3.8 MIX DESIGN EXAMPLES

Example: 1

Grade M20

(a)Design stipulations

(i) Characteristic compressive strength required in the field at 28days - 20MPa

(ii) Maximum size of aggregate - 20 mm (angular)

(iii) Degree of workability - 0.90 compacting factor

(iv) Degree of quality control - Good

(v)Type of Exposure – Mild

(b)Test data for Materials

(i) Specific gravity of cement - 3.15

(ii) Compressive strength of cement at 7 days – Satisfies the requirement of IS: 269 – 1989

(iii)
1. Specific gravity of coarse aggregates -2.60
2. Specific gravity of fine aggregates - 2.60

(iv) Water absorption:

1. Coarse aggregate-0.50%
2. Fine aggregate- 1.0%

(v) Free (surface) moisture:

1. Coarse aggregate-Nil
2. Fine aggregate- 2.0%

Design Procedure

1. Target mean strength of concrete

$$f_{ck}^{*} = f_{ck} + kS$$

f_{ck}=20, k=1.64 ,S=4

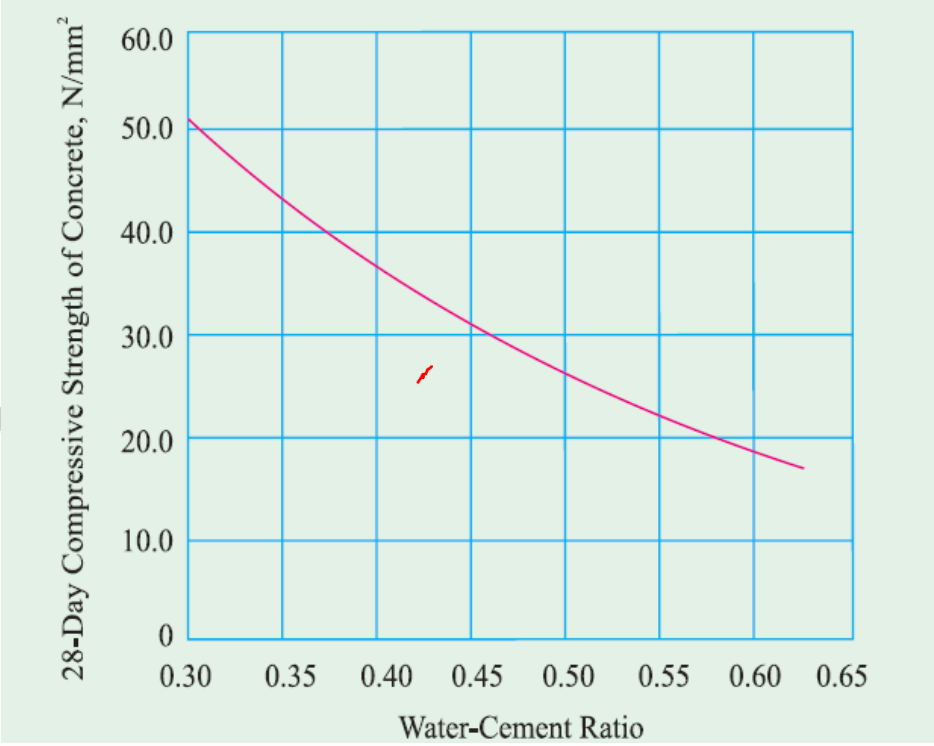
f_{ck}*=26.6MPa

f_{ck}^{*} = *Target mean strength*
f_{ck} = *Characteristic strength*
k = *Tolerance factor*
S = *Standard deviation*

Table 11.22. Assumed standard Deviation as per IS 456 of 2000

Grade of Concrete	*Assumed standard Deviation N/mm²*
M 10	
M 15	3.5
M 20	
M 25	4.00
M 30	
M 35	
M 40	5.00
M 45	
M 50	

2. Selection of Water / Cement Ratio



Durability Criteria: Mild Exposure Conditions

Table 9.18. Minimum Cement Content, Maximum W/C Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum size. IS 456 : 2000

Sl. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum cement contents kg/m³	Maximum Free W/C ratio	Minimum Grade of concrete	Minimum Cement Content kg/m³	Maximum Free W/C ratio	Minimum Grade of Concrete
1.	Mild	220	0.60	–	300	0.55	M 20
2.	Moderate	240	0.60	M 15	300	0.50	M 25
3.	Severe	250	0.50	M 20	320	0.45	M 30
4.	Very Severe	260	0.45	M 20	340	0.45	M 35
5.	Extreme	280	0.40	M 25	360	0.40	M 40

Notes: (1) Cement content prescribed in this table is irrespective of the grade of cement and it is inclusive of all supplementary cementitious materials. The additions of all supplementary cementitious materials may be taken into account in the concrete composition with respect to the cement content and W/C ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit prescribed in relevant codes.

