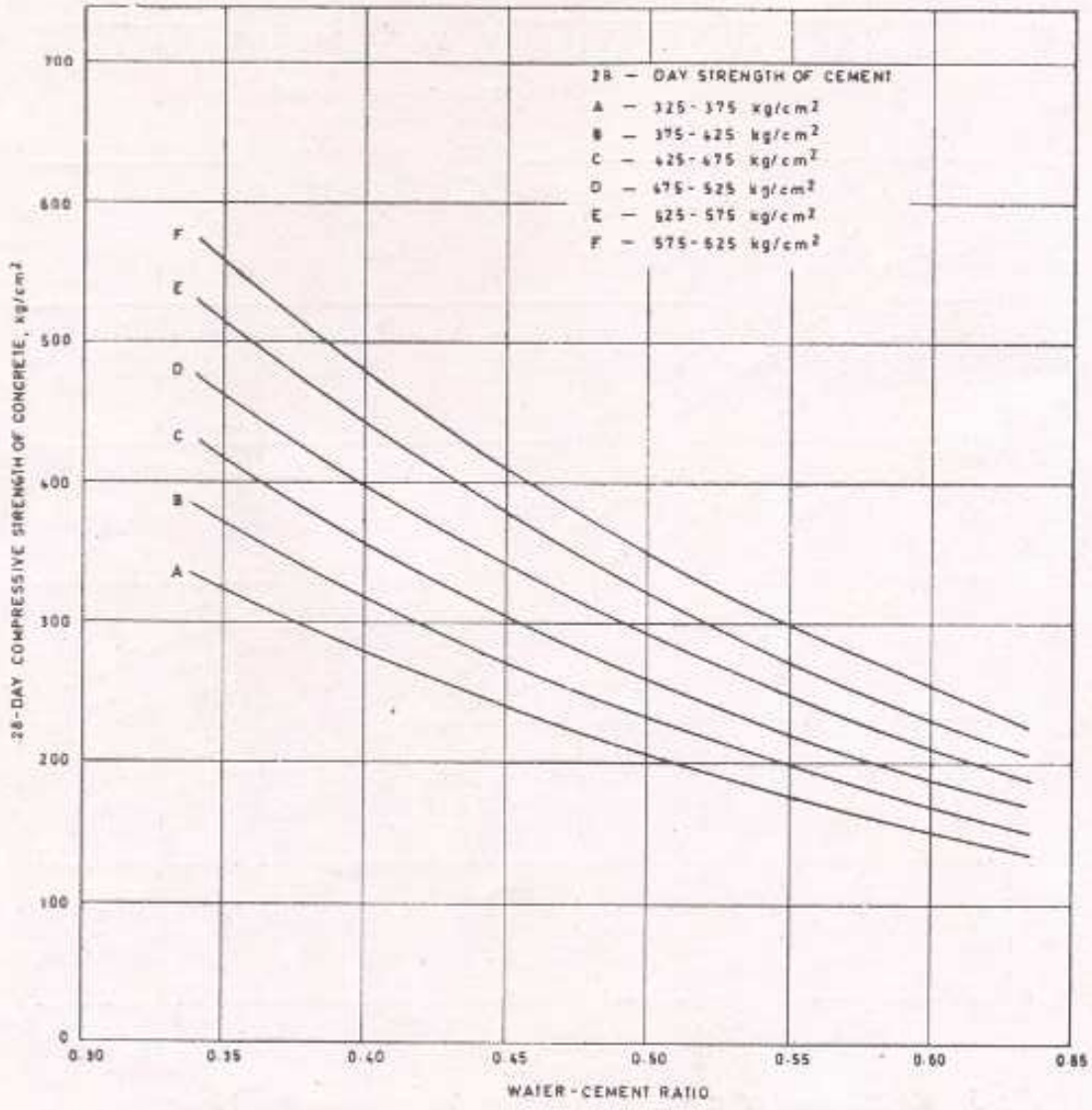

Fig 2 Relation between w/c and concrete strength for different cement strengths

Variability of materials, on the other hand, will not enable one mix design worked out earlier with one set of materials to be applicable in all the subsequent cases. In other words, another prime requirement for adoption of design mix concrete is to cut down the time required for trial mixes.

