CHAPTER 4

DESIGN OF NORMAL CONCRETE MIXES

4.1 Introduction

The British DoE method is a general method developed by the Department of Environment that can be applied to produce designed concrete, using cements and aggregates which conform to the relevant British standards. The mixes are specified by the mass of the different materials contained in a cubic meter of fully compacted fresh concrete.

4.2 Procedure for Concrete Design

This method/is suitable for the design of normal concrete having 28-day compressive strength as high as 75 MPa for non-air-entrained concretes. The method is also suitable for the design of concretes containing pulverized-fuel ash (fly ash) and GGBFS. The concrete design is carried out in the following five steps described in the flow-chart given in Fig. 4.1.

1. Selection of Free Water-Cement Ratio

(a) The target mean strength is obtained by adding a margin to the characteristic strength, f_{cu}. The margin is either specified or calculated for a given proportion of defectives and statistical standard deviation. The Egyptian Code of Practice specifies the value of the margin to be a constant value of 120 kg/cm^2. Therefore the target mean strength f_{tms} is calculated from Equation 4.1 as follows:

$$f_{tms} = f_{cu} + 120 \qquad kg/cm^2 \quad (4.1)$$

(b) The maximum free water-cement ratio is specified which will provide the target mean strength for concrete made from the given types of coarse aggregate and cement. The procedure is as follows:

For the given type of cement and aggregate, the compressive strength at the specified age corresponding to the reference water-cement ratio of 0.50 is obtained from Table 4.1. For example, when normal Portland cement and uncrushed aggregate are used, the compressive strength is 43 MPa at 28 days. With this pair of data (43 MPa and water-cement ratio:0.50) as a controlling or reference point, a strength versus water-cement ratio curve is located in Fig.4.2 In this particular case, it is the fourth (dotted) curve from the top of Fig.4.2 passing the controlling point. Using this curve, the water—cement ratio is determined corresponding to the computed target mean strength. In case an existing curve is not available which passes through the controlling point, the curve is interpolated between two existing curves in the figure.

(c) The water-cement ratio computed in the step l(b) is compared with the maximum water-cement ratio specified for the durability, and the lower of the two values is adopted.

2. Determination of Free water content The water, which is available to react with the cement, is termed the free water content of the concrete and influences the strength, durability and consistency of the concrete. It is the sum of: (a) the added water (b) the surface water of the aggregates and (c) the water content of admixtures, (d) the water absorbed by the aggregate during the period between the mixing and the setting of the concrete. The free-

water content is selected from Table 4.2, which will provide water control for the target consistence (specified in terms of slump or Vee-Bee time) for the concrete made with the given fine and coarse aggregate types and nominal size of coarse aggregate.

