Lecture 4:

Concrete Mix Design: British Method of Mix Design

Strength Determination for Mix Design

۞ In ideal condition, strength of concrete at any point of the structure should be higher than the minimum required strength.

۞ In UK, this minimum strength is called f_{min}, the specified characteristic strength or characteristic strength.

۞ In USA, the minimum strength is called f'_c, the specified design strength or specified compressive strength.

۩ **The first step in designing a concrete mix** is to decide on a strength higher than the minimum required strength. This higher strength is called

- Target mean strength, f_m in UK and
- Reqd. avg. strength or reqd. avg. comp. strength, f'_{cr} in USA

** i.e. the higher strength
= minimum strength + some additional strength

** In British method, this additional strength is called **margin**, M = k.s

- k= Himsworth constant, and
- s= standard deviation

∴ Target mean strength, $f_m = f_c + k.s$

Additional strength is the result of the statistical behaviour of hardened concrete which is the reflection of the quality control of concrete manufacturing.

Statistical Behaviour of Concrete:

Statistical Terms:

- Normal distribution curve, comp. strength of concrete
- Mean strength
- Variance
- Standard deviation
- Coefficient of variance

SALIENT FEATURES FOR BS METHOD

- Design of normal concrete mixes – 2nd edition 1997
  - British method (1987)
  - Current British method (1981)
  - Modified Road Note No.4 method

- Developed by Teychenne D C, Franklin R E and Entroy H C
- The principle of the method is to obtain mix proportion in an attempt to produce concrete having the required
  - Workability
  - Strength

- The method employs
  - Target mean strength
  - Slump or V-B value for workability
  - Free water to cement ratio (w/c)
  - SSD coarse and fine aggregate
  - Fine aggregate grading (BS 882)

- Results of the method are
  - Kg of coarse aggregate
  - Kg of fine aggregate
  - Kg of cement, and
  - Kg of water, for 1 cubic metre of fresh concrete

Mix Design Process:

The method of concrete mix design applied here is in accordance to the method published by the Department of Environment, United Kingdom (in year 1988).

Mix design procedure are described by the following steps:

step-1: Determining the Water/ Cement Ratio

Set the required characteristic strength at a specified age, f_c
Calculation of the margin, M.
M = k * s ….. [1]
Here;
k = A value appropriate to the defect percentage permitted below the characteristic strength.
[k = 1.64 for 5 % defect]

- Value of 'k' which depends on % defectives
  - ***For 10% defectives, k=1.28***
  - ***For 5% defectives, k=1.64***
  - ***For 2.5% defectives, k=1.96***
  - ***For 1% defectives, k=2.33***

s = The standard deviation (obtained from Figure 1).

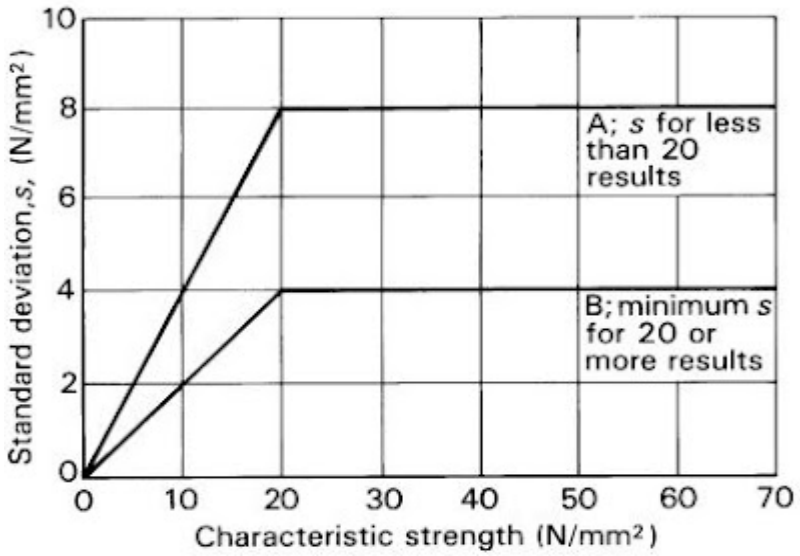


Figure 1: Relationship between standard deviation and characteristic strength.