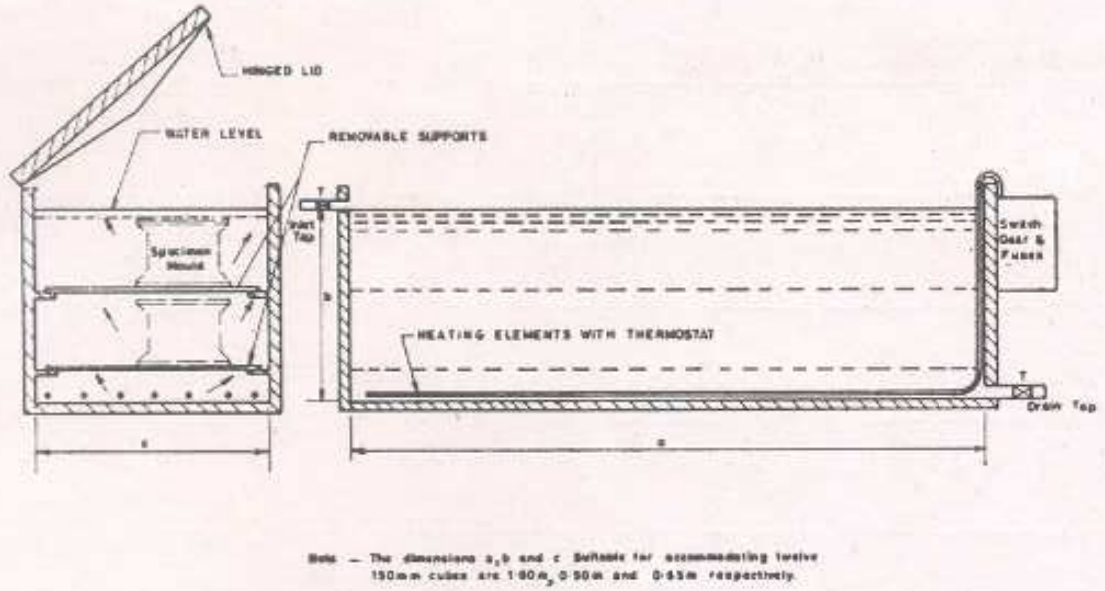

Fig 3 Details of accelerated curing tank as per IS:9013-1978

This was the second aspect of the study by CRI, where use of accelerated curing methods of testing compressive strength of concrete have brought down the time required for mix proportioning to 3 days only. Such methods of accelerated curing of concrete for strength tests are now standardised and covered in IS: 9013-1978. Fig 3 shows the details of accelerated curing tank needed for such tests, as per IS: 9013-1978. In so far as concrete is concerned, there exists a statistically significant correlation between its 28-day strength and accelerated strength, so much so that the trial of mixes can be related to target 'accelerated strength' rather than the target 28-day strength, with the help of correlation between the two. A typical correlation is shown in Fig 4, which is based on cements from all plants in the country and different grades of concrete, using boiling water method of accelerated curing. The correlation is found to be not affected by the type or characteristics of cements, presumably because they affect both the accelerated and 28-day strength of concrete in a proportionate manner, so that the influence is nullified, when their ratios are compared. Moreover, for individual applications, such correlations can be easily established for the type of materials and mix proportions in hand.