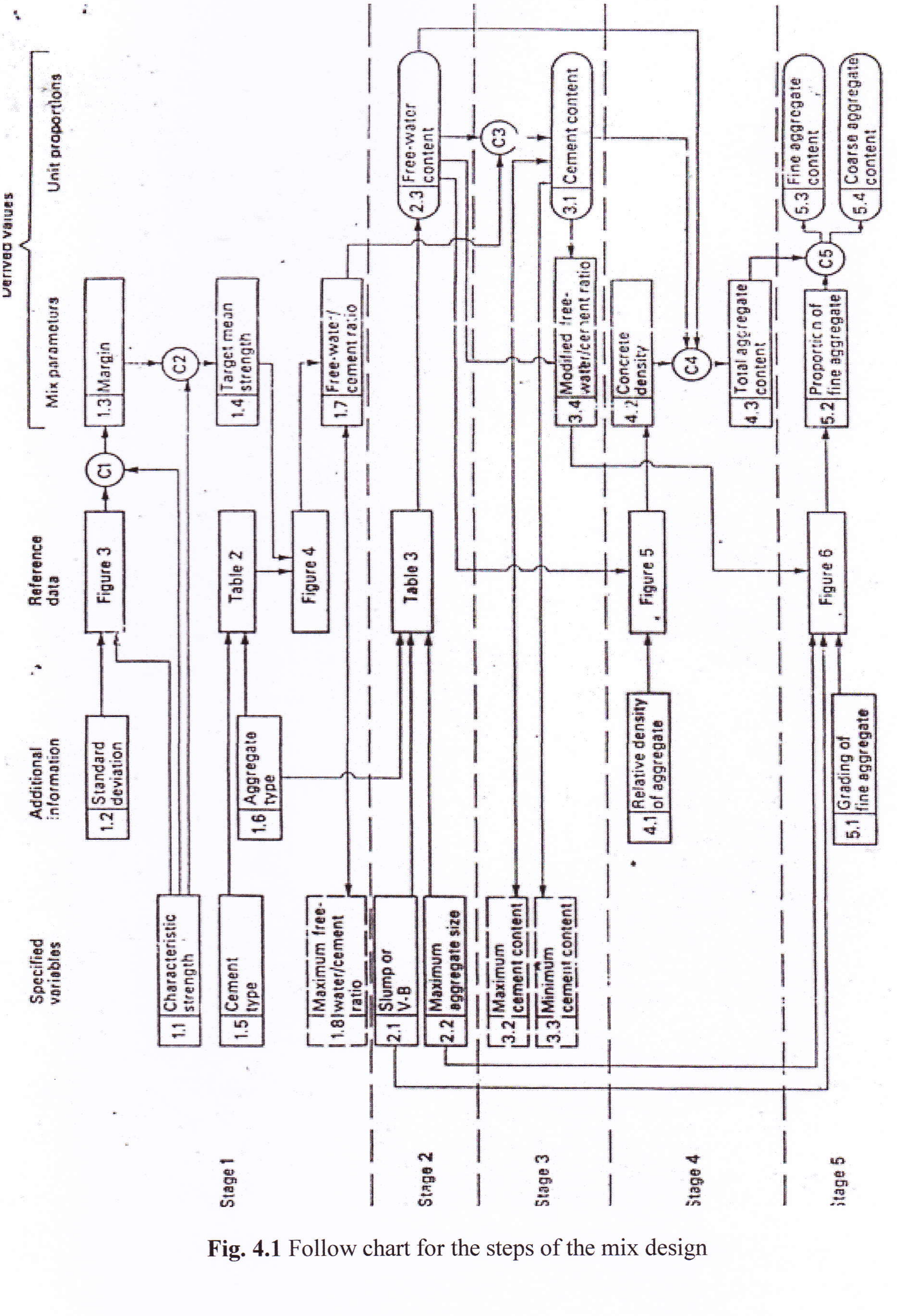

Fig. 4.1 Follow chart for the steps of the mix design

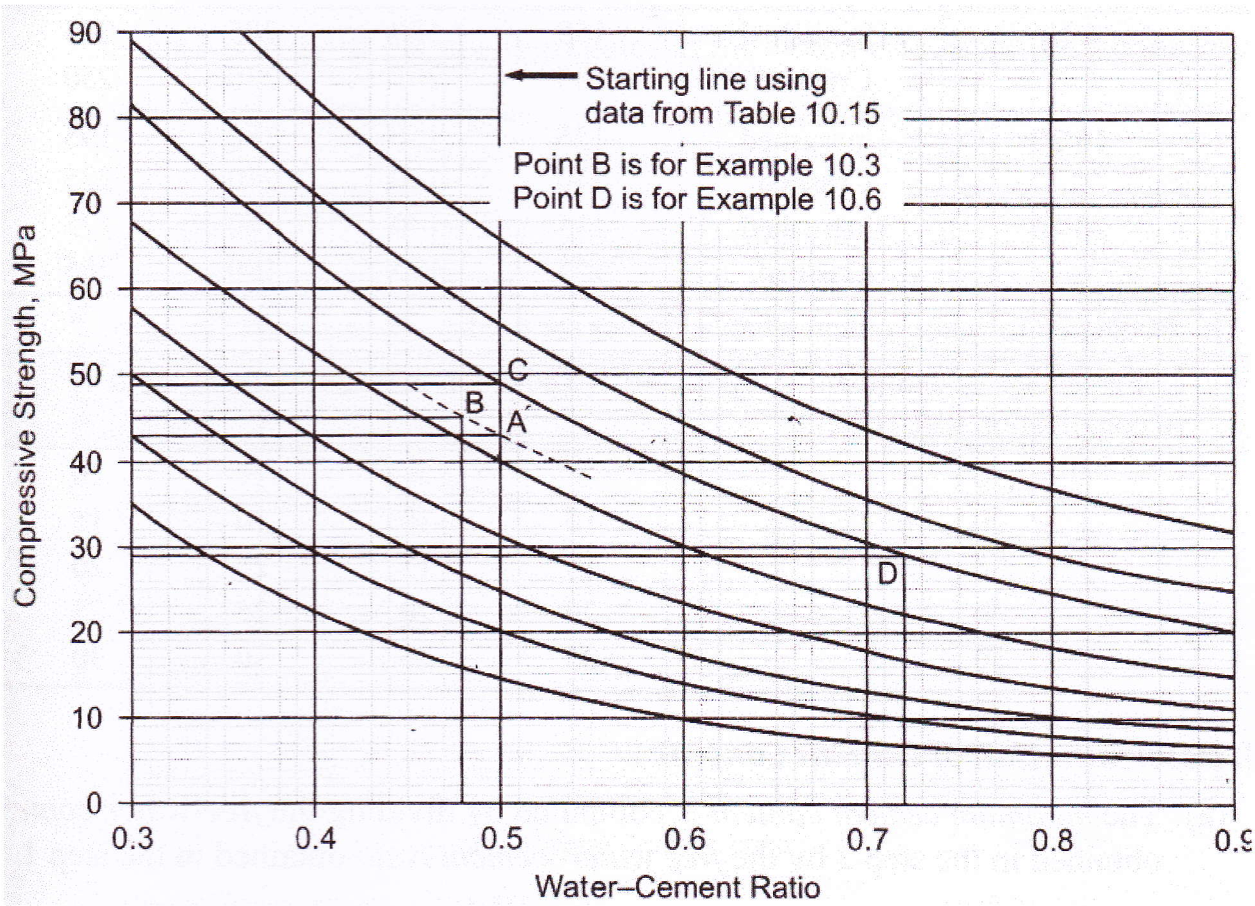

Fig. 4.2 Relation between compressive strength and water-cement ratio

Table 4.1 Approximate compressive strength (kg/cm2)of concrete mixes with a water/ cement ratio of 0.5

Type of cement	*Type of coarse aggregate*	*Compressive strength (MPa) Age (days)*			
		3	*7*	*28*	*91*
Ordinary (CEM 1) or sulphate	Uncrushed	22	30	43	49
resisting cement (SRPC)	Crushed	27	36	49	56
Rapid-hardening	Uncrushed	29	37	48	54
Portland cement	Crushed	34	43	55	61

3. Determination of Cement Content

(a) The minimum cement content is computed by dividing the free-water content obtained in the step 2 by the free water-cement ratio obtained in the step 1.

Table 4.2 Approximate free-water contents (kg/m3) required to various levels of workability

Slump(mm)		0 – 10	10 – 30	30 – 60	60 – 180
V.B (sec)		>12	6 – 12	3 – 6	0 - 3
Maximum size of coarse aggregate (mm)	Type of aggregate				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

$$\text{Cement content } (kg/m^3) = \frac{\text{water content}}{\text{Water-cement ratio}} \quad (4.2)$$

(b) The computed cement content required for strength is compared with the maximum cement content which is permitted. If the calculated cement content is higher than the specified maximum, then the target strength and target consistency cannot be achieved simultaneously with selected materials. In such a situation, the process is repeated by changing the type of cement, the type and size of the aggregate.

(c) The computed cement content required for target strength is compared with the minimum cement content which is specified for durability and the greater of the two is adopted in the concrete.

(d) Divide the free-water content by the cement content adopted in the concrete to obtain a modified free water-cement ratio.

Thus, the cement content is the minimum given by a free water-cement ratio that is low enough to provide the target strength and durability.

4. Computation of Total Absolute Volume of Aggregates

(a) The total aggregate content (kg/m^3) can be computed from the wet density of concrete obtained from Fig. 4.3. The wet density of concrete depends on the specific gravity of overall aggregates in the saturated surface dry condition.