step-2: Calculation of the target mean strength, f_m

$f_m = f_c + M$ ….. [2]

where;

f_m = Target mean strength

f_c = The specified characteristic strength

Cement strength class	Type of coarse aggregate	Compressive strengths (N/mm^2) Age (days) 3	7	28	91
42.5	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
52.5	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

Throughout this publication concrete strength is expressed in the units N/mm^2.
$1\ N/mm^2 = 1\ MN/m^2 = 1\ MPa$. (N = newton; Pa = pascal.)

Table. 1*: Approximate compressive strength (N/mm2) of concrete mixes made with a water/cement ratio of 0.5*

Table 1 is used to obtain the compressive strength, at the specified age that corresponds to a free water/cement ratio of 0.5.

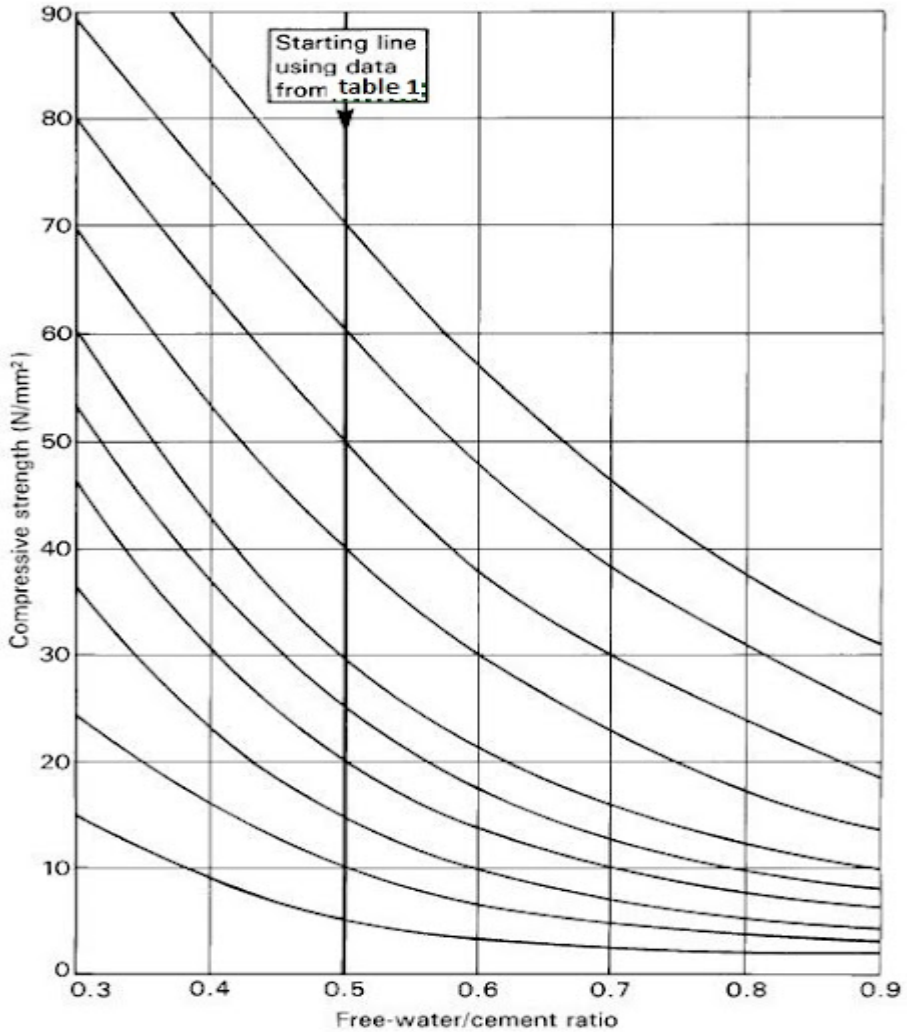


Figure. 2: *Relationship between compressive strength and water/ cement ratio.*

iv) a value is obtained from Table 1 for the strength of a mix made with a water/cement ratio of 0.5 according to the specified age, the strength class of the cement and the aggregate to be used. This strength value is then plotted on Figure 2 and a curve is drawn from this point and parallel to the printed curves until it intercepts a horizontal line passing through the ordinate representing the target mean strength.

