Course: Concrete Technology

Lecture 11: Alternative Mix Design Methods

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Session Objectives

- Learn two alternative mix design methods
- Compare methods with traditional ACI procedure
- Analyze procedures and resulting mix designs
- Select best method for each project

Content

- Total fineness modulus method
- Theoretical curves method
- Applied case studies

Mix Design Fundamentals

- Mix design is empirical and iterative
- Parameters adjusted to project requirements
- All methods follow similar design logic
- ACI provides the reference framework

Source: Open AI (2026)

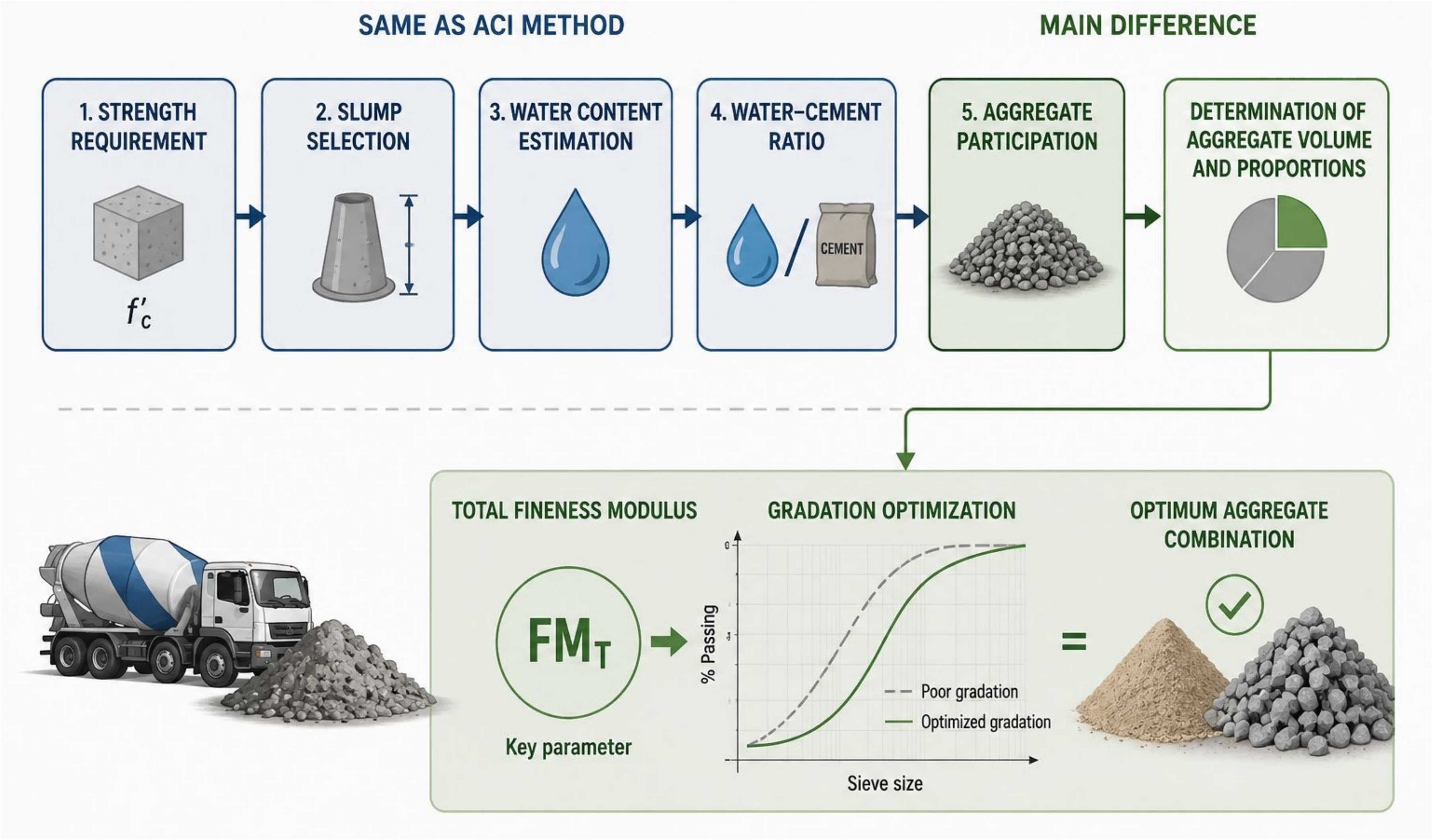
Aggregate Gradation and Fineness Modulus