(b) Alternatively, the volume of the total aggregate is calculated by subtracting the proportional volumes of the free water and cement from a unit volume of concrete using Eq. (4.3).

$$\text{Absolute volume of aggregates} = 1\text{- Cement content} - \text{Water content} \quad (4.3)$$

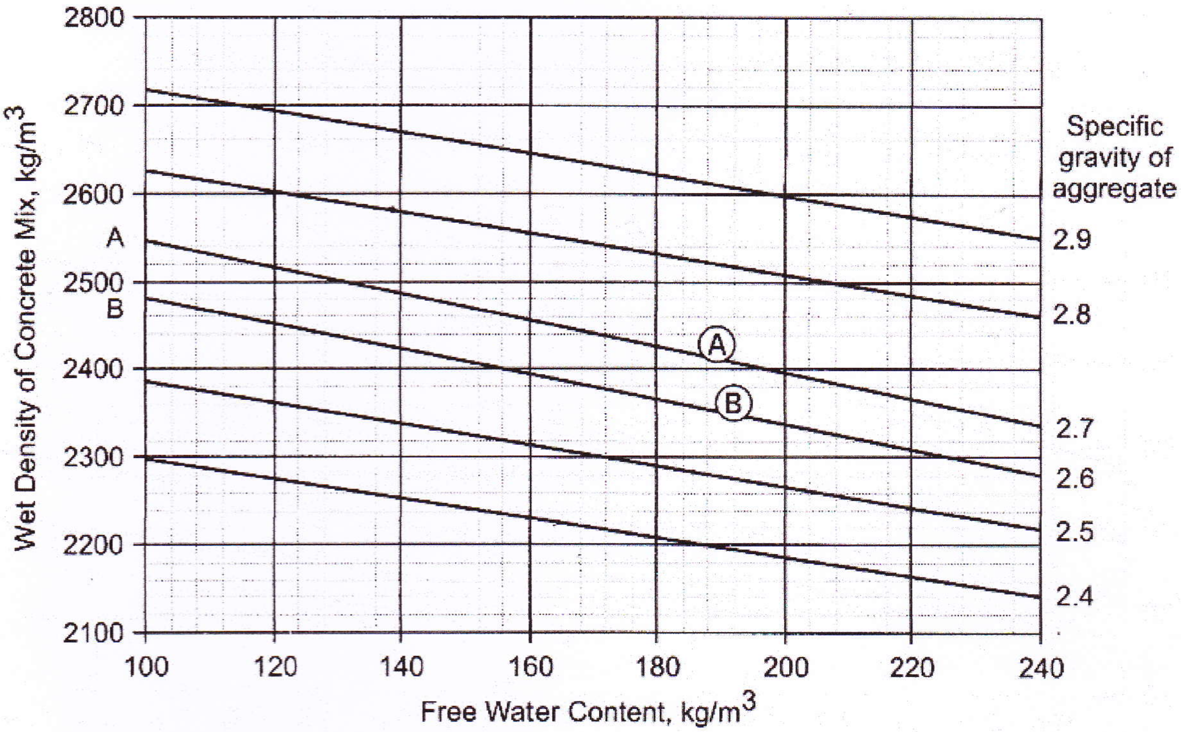

Fig. 4.3 Estimated wet density of fully compacted concrete

5. Determination of Fine and Coarse Aggregate Contents

(a) The percentage of fine aggregate is obtained from Fig.4.4 expressed as a percentage of total aggregate that will provide the target consistency of the fresh concrete to be made with the given grading of fine aggregate, the nominal size of coarse aggregate and the free water-cement ratio obtained in the step 2.

(a) The content of coarse aggregate is calculated from the total aggregate content obtained in the step 4 as follows:

Coarse aggregate content (per cent) = 100 - content of fine aggregate (percent) (4.4)

4.3 References

1- M. L. Gambhir, "Concrete Technology-Theory and Practice", Text book, The McGraw Hill Education Private Limited, New Delhi, Fourth Edition.