Step-3: Determination of the Free-Water Content

the free-water content can be determined from Table 2 depending upon the type and maximum size of the aggregate to give a concrete of the specified slump or Vebe time.

Slump (mm)		0–10	10–30	30–60	60–180
Vebe time (s)		>12	6–12	3–6	0–3
Maximum size of 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

Table 2: *Approximate free-water contents (kg/m3) required to give various levels of workability.*

Note: When coarse and fine aggregates of different types are used, the free-water content is estimated by the following expression.

$$2/3 * W_f + 1/3 * W_c$$

Where,
W_f = free-water content appropriate to type of fine aggregate
W_c = free-water content appropriate to type of coarse aggregate.

Step-4: Determination of Cement Content

The cement content can be determined from equation 3...

Cement Content = Free Water Content / water-Cement Ratio ….. [3]

The resulting value should be checked against any maximum or minimum value that may be specified. If the calculated cement content from equation 3 is below a specified minimum, this minimum value must be adopted and a modified free-water/cement ratio calculated.

If the design method indicates a cement content that is higher than a specified maximum then it is probable that the specification cannot be met simultaneously on strength and workability requirements with the selected materials. Consideration should then be given to changing the type or strength class, or both, of cement, the type and maximum size of aggregate or the level of workability of the concrete, or to the use of a water-reducing admixture.

Step 5: Determining the Total Aggregate Content

Density of fully compacted concrete can be estimated from Figure 3. This value depends upon the free-water content and the relative density of the combined aggregate in the saturated surface-dry condition. If no information is available regarding the relative density of the aggregate, an approximation can be made by assuming a value of 2.6 for un-crushed aggregate and 2.7 for crushed aggregate.