- Gradation defines particle size distribution
- Proper gradation improves compaction performance
- Fineness modulus estimates average particle size
- Influences workability, water demand, proportioning

Source: Open AI (2026)

Total fineness modulus method

Procedure Compared with ACI



Source: Open AI (2026)

Required Average Strength

$$f'cr = f'c + 1.34s$$

$$f'cr = f'c + 2.33s - 35$$

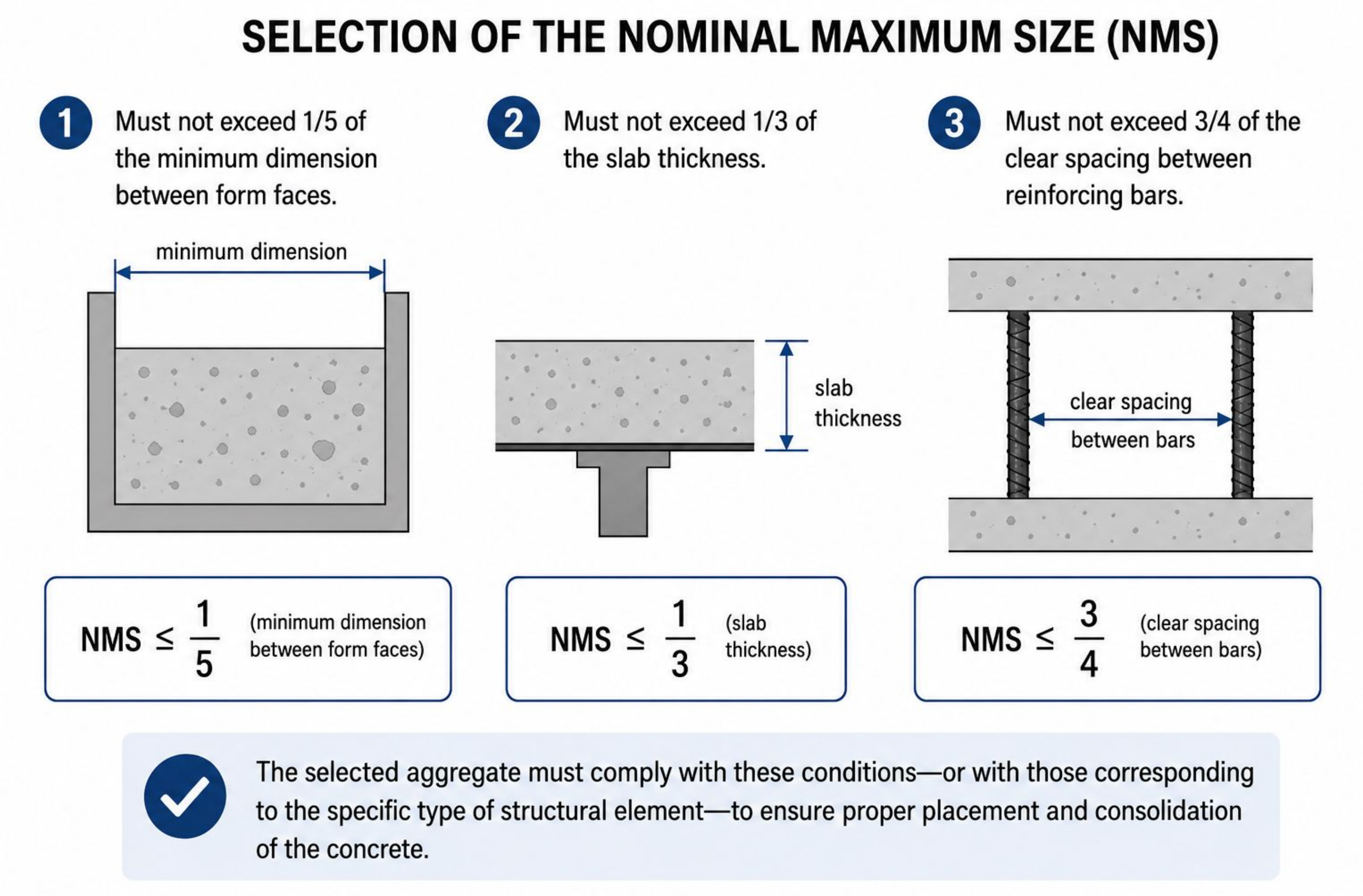
Tests	Correction factor
Less than 15	Refer to another table
15	1.16
20	1.08
25	1.03
30	1

Source: ACI 211 Comittee

f'c (Mpa)	f'cr
Less than 21	f'c + 7.0
21 to 35	f'c + 8.5
More than 35	1.1*f'c + 5.0

