ACC

Principles of Concrete
&
Concrete Mix Design- IS 10262

Concrete

- Concrete is an intimate mixture of:

  Cement,

  Sand (Fine Aggregate),

  Coarse Aggregate,

  Water.

- New Generation Concrete needs use of Special Materials in addition to above i.e. “ADMIXTURES”
- Admixtures may be Mineral or Chemical Admixtures.

Concrete

Versatility of making concrete with locally available materials, ease in moulding it into any shape and size and economy in its making has made concrete the **2nd largest consumed material on earth!!**

Concrete

Structures of such dimensions possible today due to developments in Concrete.

Requirements of Good Concrete

A good concrete should:

- meet the strength requirements as measured by compressive strength,
- fulfill durability requirements to resist the environment in which the structure is expected to serve,
- be mixed, transported and compacted as efficiently as possible and
- will be as economical as possible.

Concrete Durability

- "Durability of concrete is the ability of concrete to withstand the harmful effects of environment to which it will be subjected to, during its service life, without undergoing into deterioration beyond acceptable limits".

- Durability can be assured keeping in view the environment exposure of structure, certain minimum cement binder content, max limit on w/c ratio and a certain minimum grade of concrete for that particular exposure.

Making Durable Concrete

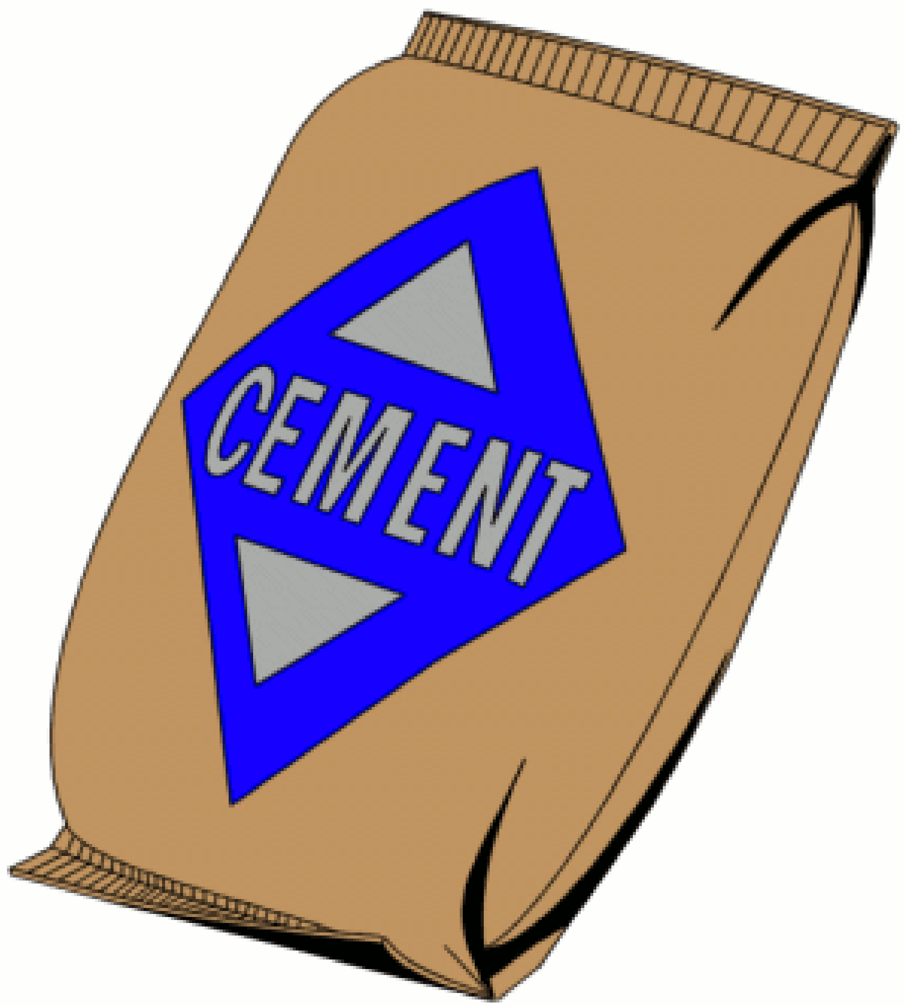
- Lowering the porosity and permeability of concrete is only way to reduce environmental attacks on concrete,

- Dense and compact concrete that prevents the ingress of harmful elements is the key to "*DURABLE CONCRETE*".

Making Good Concrete

Making good concrete involves:

- Good quality raw materials,
- Proportioning of materials,
- Mixing,
- Transporting,
- Placing,
- Compacting,
- Curing.


CEMENT

Cement

- Cement is a fine powder, which when mixed with water and allowed to set and harden can join different components or members together to give a mechanically strong structure.
- Although the percentage of cement in concrete is around 15%, the role of cement is very important in the strength and durability of concrete.

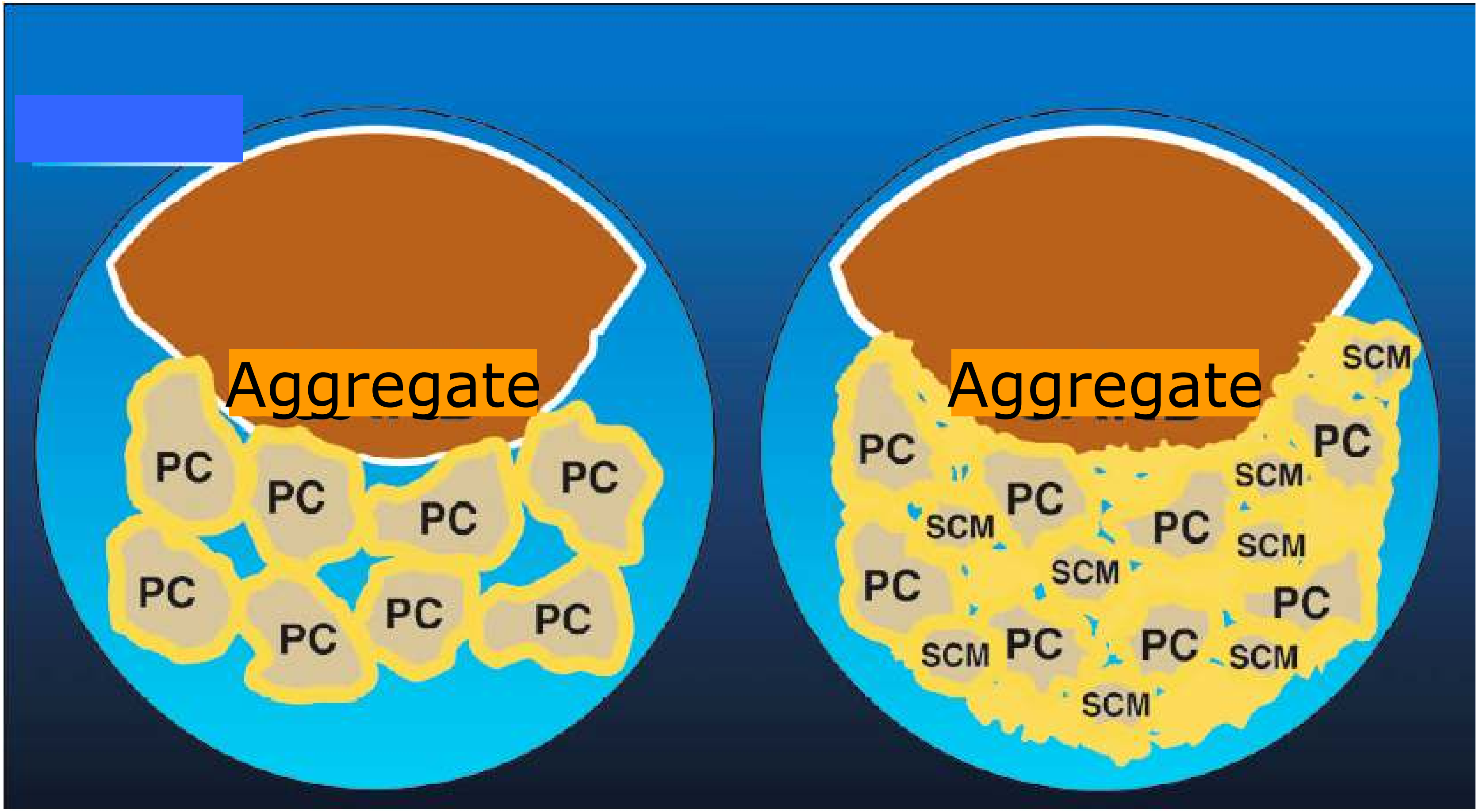
Selection of good quality cement is therefore essential.