(2) Minimum grade for plain concrete under mild exposure condition is not specified.

W/C ratio from strength considerations =0.50

W/C ratio from durability considerations = 0.55

Adopt the lower value

3. Selection of water and sand content

Table 11.24. Approximate Sand and Water Contents Per Cubic Metre of Concrete W/C = 0.60, Workability = 0.80 C.F. (Slump 30 mm approximately) (Applicable for concrete upto grade M 35)

Maximum Size of Aggregate (mm)	Water Content including Surface Water, Per Cubic Metre of Concrete (kg)	Sand as per cent of Total Aggregate by Absolute volume
10	200	40
20	186	35
40	165	30

Adjustments in Water and Sand Contents

Change in Condition (See Table 11.26)	*Per cent adjustment required*	
	Water content	*Sand in total aggregate*
For decrease in water-cement ratio by (0.60–0.50) that is 0.10.	0	– 2.0
For increase in compacting factor (0.9–0.8), that is 0.10	+ 3	0
For sand conforming to Zone III of Table 4, IS: 383–1970	0	– 1.5
Total	+ 3	– 3.5

4. Determination of cement content

Water-cement ratio=0.50 water=191.6 kg/m^3

Cement =191.6/0.50 =383kg/m^3

Is this satisfactory for 'mild' exposure condition?

5. Determination of coarse and fine aggregate contents

Specified max. Size of aggregate = 20mm

Corresponding entrapped air =2%

f_a=546kg/m^3,

C_a=1188kg/m^3

Final Mix Proportions

Water	Cement	FA	CA
191.6	383	546	1188
0.50	1	1.425	3.10

Example: 2

Mix Design for Grade M30

Step 01: Data to be collected

- Grade Designation = M 30
- Type of cement = O.P.C- 43 grade
- Fine Aggregate = Zone-II
- Sp. Gravity Cement = 3.15
- Fine Aggregate = 2.61
- Coarse Aggregate (20mm) = 2.65
- Coarse Aggregate (10mm) = 2.66

Step 02: Target Mean Strength

According to IS: 456–2000 and IS: 1343–'80, the characteristic strength is defined as that value below which not more than 5 per cent results are expected to fall, in which case the Target mean strength for mix design

Table 11.22. Assumed standard Deviation as per IS 456 of 2000

Grade of Concrete	Assumed standard Deviation N/mm^2
M 10	
M 15	3.5
M 20	
M 25	4.00
M 30	
M 35	
M 40	5.00
M 45	
M 50	

$f_{ck}^{*}=f_{ck}+kS$

$f_{ck}=30+1.65\ x\ 5.0$

$f_{ck}=38.25\ MPa$

*f_{ck}** = *Target mean strength*
f_{ck} = *Characteristic strength*
k = *Tolerance factor*
S = *Standard deviation*

Step 03: Water/cement ratio

Selection of Water / Content Ratio consider from the specified table (Table-5) of IS: 456 for desired exposure condition as preliminary w/c ratio that has to be further checked for limiting value ensuring durability.

Sl. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum cement contents kg/m^3	Maximum Free W/C ratio	Minimum Grade of concrete	Minimum Cement Content kg/m^3	Maximum Free W/C ratio	Minimum Grade of Concrete
1.	Mild	220	0.60	–	300	0.55	M 20
2.	Moderate	240	0.60	M 15	300	0.50	M 25
3.	Severe	250	0.50	M 20	320	0.45	M 30
4.	Very Severe	260	0.45	M 20	340	0.45	M 35
5.	Extreme	280	0.40	M 25	360	0.40	M 40

Step 04: Calculation of Water Content

IS: 10262-2009 allows use of water reducers/ super plasticizers and also specifies the alteration in water content accordingly.

Further water adjustment was specified in terms of variation of compaction factor in the older version whereas the same has been remoulded in terms of slump variation (+3% for every 25mm slump over 50mm) in the revised one.