Source: ACI 211 Comittee

Nominal Maximum Aggregate Size



Source: Open AI (2026)

Slump Selection

Type of Construction	Maximum	Minimum
Reinforced footings and foundation walls	3"	1"
Plain foundations, caissons, and wall substructures	3"	1"
Reinforced beams and walls	4"	1"
Building columns	4"	1"
Slabs and pavements	3"	1"
Cyclopean concrete	2"	1"

Source: ACI 211 Comittee

Design Water Content

Slump	Water (L/m³) for the indicated maximum nominal size (MNS) of coarse aggregate and consistency							
	3/8"	1/2"	3/4"	1"	1 1/2"	2"	3"	6"
Non-air-entrained								
1" to 2"	207	199	190	179	166	154	130	113
3" to 4"	228	216	205	193	181	169	145	124
6" to 7"	243	228	216	202	190	178	160	-
Air-entrained								
1" to 2"	181	175	168	160	150	142	122	107
3" to 4"	202	193	184	175	165	157	133	119
6" to 7"	216	205	197	184	174	166	154	-

Source: ACI 211 Comittee

Air Content Selection

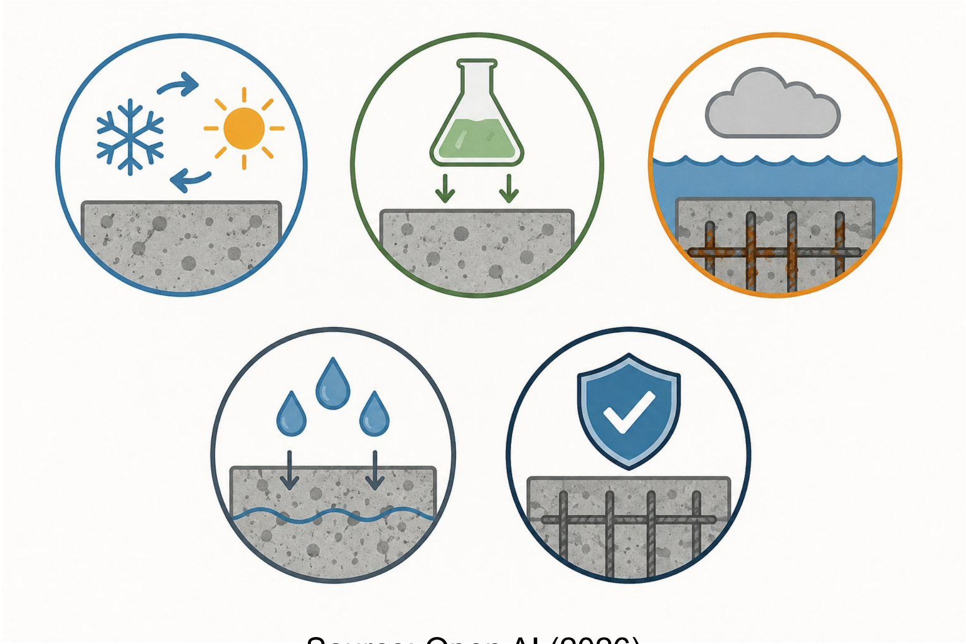
MNS	Entrained air
3/8"	3,0%
1/2"	2,5%
3/4"	2,0%
1"	1,5%
1 1/2"	1,0%
2"	0,5%
3"	0,3%
6"	0,2%

MNS	Total Air Content (%) (*)		
	Mild Exposure	**Moderate Exposure**	**Severe Exposure**
3/8"	4,50%	6,00%	7,50%
1/2"	4,00%	5,50%	7,00%
3/4"	3,50%	5,00%	6,00%
1"	3,00%	4,50%	6,00%
1 1/2"	2,50%	4,50%	5,50%
2"	2,00%	4,00%	5,00%
3"	1,50%	3,50%	4,50%
6"	1,00%	3,00%	4,00%
*	A tolerance of 1.5% is permitted		

Source: ACI 211 Comittee

Water-Cement Ratio

- Controls concrete strength, durability, and permeability directly.
- Selection depends on strength or durability governing criteria.
- Environmental exposure may impose stricter durability requirements.
- Most restrictive value ensures structural and long-term performance.