Types of Cement

Although around 18 types of cements are recognized by BIS, more commonly used ones are:

- Ordinary Portland Cement 33, 43, & 53 grade OPC,
- Blended Cements (PPC and PSC).
- Sulphate Resisting Cement (SRC),
- Low Heat Portland Cement (LHPC),
- Hydrophobic Portland Cement,
- Coloured Cement (White Cement).

Advantages of Blended Cements



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Ideal Applications of PPC/ PSC

Structures within/ along the Sea Coast

Mass Concrete structures, huge foundations

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Sewage and Water Treatment Plants

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Port Facility/ Jetty

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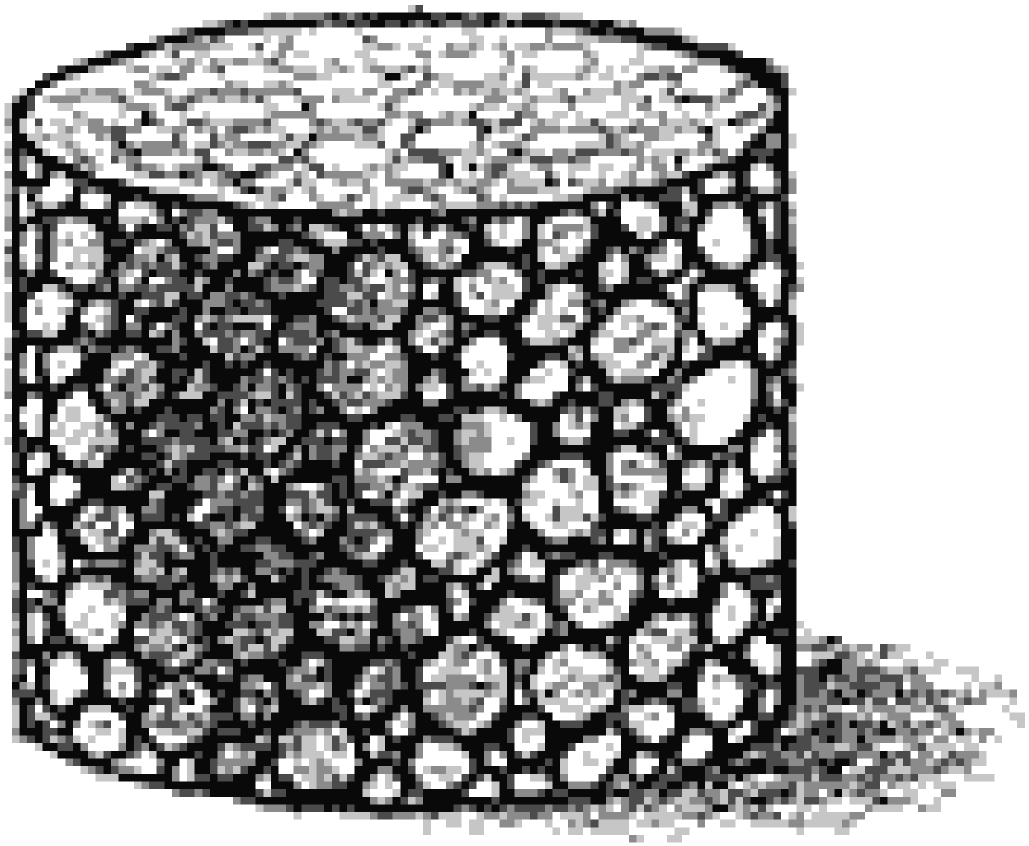
Gradation of Aggregates