4.4 Problems

1- Make a complete mix design for the following mixes in the table.

f_{cu} (MPa)	Slump (mm)	Cement Type	Agg. Type	Max. Agg. Size (mm)	Zone of fine Agg.	Max. W/C	Max. Cement content (kg/m^3)	Min. Cement content kg/m^3)
25	60-180	OPC	Uncrushed	40	3	0.55	300	250
35	30-60	OPC	Uncrushed	20	2	0.5	350	300
45	10-30	OPC	Crushed	10	1	0.48	400	350

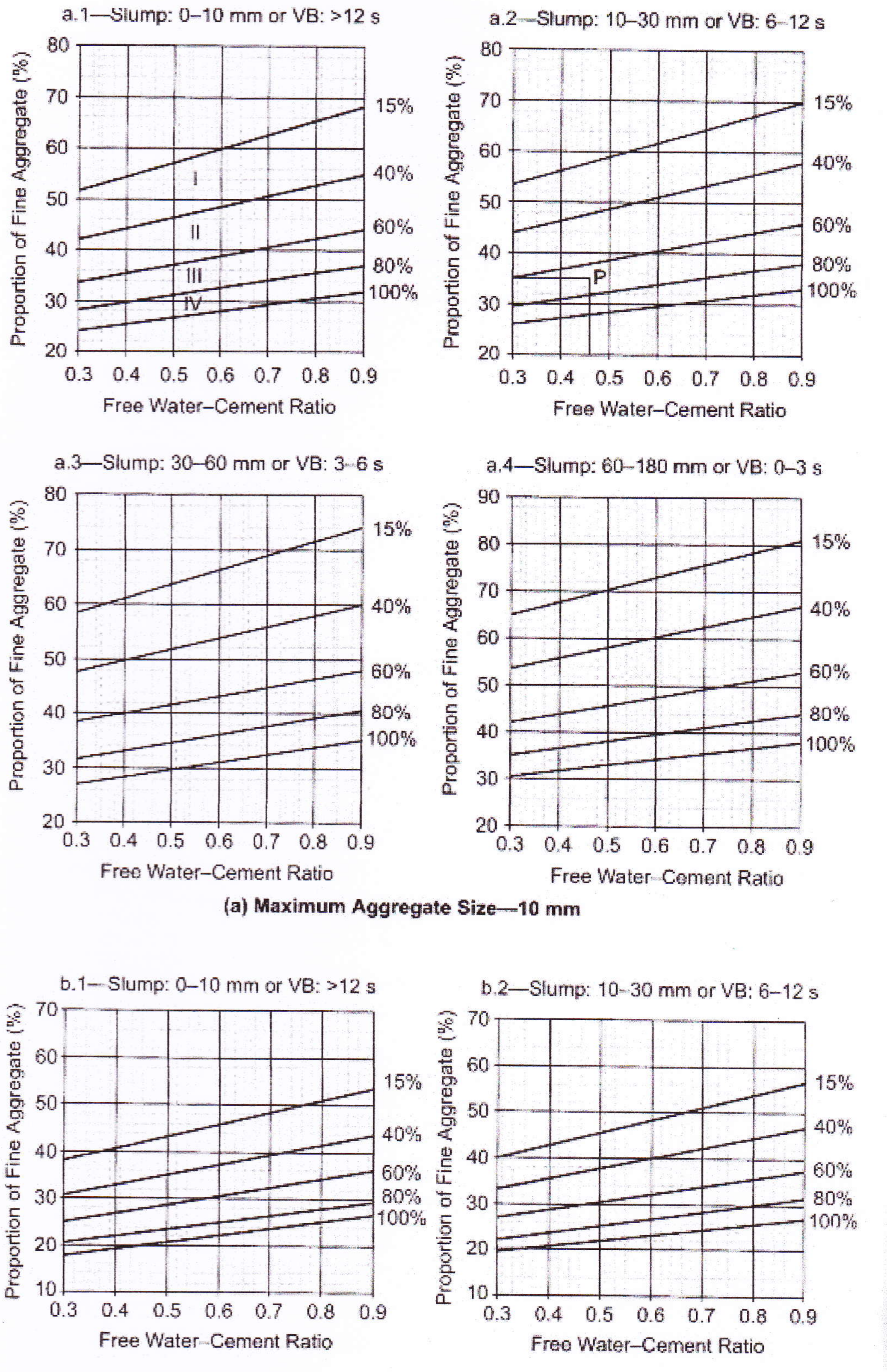

Fig. 4.4 Recommended proportions of fine aggregate for grading zones 1, 2, 3, 4 (I, II, II, IV)