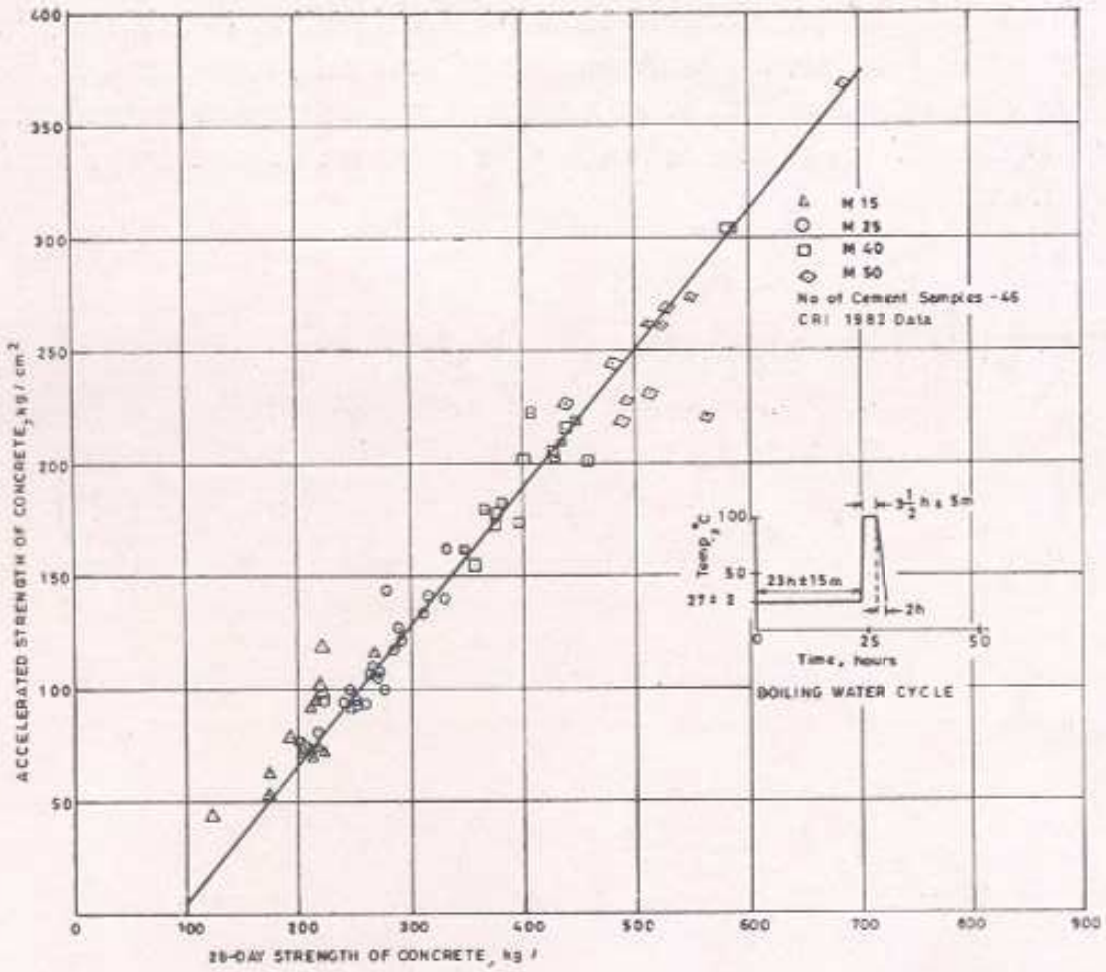

Fig 4 Relation between accelerated and 28-day strengths of concrete

In so far as the compressive strength of cements is concerned, accelerated tests on standard cement mortars (as per IS: 4031-1968) have not given equally reliable results. This problem has been overcome by testing cements also in a reference concrete mix and determining its accelerated strength. The reference concrete mix has w/c = 0·35 and workability = 0·80 (compacting factor). The nominal maximum size of natural crushed aggregate should be 10 mm and fine aggregate conforming to zone II of Table 4 of IS: 383-1970. Typical composition of such a reference concrete mix, per m^3 of concrete is:

Cement	— 570 kg	
Water	— 200 kg	
Fine aggregate	— 460 kg	on saturated-surface dry basis
Coarse aggregate	— 1178 kg	

Cube specimen of 150 mm size of such reference concrete mix are made with the cement at hand. From the strength (boiling water method), the 28-day compressive strength of concrete is obtained and using correlations between cement and concrete strengths of such mix proportions, established by exhaustive tests at CRI, the 28-day cement strength can be estimated. However, for use in the field, the relationships given in Fig 2 are re-cast in terms of the accelerated strengths of the reference concrete mix, which are shown in Fig 5.