Densely packed Graded Aggregates, less voids



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Gradation of Aggregates

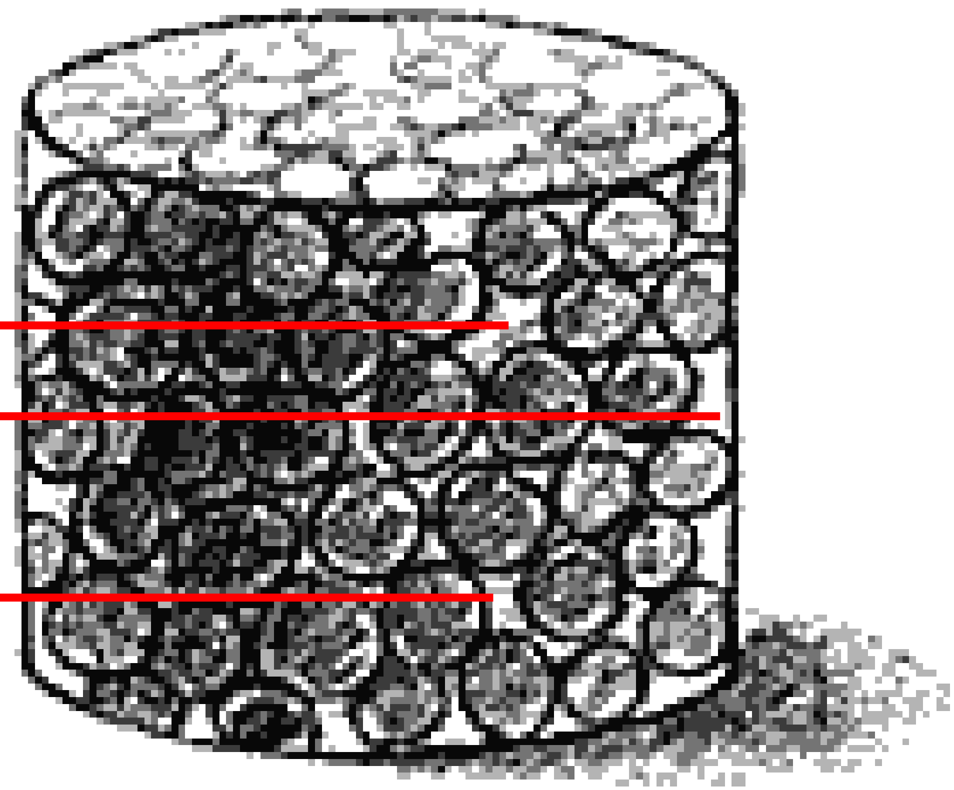
Single Size Aggregates with more voids

VOIDS

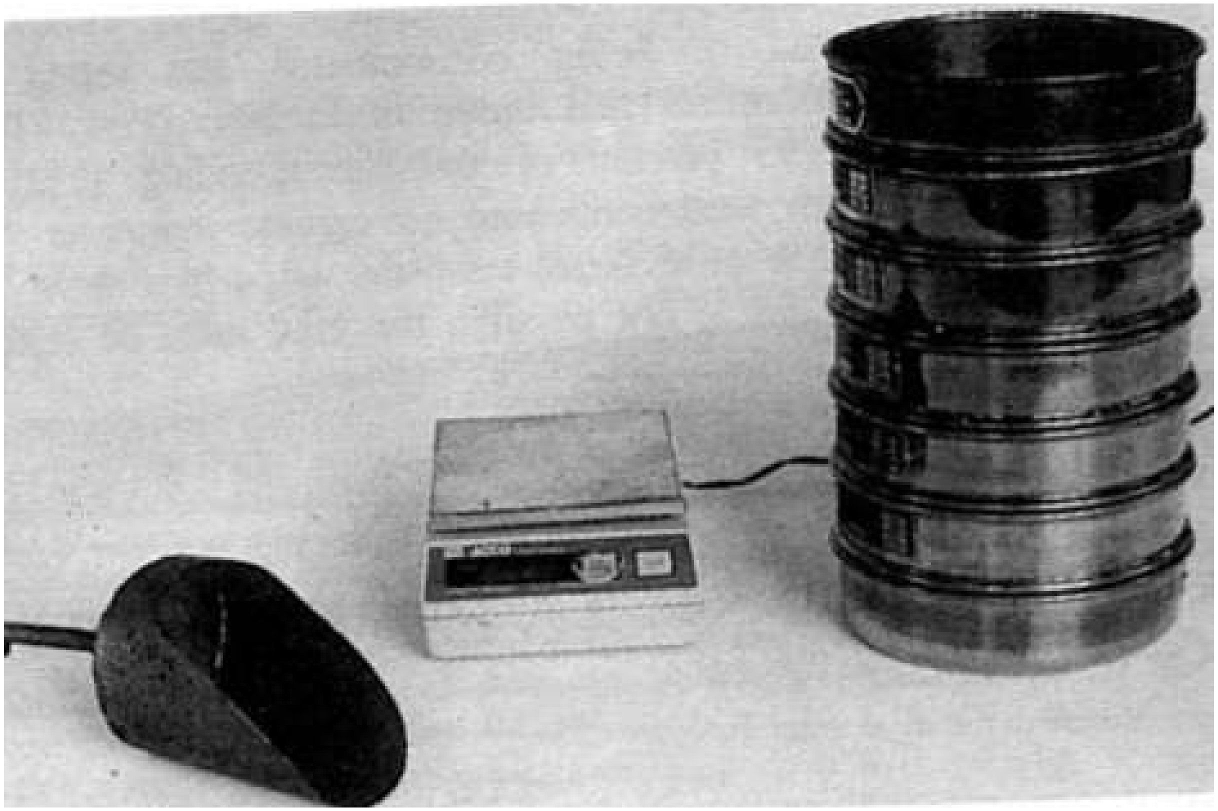
&

EMPTY

SPACES



Sieve Analysis



Equipments for Sieve Analysis Test on Aggregates

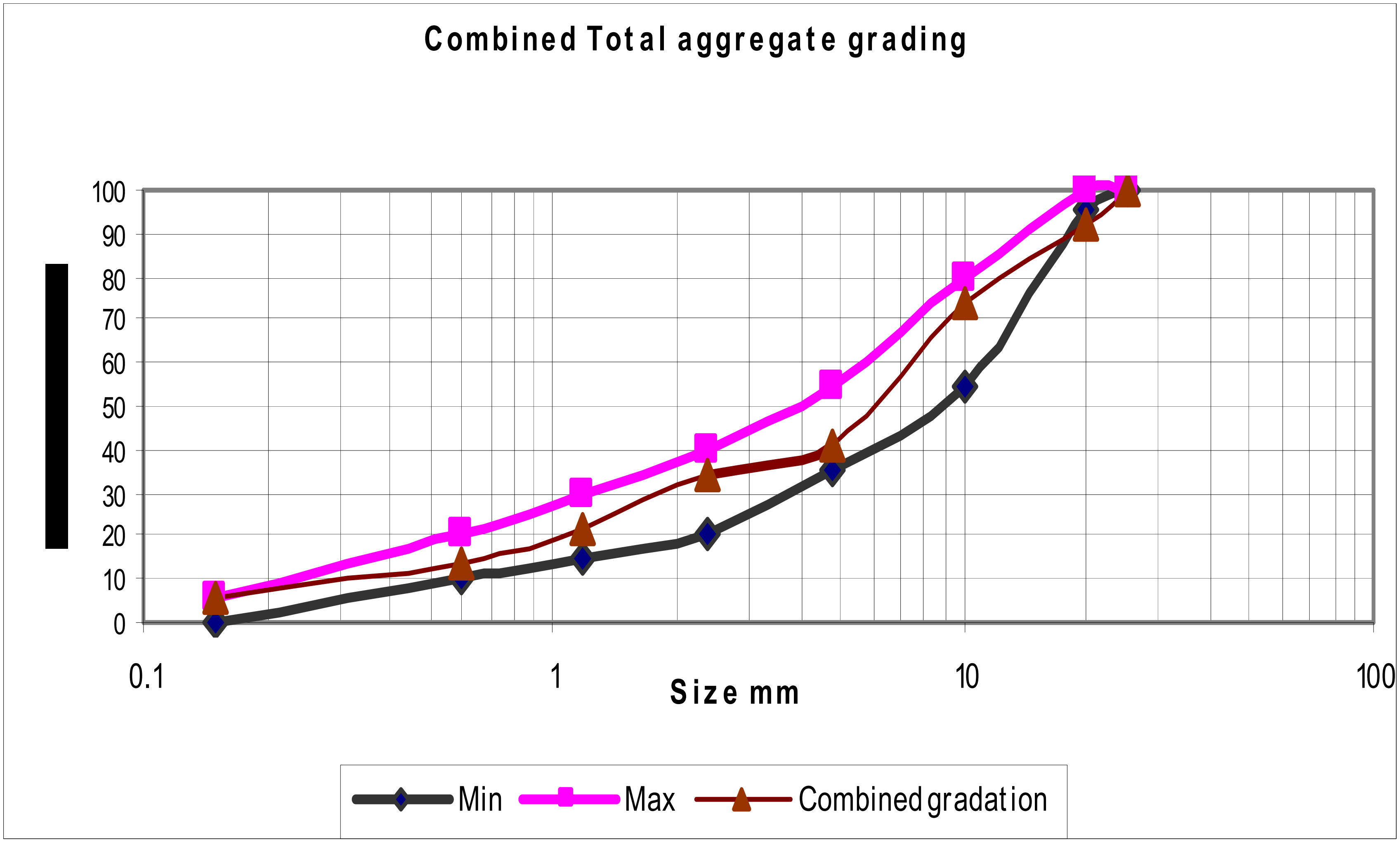
Gradation Limits as per IS 383

IS sieve	Zone I	Zone II	Zone III	Zone IV
4.75 mm	90- 100	90- 100	90- 100	90- 100
2.36 mm	60- 95	75- 100	85- 100	95- 100
1.18 mm	36- 70	55- 90	75- 100	90- 100
600 micron	**15- 34**	**35- 59**	**60- 79**	**80- 100**
300 micron	5- 20	8- 30	12- 40	15- 50
150 micron	0- 10	0- 10	0- 10	0- 15
Remarks	**V. Coarse**	**Coarse**	**Medium**	**Fine**

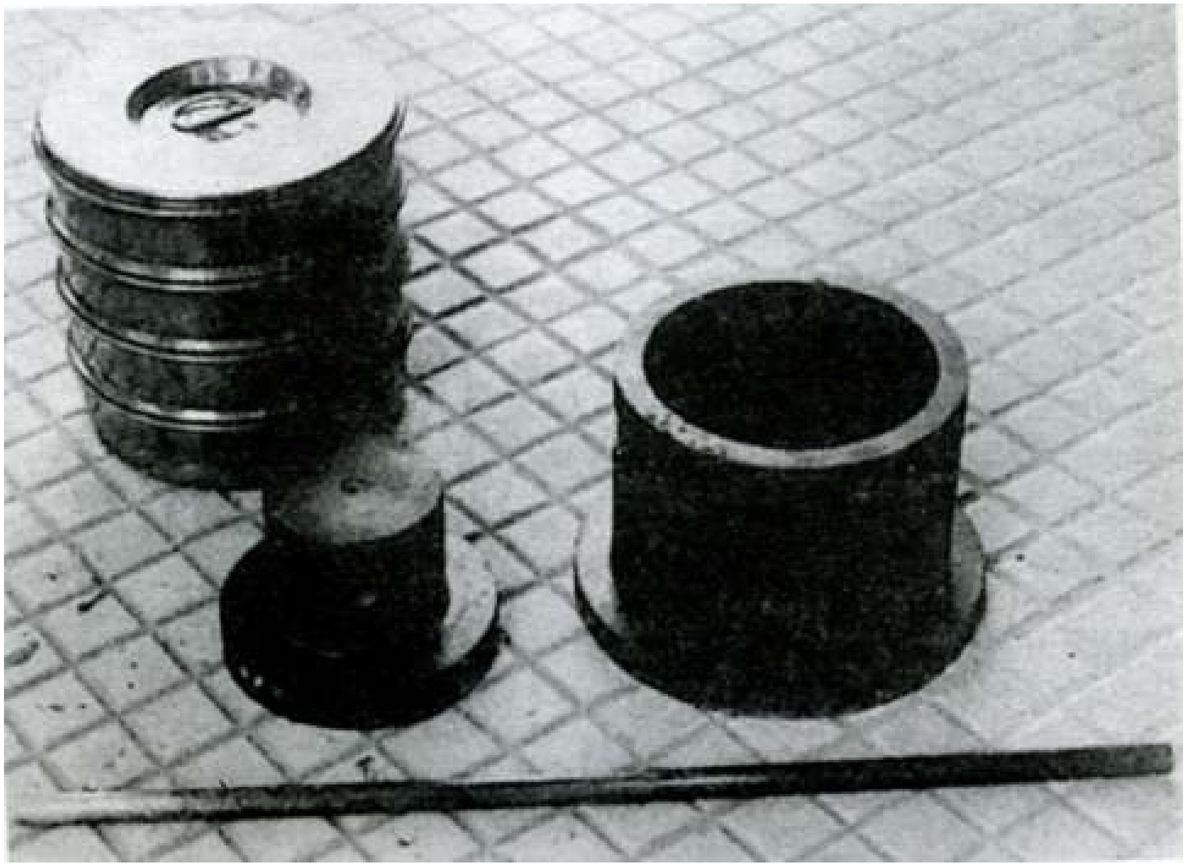
IS Limits for Graded Coarse Aggregates

IS sieve size	**40 mm MAS** **% passing**	**20 mm MAS** **% passing**	**10 mm MAS** **% passing**
40 mm	95- 100	100	100
20 mm	30- 70	95- 100	100
10 mm	10- 35	25- 55	40- 85
4.75 mm	0- 5	0- 10	0- 10

Combined Grading of CA & FA



Aggregate Crushing Value



Equipments for Crushing Value Test on Aggregates

Important mechanical properties of Aggregates

Properties	Limiting values, percent	
	For wearing surfaces	Other than wearing surfaces
Crushing Value	30	45
Impact Value	30	45
Abrasion Value (Los Angeles)	30	50

Properties of Aggregates

Specific Gravity	Indicates density & crushing strength,
Surface Texture	Rough texture for bond,
Particle Shape	Should be cubical and not flaky and elongated,
Porosity	Should have very low water absorption,
Stability	Be chemically inert,
Impurities	Free from organic/ mineral impurity,
Compactness	Should be graded, for reducing voids.