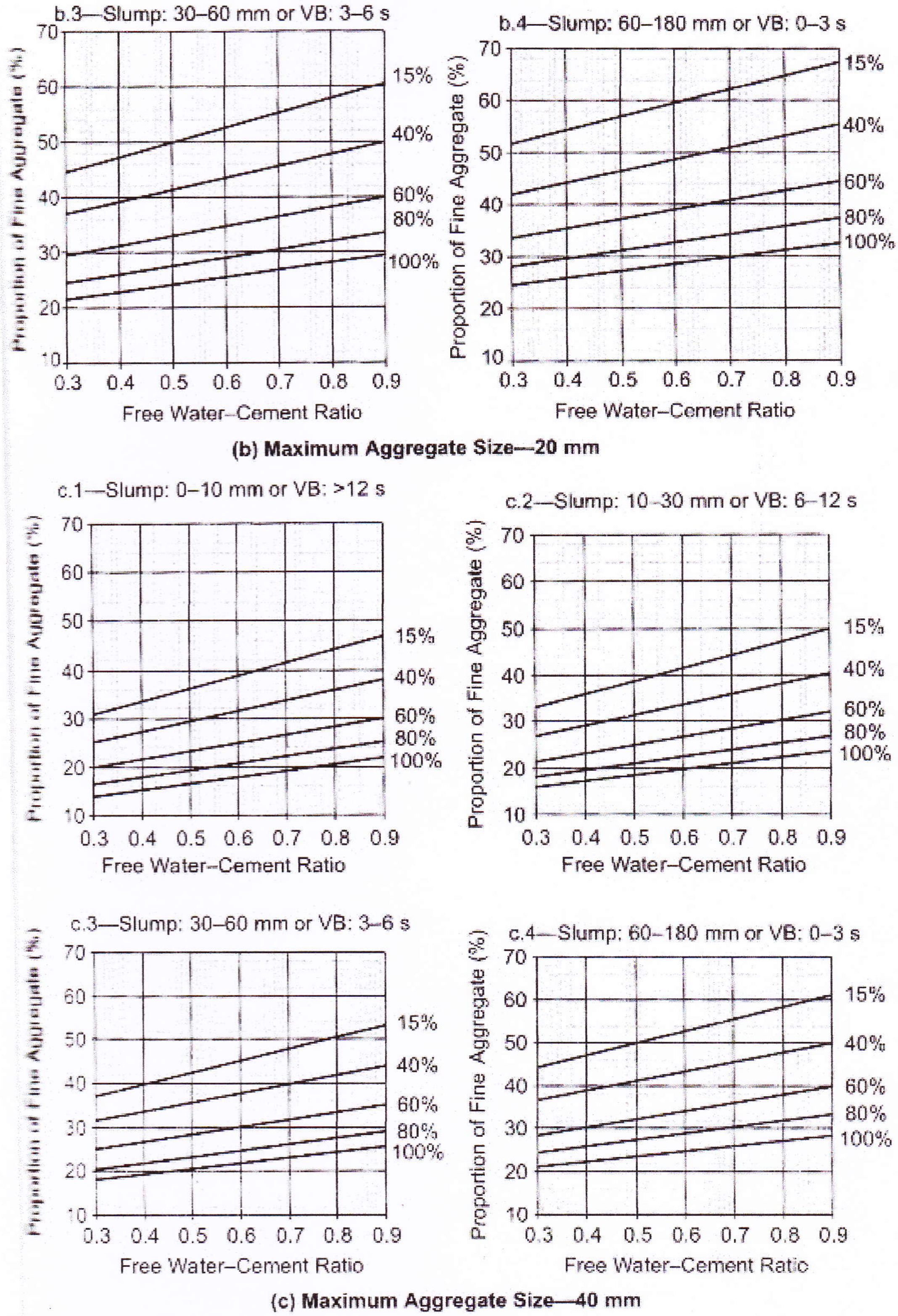
b.3—Slump: 30–60 mm or VB: 3–6 s
b.4—Slump: 60–180 mm or VB: 0–3 s
Proportion of Fine Aggregate (%)
15%
40%
60%
80%
100%
Free Water–Cement Ratio
(b) Maximum Aggregate Size—20 mm
c.1—Slump: 0–10 mm or VB: >12 s
c.2—Slump: 10–30 mm or VB: 6–12 s
c.3—Slump: 30–60 mm or VB: 3–6 s
c.4—Slump: 60–180 mm or VB: 0–3 s
(c) Maximum Aggregate Size—40 mm

Fig. 4.4 Cont.