Table No. 2 Maximum Water Content per Cubic Meter of Concrete for Nominal Maximum Size of Aggregate		
Sr. No.	Nominal Maximum Size of Aggregate	Maximum Water Content kg/m^3
1	10	208
2	**20**	**189**
3	40	165

Step 05: Cement Content

From Table 5, of IS: 456 for desired exposure condition as preliminary w/c ratio 0.40 ,the mixing water content is 189 kg/m3 of concrete.

$CementContent$=1890.40

$CementContent$=475.0 $kgm3$

Which is more than 360 kg (As per Table No. 5, IS: 456) Hence o.k.

Step 06: Weight of Coarse Aggregate

5. Calculation of Coarse Aggregate Proportion: For the desired workability, the quantity of mixing water per unit volume of concrete and the ratio of coarse aggregate to total aggregate by absolute volume are to be estimated from Table 3

Table No. 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate					
Sr. No.	**Nominal Size of Aggregate**	**Zone IV**	**Zone III**	**Zone II**	**Zone I**
1	10	0.50	0.48	0.46	0.44
2	**20**	**0.66**	**0.64**	**0.62**	**0.60**
3	40	0.75	0.73	0.71	0.69

Step 06: Weight of Coarse Aggregate

Find Aggregate (Sand) belongs to Zone II and maximum size of aggregate is 20 mm, the ratio of coarse aggregate to total aggregate by absolute volume are 0.62

As per Table No. 3, IS-10262, for 20mm maximum size entrapped air is 2%

V = $[W+C/Sc+1/P\times Ca/Sca]$ ×1/1000

(1−0.02) = [189+475.0/3.15+1/0.62×Ca/2.65×1/1000

Ca=1052.0$kg/m3$

Step 07: Weight of Fine Aggregate

Similarly Weight of Fine Aggregate is calculated as

V = $[W+C/Sc+1/1-P\times fa/Sfa$×1/1000

(1−0.02) = [189+475.0/3.15+1/0.38×Ca2.61×1/1000

fa=634.0kgm^3

Step 08: Combination of Different Coarse Aggregate Fractions

The coarse aggregate used shall conform to IS 383 – 1970. Coarse aggregate of different sizes may be combined in suitable proportions so as result in an overall grading conforming to Table 2 of IS 383 – 1970 for nominal maximum size of aggregate

Table 3.14. Grading Limits for Coarse Aggregate IS: 383-1970

IS Sieve Designation	Percentage passing for single-sized aggregate nominal size (by weight)						Percentage passing for Graded aggregate of nominal size (by weight)			
	63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
80 mm	100	–	–	–	–	–	100	–	–	–
63 mm	85–100	100	–	–	–	–	–	–	–	–
40 mm	0–30	85–100	100	–	–	–	95–100	100	–	–
20 mm	0–5	0–20	85–100	100	–	–	30–70	95–100	100	100
16 mm	–	–	–	85–100	100	–	–	–	90–100	–
12.5 mm	–	–	–	–	85–100	100	–	–	–	90–100
10 mm	–	0–5	0–20	0–30	0–45	85–100	10–35	25–55	30–70	40–85
4.75 mm	–	–	0–5	0–5	0–10	0–20	0–5	0–10	0–10	0–10
2.36 mm	–	–	–	–	–	0–5	–	–	–	–

Step 09: Proportions

Ingredients	Cement	Fine Aggregate	Coarse Aggregate	Water	Chemical
Quantity $kgm3$	**475.0**	**634.0**	**1052.0**	**189.0**	**NM**
Ratio	**1.00**	**1.33**	**2.21**	**0.40**	**NM**
1 Bag Cement	**50.0**	**66.5**	**110.5**	**20.0**	**NM**

Step 10: Adjustment for Field Condition

The proportions are required to be adjusted for the field conditions. Fine Aggregate has surface moisture of 2 %

Weight of F. A. = 634.0 + 2/100 634.0
= 643.7 kg/m3

Course Aggregate absorbs 1% water

Weight of C. A. = 1052.0 – 1/100 1052.0
= 1041.5 kg/m3

Step 10: Final Design Proportions

Ingredients	Cement	Fine Aggregate	Coarse Aggregate	Water	Chemical
Quantity $kgm3$	475.0	643.7	1041.5	189.0	NM
Ratio	**1.00**	**1.36**	**2.19**	**0.40**	NM
1 Bag Cement	50.0	68.0	109.5	20.0	NM