Typical limits for solids in water

Solids	Permissible limits, max, mg/ l
Organic	200
Inorganic	3000
Sulphates (as SO_3)	400
Chlorides (as Cl)	
▪ For plain concrete	2000
▪ For reinforced concrete	500
Suspended matter	2000

Limits of Chloride content of Concrete

Type or use of concrete	Maximum total acid soluble chloride content expressed as kg/m^3 of concrete
Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete	0.4
Reinforced concrete or plain concrete containing embedded metal	0.6
Concrete not containing embedded metal or any material requiring protection from chloride	3.0

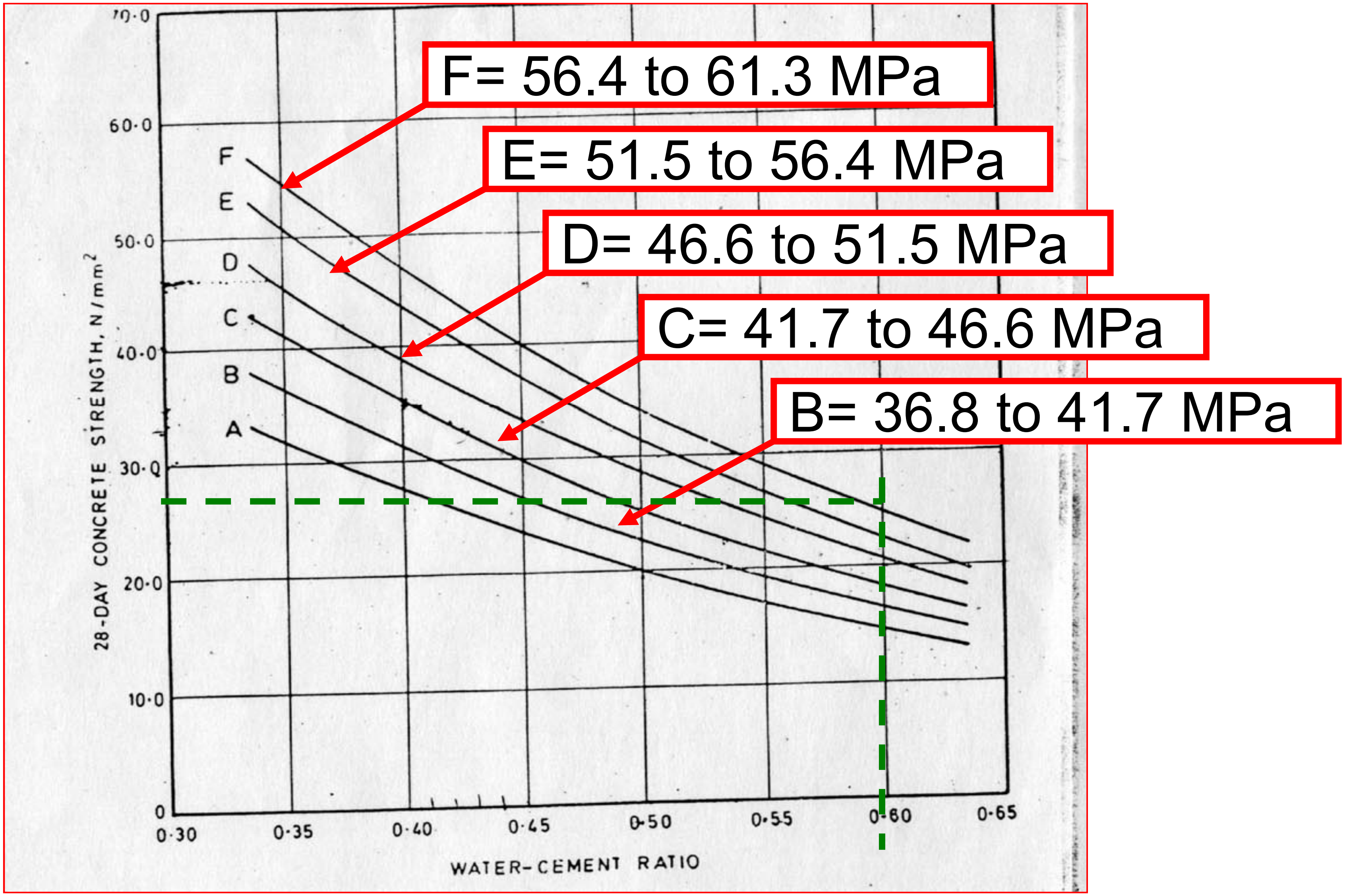
Durability Criteria as per IS 456- 2000

Exposure	Plain Concrete			Reinforced Concrete		
	Min. Cement	Max w/c	Min grade	Min. Cement	Max w/c	Min grade
Mild	**220 kg/m³**	**0.60**	**--**	**300 kg/m³**	**0.55**	**M 20**
Moderate	**240 kg/m³**	**0.60**	**M 15**	**300 kg/m³**	**0.50**	**M 25**
Severe	**250 kg/m³**	**0.50**	**M 20**	**320 kg/m³**	**0.45**	**M 30**
V. Severe	**260 kg/m³**	**0.45**	**M 20**	**340 kg/m³**	**0.45**	**M 35**
Extreme	**280 kg/m³**	**0.40**	**M 25**	**360 kg/m³**	**0.40**	**M 40**

Durability Criteria as per IS 456- 2000

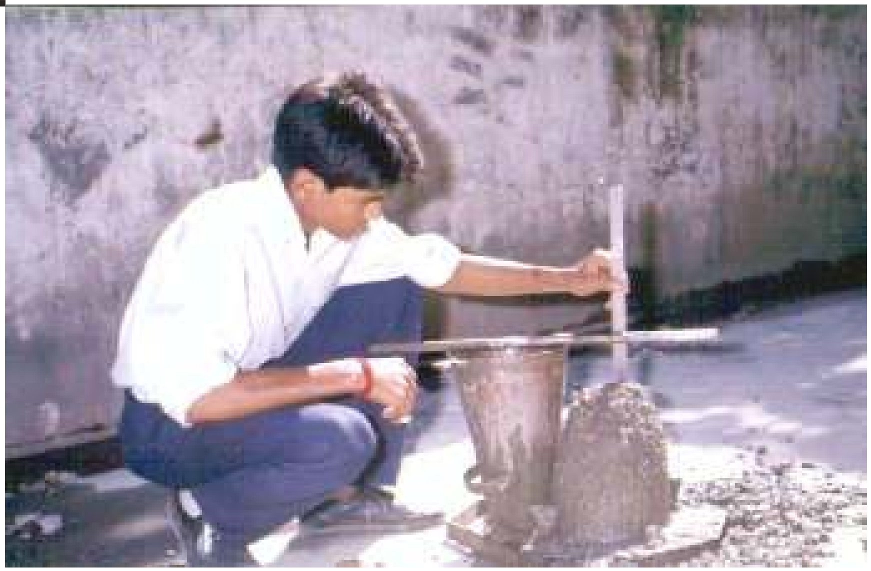
Adjustments to minimum cement content for aggregates other than 20 mm nominal max. size aggregates as per IS 456: 2000.