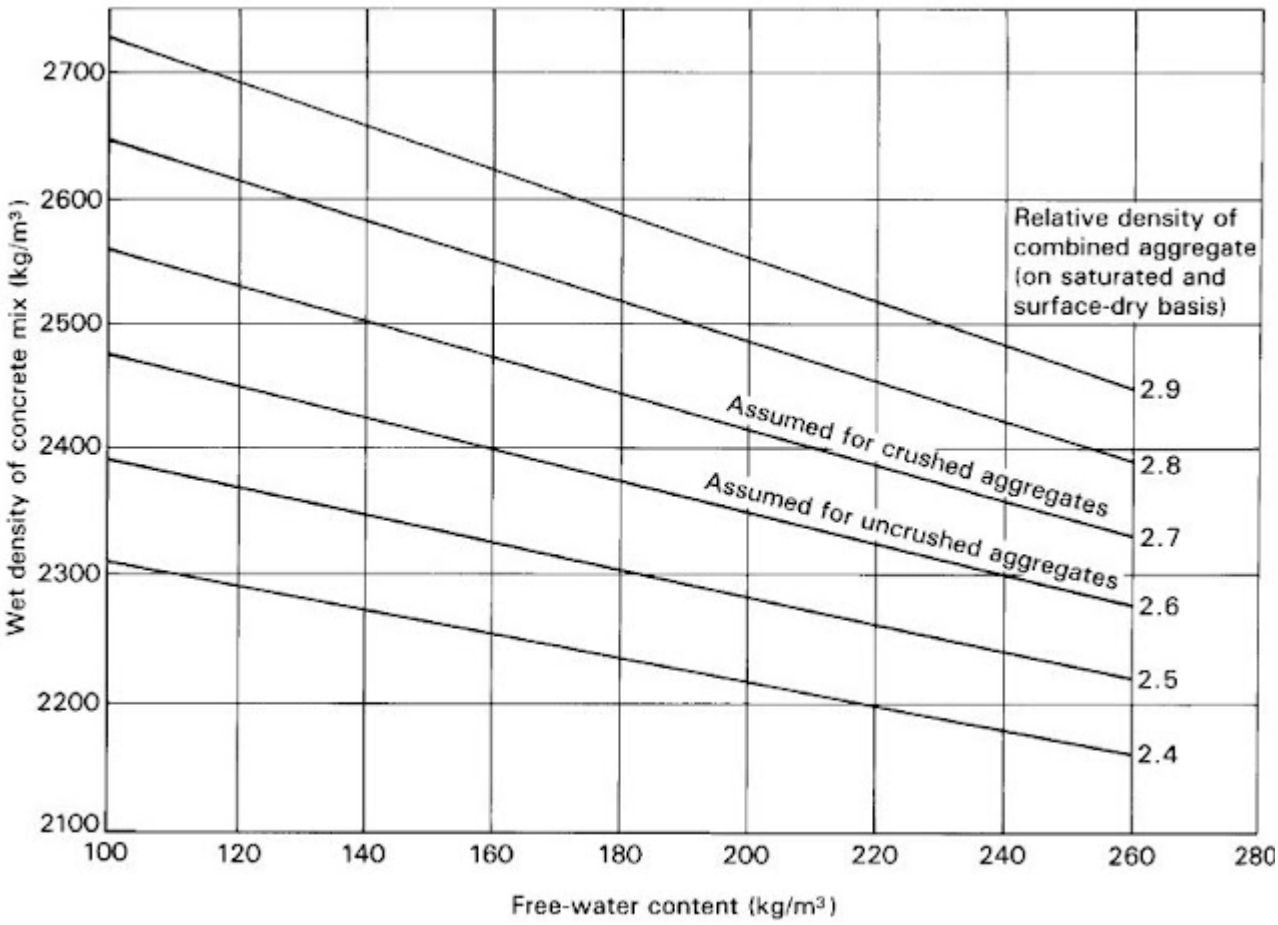


Figure 3: Estimated wet density of fully compacted concrete.

The total aggregate content can be calculated using equation 4:
Total Aggregate Content = D – C – W ….. [4]
where;
D = The wet density of concrete (in kg/m^3)
C = The cement content (in kg/m^3)
W = The free-water content (in kg/m^3)

Step 6: Determining of The Fine and Coarse Aggregate Contents

Current step demonstrate how to find out total fine aggregate (materials smaller than 5 mm, i.e. the sand or fine aggregate content). The figure 4 shows recommended values for the proportion of fine aggregate depending on the maximum size of aggregate, the workability level, the grading of the fine aggregate (defined by the percentage passing a 600 μm sieve) and the free-water/ cement ratio. The best proportion of fines to use in a given concrete mix design will depend on the shape of the particular aggregate, the grading and the usage of the concrete.