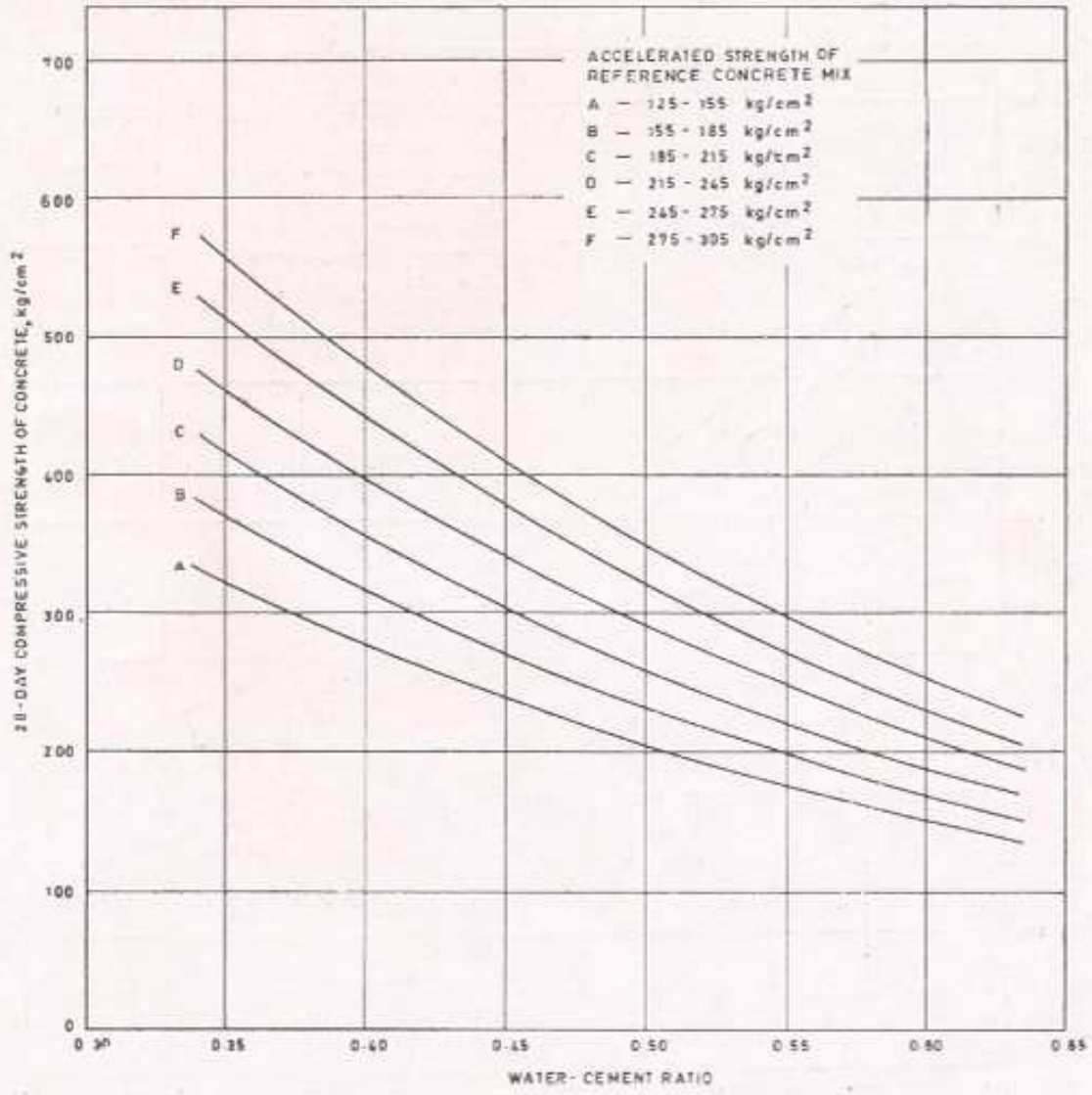

Fig 5 Relation between water-cement ratio and compressive strength of concrete for different cement strengths—determined on reference mixes (accelerated test-boiling water method)

PROCEDURE OF MIX DESIGN

a) Determine the accelerated strength (boiling water method) of 150 mm cube specimens of a reference concrete mix, using the cement at hand, as per IS: 9013-1978.

b) Corresponding to the accelerated strength in step (a) determine the water-cement ratio for the required target strength of concrete mix from Fig 5.

Example: Suppose the target 28-day strength of concrete mix to be designed is 300 kg/cm^2, and accelerated strength of reference concrete mix is 180 kg/cm^2. Then from Fig 5 (Curve B) the required water-cement ratio is 0·423.

c) Work out the remaining mix proportions as per the IS 'Recommended Guidelines for Concrete Mix Design' or any other accepted method of mix design and check the workability of fresh concrete against the designed value.

d) Determine the accelerated compressive strength of the trial mix.

e) Estimate the 28-day compressive strength from the accelerated strength in step (d), using correlations of the type of Fig 4 and check against the target strength.

Prepared by : Dr A K Mullick
Edited by : Shri S S Kalra

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