10 mm	**+ 40 kg/cum**
20 mm	**0**
40 mm	**- 30 kg/cum**



F= 56.4 to 61.3 MPa
E= 51.5 to 56.4 MPa
D= 46.6 to 51.5 MPa
C= 41.7 to 46.6 MPa
B= 36.8 to 41.7 MPa
F
E
D
C
B
A
70·0
60·0
50·0
40·0
30·0
20·0
10·0
0
28-DAY CONCRETE STRENGTH, N/mm²
0·30
0·35
0·40
0·45
0·50
0·55
0·60
0·65
WATER-CEMENT RATIO

Workability of Concrete

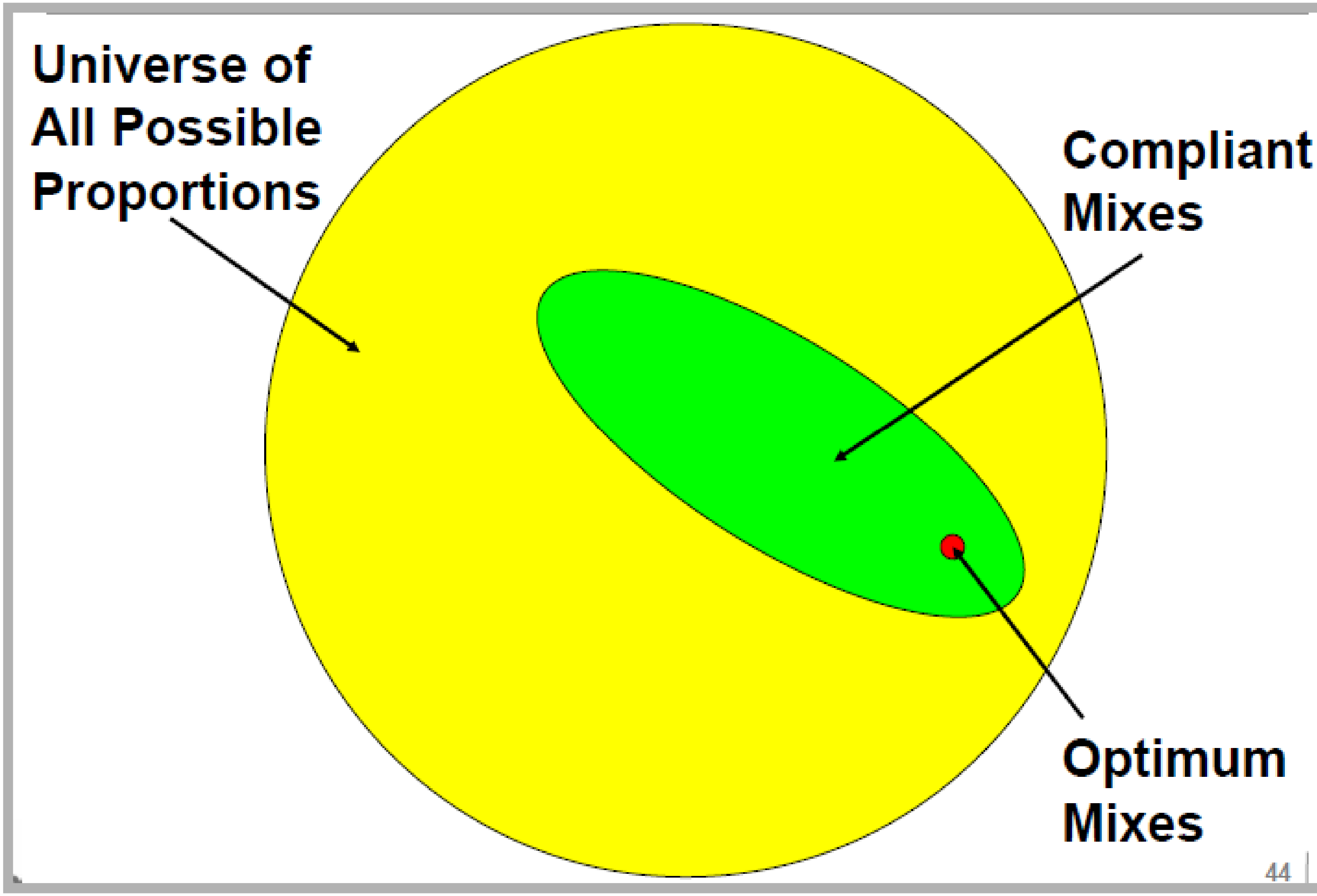


Placing condition	Degree	Slump (mm)	Compaction factor
Mass concrete, lightly reinforced sections in beams, walls, columns and floors	LOW	25 to 75	0.8 to 0.85
Heavily reinforced sections in slabs, beams, walls, columns and footings	**MEDIUM**	**50 to 100**	**0.9 to 0.92**
Slip formwork, pumped concrete, in- situ piling	HIGH	100 to 150	0.95 to 0.96

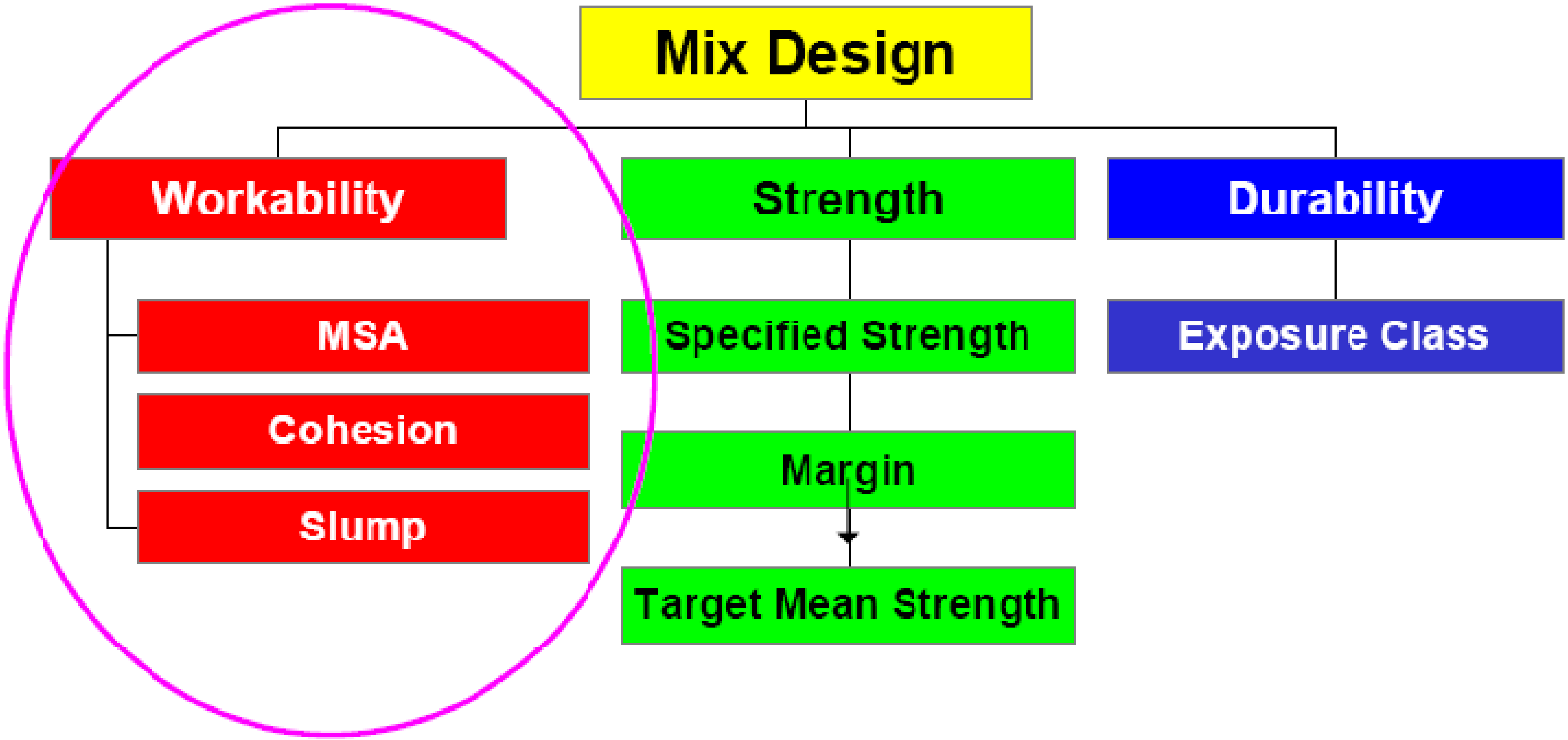
Concrete Mix Design - Definition

- Concrete mix design is defined as the appropriate selection and proportioning of constituents to produce a concrete with pre-defined characteristics in the fresh and hardened states.
- In general, concrete mixes are designed in order to achieve a defined workability, strength and durability .
- The selection and proportioning of materials depend on:
  - the structural requirements of the concrete
  - the environment to which the structure will be exposed
  - the job site conditions, especially the methods of concrete production, transport, placement, compaction and finishing
  - the characteristics of the available raw materials