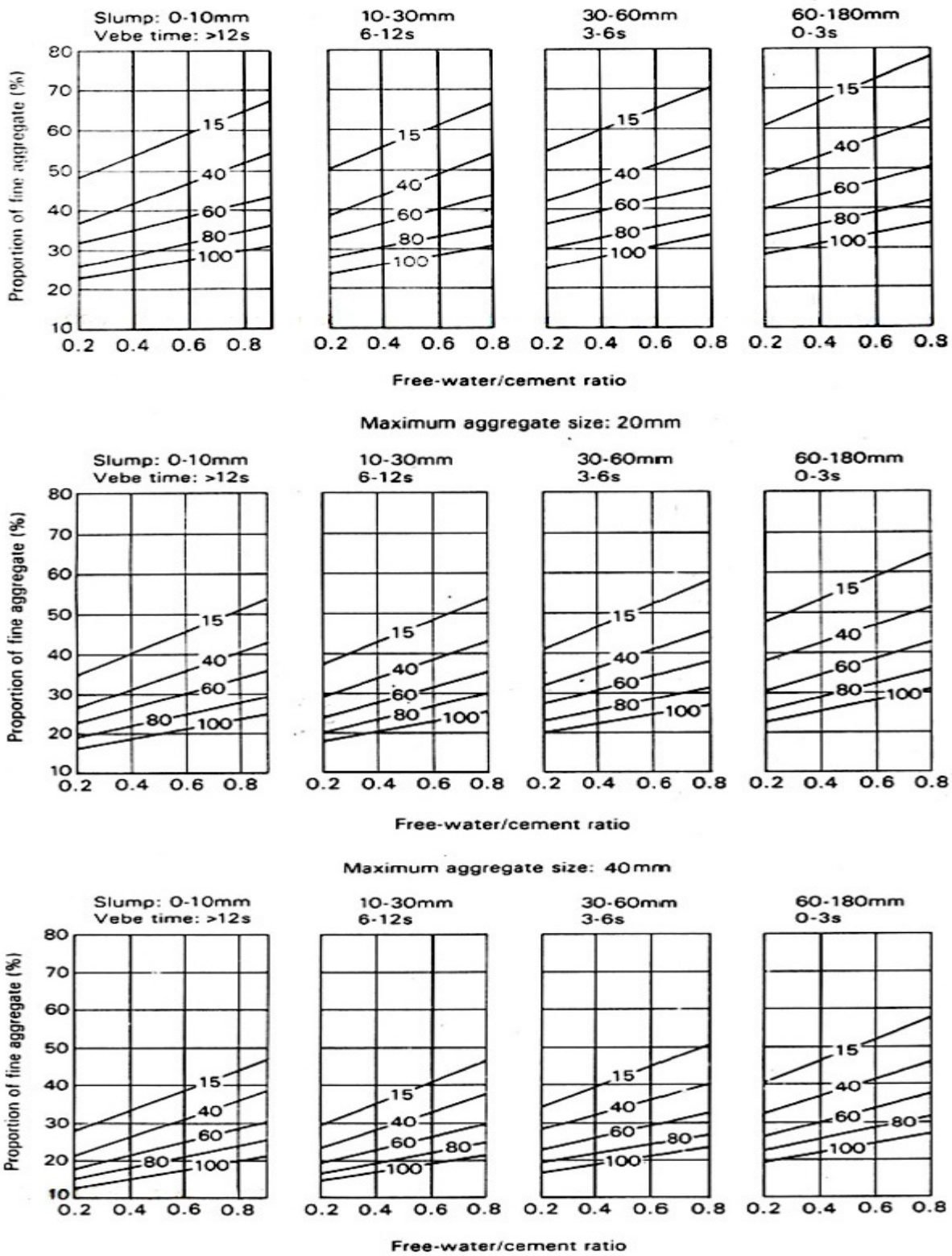


Figure 4: Recommended proportions of fine aggregate according to percentage passing a 600 μm sieve.

Determination of fine and coarse aggregate can be made using the proportion of fine aggregate obtained from **Figure 4** and the total aggregate content derived from Step-5

Fine Aggregate Content = Total Aggregate Content * Proportion of Fines ….. [5]

Coarse Aggregate Content = Total Aggregate Content – Fine Aggregate

Assignment No. 1: Solve the mix design problem as in supplied sheet

Questions:

What are the salient features of British method?

Mix Design Problem – British Method

A concrete is to be manufactured for casting of superstructure elements of a girder bridge. Design stipulations are as follows:

Characteristic strength = 43 MPa

More than 40 results of cube strengths are available

Moderate quality control is expected i.e 5% defectives is allowed

Aggregate type = crushed gravel

Maximum size of aggregate = 20 mm

Cement type: OPC [Ordinary Portland Cement]

Workability is measured by slump and is 10 – 30 mm

Maximum free water cement ratio is 0.50

Minimum cement content is 350 kg/m^3

Relative density of combined aggregate on SSD basis is 2.58

Fine aggregate grading comprises with grading zone 2 of BS 882 [nearly centerline]

a) Find the ingredients for 1m^3 of fresh concrete

b) If the absorption of fine and coarse aggregates are 2 and 1 percent respectively, find the quantities of the ingredients considering oven-dry aggregates for a trial mix for casting nine 150 mm cubes.

Figures and Tables are required for the solution.