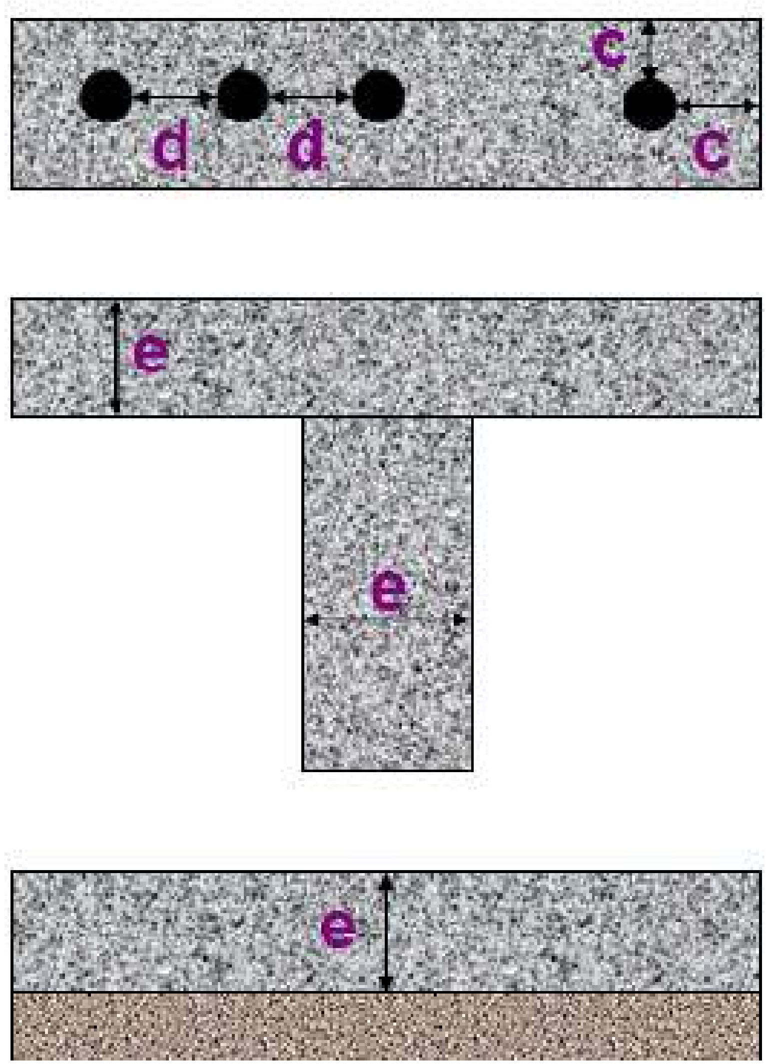
Mix Design (Technically Compliant Mixes) vs. Mix Optimization (Lowest Cost Compliant Mixes)



Main Aspects to be considered in Mix Design



Limits to MSA



MSA < 3d/4

MSA < 3c/4

MSA < e/5

MSA < e/3

Factors Influencing Consistency (Slump)

- The consistency of fresh concrete depends on many factors, the main ones being:
  - Water Content (kg/m3)
  - W/c Ratio
  - Fineness Modulus of the Aggregate
  - Use of Water Reducers (Plasticizers / Super plasticizers)
  - Type and shape of Aggregate
  - Entrained Air Content

- There are other secondary factors too, such as:
  - Mix temperature, aggregates' dust, cement type, additions (silica fume, fly-ash, slag, fibers), etc.

Durability Constraints

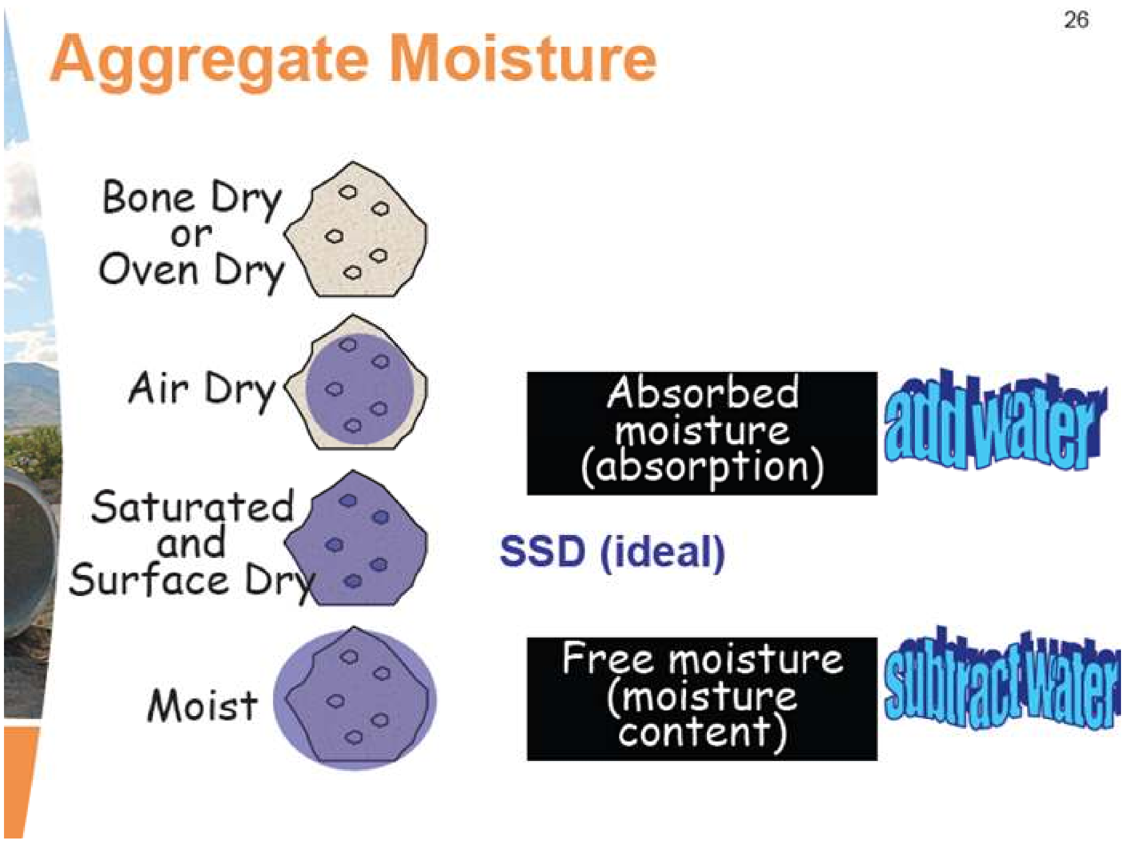
- Usually, durability requirements end in some constraints to the maximum W/C ratio and/or to the minimum cement content of the mix.
- Very often these requirements are more stringent than those demanded by the strength requirements, which usually ends in concretes which are overdesigned in strength.

Factors affecting Strength

- The strength of hardened concrete depends on many factors, the main ones being:
  - W/C Ratio
  - Strength of the Cement
  - Type and shape of Aggregate
  - Entrained Air Content

- There are other secondary factors too, such as:
  - Mix temperature, etc.

Aggregate Moisture



Concrete Mix Design steps by IS: 10262

First Revision - 2009

Step 1

Determine Target mean strength of concrete as:

$$\mathbf{f_t = f_{ck} + k.\ s}$$

where, f_t = target mean compressive strength at 28 days,

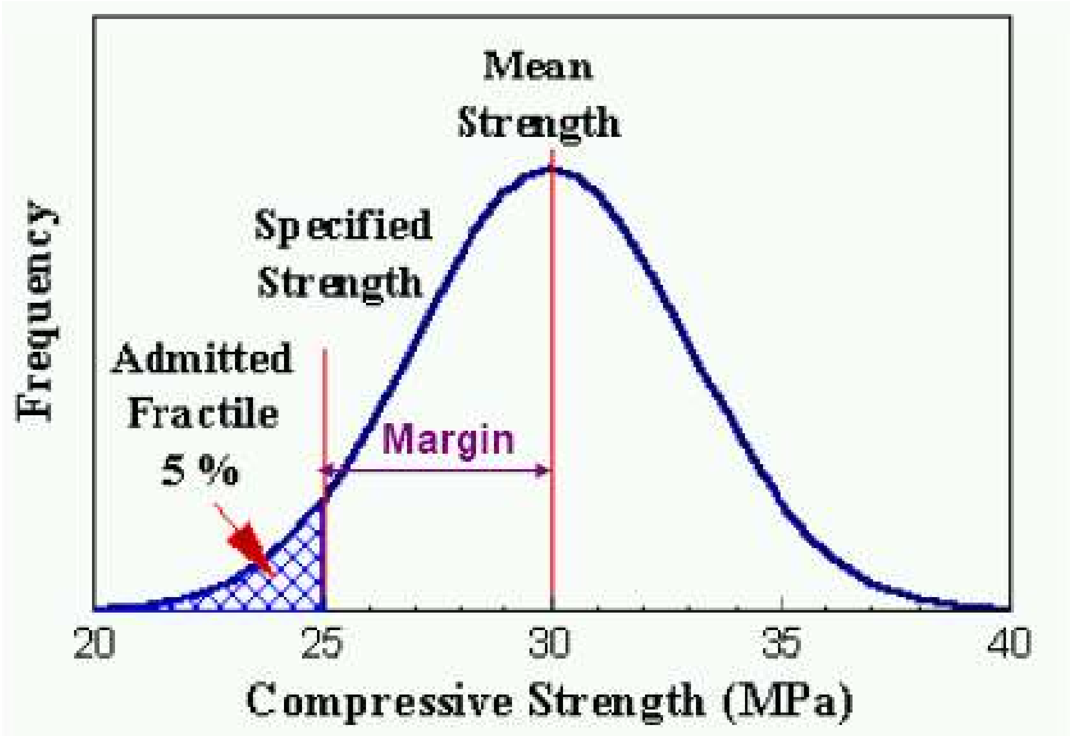
f_{ck} = Characteristic compressive strength of concrete at 28 days,

k = usually 1.65 as per is 456-2000

s = standard deviation.

Specified and Target Mean Strength

- The specified strength, is a statistical minimum value of strength. It is a value of strength such that only a given % (the Admitted Fractile or „defectives“) of results is expected to show lower strengths.
- The graph illustrates the meaning of the Specified Strength, the Admitted Fractile (5% in this case) and the Target Mean Strength.

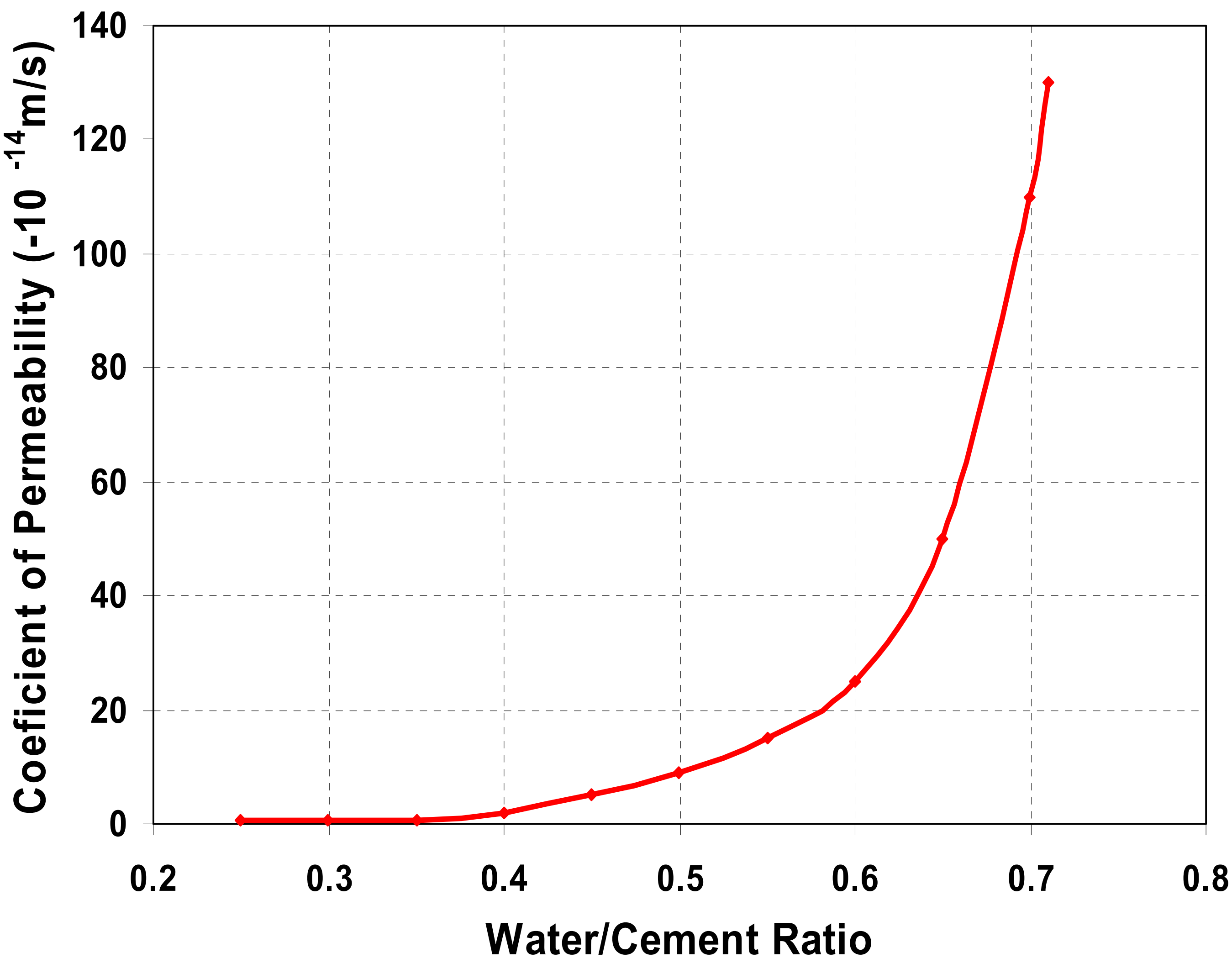


Grade of concrete	Assumed Standard Deviation
M 10	3.50 N/ mm²
M 15	
M 20	**4.00 N/ mm²**
M 25	
M 30	5.00 N/ mm²
M 35	
M 40	
M 45	
M 50	

Chosen the Right w/c Ratio

- Studies show that capillary porous start to be connected when w/c is higher than 0.40
- When w/c is higher than 0.70, all capillary porous are connected
- Based on this:
  - Standards tend to establish 0.70 as the maximum value for w/c ratio
  - Higher is the aggressiveness of the environment lower should be the w/c ratio
  - For concrete exposed to a very aggressive environment the w/c should be lower that 0.40

Relationship Between W/C and Permeability



After Neville (1995) Properties of Concrete

Step 2 (Selection of Water-Cement Ratio)

Choose w.c.ratio against max w.c.ratio for the requirement of durability. (Table 5, IS:456-2000)

Make a more precise estimate of the preliminary w/c ratio corresponding to the target average strength.

Durability Criteria as per IS 456- 2000

Exposure	Plain Concrete			Reinforced Concrete		
	Min. Cement	Max w/c	Min grade	Min. Cement	Max w/c	Min grade
Mild	**220 kg/m^3**	**0.60**	**--**	**300 kg/m^3**	**0.55**	**M 20**
Moderate	**240 kg/m^3**	**0.60**	**M 15**	**300 kg/m^3**	**0.50**	**M 25**
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Durability Criteria as per IS 456- 2000

Adjustments to minimum cement content for aggregates other than 20 mm nominal max. size aggregates as per IS 456: 2000.

10 mm	**+ 40 kg/cum**
20 mm	**0**
40 mm	**- 30 kg/cum**

Step 3

Estimate the air content for maximum size of aggregate used

Approximate Entrapped Air Content

Max. size of Aggregate (mm)	Entrapped air as % of concrete
10	3.0
20	**2.0**
40	1.0

Step 3 – Selection of Water Content

- Water Content is Influenced By:
  - Aggregate size
  - Aggregate shape and texture
  - Workability required
  - Water cement ratio
  - Cementations material content
  - Environmental exposure condition

Nominal Max aggregate size	Water content per cum of concrete (kg)
10	208
20	**186**
40	165

- For angular coarse aggregates – SSD condition
- Slump 25 – 50 mm

For Other Conditions

Condition	Correction
Sub-Angular Aggregates	- 10 Kg
Gravel + Crushed Particles	- 20 Kg
Rounded Gravel	- 25 Kg
For every slump increase of 25 mm	+ 3 %
Use of Water Reducing Admixture	- 5 to 10 %
Use of Superplasticzing Admixtures	- 20 %

Step 4 – Calculation of Cementations Material

Calculate the cement content from W/C ratio and final water content arrived after adjustment.

Check the cement content so calculated against the min. cement content from the requirement of durability. Adopt greater of the two values.

Step 5 – Estimation of Coarse Aggregate Proportion

- For W/C ration of 0.5 use following Table

Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate
(*Clauses* 4.4, A-7 *and* B-7)

Sl No.	Nominal Maximum Size of Aggregate mm	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
		Zone IV	Zone III	Zone II	Zone I
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	0.50	0.48	0.46	0.44
ii)	20	0.66	0.64	0.62	0.60
iii)	40	0.75	0.73	0.71	0.69

[1] Volumes are based on aggregates in saturated surface dry condition.

Correction in Coarse Aggregate values

The table specified for W/C ratio of 0.5

1. For Every +0.05 change in W/C ratio: -0.01
2. For Every -0.05 change in W/C ratio: +0.01
3. For Pumpable Mix : -10 %

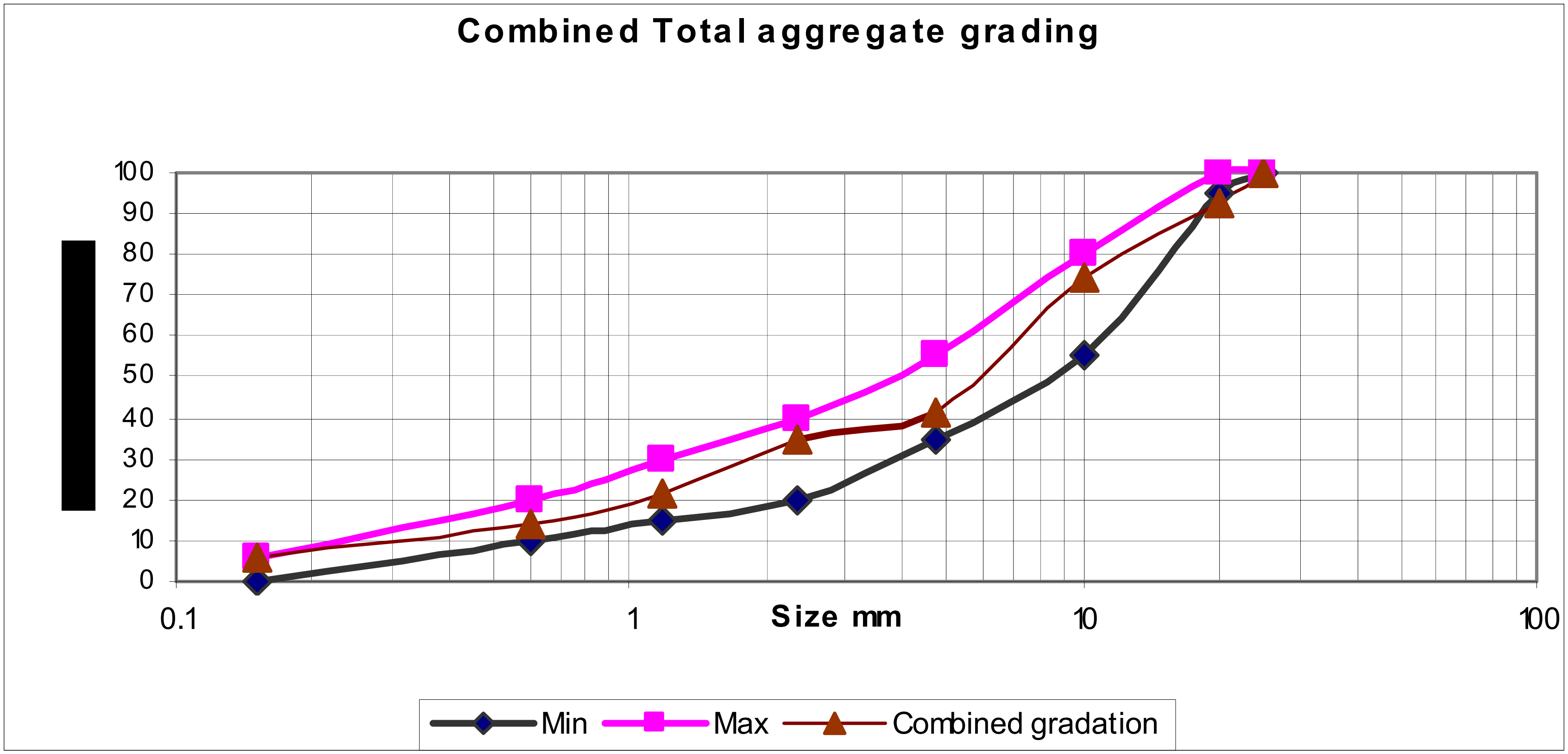
Step 6 – Combination of Different Coarse Aggregate Fraction

- It can be done based on IS 383

IS Sieve designation (mm)	Percentage passing for Graded aggregates of nominal size (by Weight)			
	40 mm	20 mm	16 mm	12.5 mm
80	100			
63				
40	95- 100	100		
20	30- 70	95- 100	100	100
16			90- 100	
12.5				90- 100
10	10- 35	25- 55	30- 70	40- 85
4.75	0- 5	0- 10	0- 10	0- 10
2.36				

IS Sieve designation	Percentage passing by weights for all in aggregates of	
	40 mm nominal size	20 mm nominal size
80 mm	100	--
40 mm	95- 100	100
20 mm	45- 75	95- 100
4.75 mm	25- 45	30- 50
600 micron	8- 30	10- 35
300 micron	0- 6	0- 6

Combined Grading of CA & FA



Step 7 – Estimation of Fine Aggregate Proportion

a **Volume of Concrete** = 1 m3

b **Volume of Cement** = (Mass of Cement / SG of Cement) * 1/1000

c **Volume of Water** = (Mass of Water / SG of Water) * 1/1000

d **Volume of Chemical Admixture**

(2 % of Mass of cementations material)

= (Mass of Admixt. / SG of Admixt) * 1/1000

e **Volume of All in Aggregates** = [a - (b + c + d)]

f **Mass of Coarse aggregate** = e * Volume of coarse aggregate * SG of coarse aggregate * 1000

g **Mass of fine aggregate** = e * Volume of fine aggregate * SG of fine aggregate * 1000

Major Changes

S.N.	Old Edition	Revised 2009 Edition
1	Title - " Recommanded guidelines for Concrete mix Design"	Title - "Concrete mix Proportioning - Guidelines"
2	Applicability was not specified for any specific Concrete Grades	Specified for Ordinary (M 10 - M 20) and Standard (M25 - M 55) Concrete Grades only.
3	Based on IS 456 : 1982	Modification in line with IS 456 : 2000
4	W / C ratio was based on Concrete grade and 28 days compressive strength of Concrete and the durability criteria	W/C ratio is based on Durability criteria and the Experience and Practical trials
5	Water Content could be modified taking into account the compaction factor value (Laboratory based test for Workability) and the shape of aggregates.	Water content can be modified Based on Slump vale (Field test of Workability) and Shape of Aggreagtes, and use of Admixtures.
6	Entrapped Air cotent considered according to Nominal Maximum size of Aggregates	No Entrapped Air content taken into account
7	Not much Consideration for Trial Mixes	Trial Mixes concept is mentioned
8	Concrete Mix Design with Fly ash is not mentioned	An illustrative example of Concrete Mix Prportioning using Fly ash has been added

Nominal Mixes for Concrete

Proportions for Nominal Mix Concrete

Grade of Concrete	Total qty of dry aggregate (CA + FA) per 50 kg cement	Proportion of FA to CA by volume	Water per 50 kg cement (max) lit
M 5	800	1: 2 (Zone II) subject to upper limit of 1: 1.5 (Zone I) & lower limit of 1: 2.5 (Zone III)	60
M 7.5	625		45
M 10	480		34
M 15	330		32
M 20	250		30

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Example for Nominal Mixes

- Grade of Concrete: M 20
- Total Aggregate (CA + FA) per 50 kg cement: 250 kg, FA of Zone II (say)
- Water content: 30 lit per 50 kg cement
- w/c ratio= 30/50= 0.60
- Considering FA: CA= **1: 2**,
  - Sand= (250 X 1)/ 3= **83** kg
  - Coarse Aggregate= (250 X 2)/ 3= **167** kg

Cement	FA	CA	Water
50 kg (35 Lit)	83 kg	167 kg	30 lit

Cement	FA	CA	Water
50 kg	83 kg	167 kg	30 lit
(by weight) **1**	**1.66**	**3.32**	**0.6**
1.43 kg/ lit	1.52 kg/ lit	1.60 kg/ lit	
35 lit	54.6 lit	104.4 lit	30 lit
(by volume) **1**	**1.56**	**2.98**	

M 20 Grade Concrete (by Volume) is 1: 1 ½ : 3

Thank You