Source: Open AI (2026)

Total Fineness Modulus Concept

MNS of Coarse Aggregate	Fineness modulus of the aggregate combination with optimum workability for the indicated cement contents (bags/m³).			
	6	7	8	9
3/8"	3,96	4,04	4,11	4,19
1/2"	4,46	4,54	4,61	4,69
3/4"	4,96	5,04	5,11	5,19
1"	5,26	5,34	5,41	5,49
1 1/2"	5,56	5,64	5,71	5,79
2"	5,86	5,94	6,01	6,09
3"	6,16	6,24	6,31	6,39

Source: Staton Walker

Aggregate Proportioning Equations

$$r_f = \frac{m_g - m}{m_g - m_f} \times 100$$

$$m = r_f \times m_f + r_g \times m_g$$

Where:

m : Fineness modulus of the aggregate combination

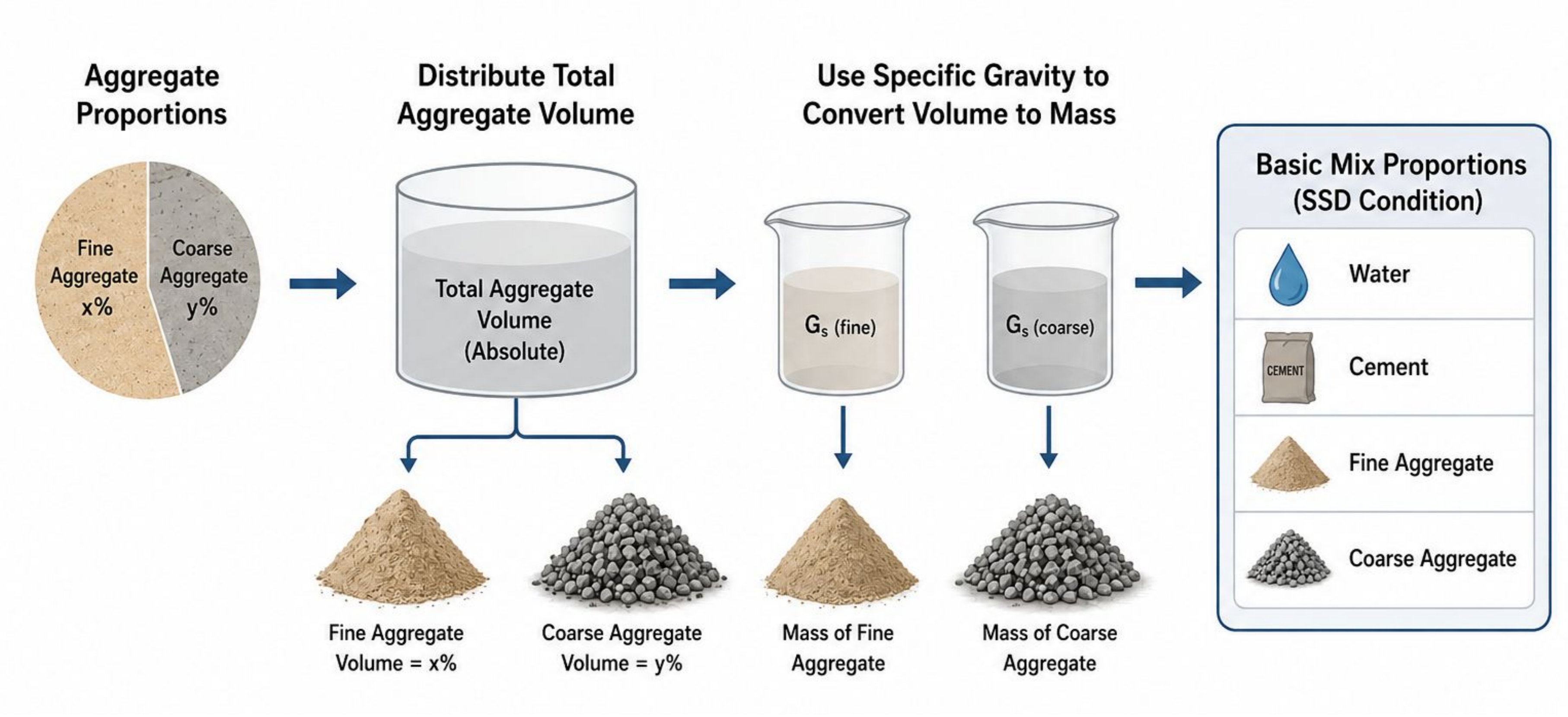
mf : Fineness modulus of the fine aggregate

mg : Fineness modulus of the coarse aggregate

rf : % Fine aggregate relative to the absolute aggregate volume

rg : % Coarse aggregate relative to the absolute aggregate volume

Absolute Aggregate Volumes



Source: Open AI (2026)

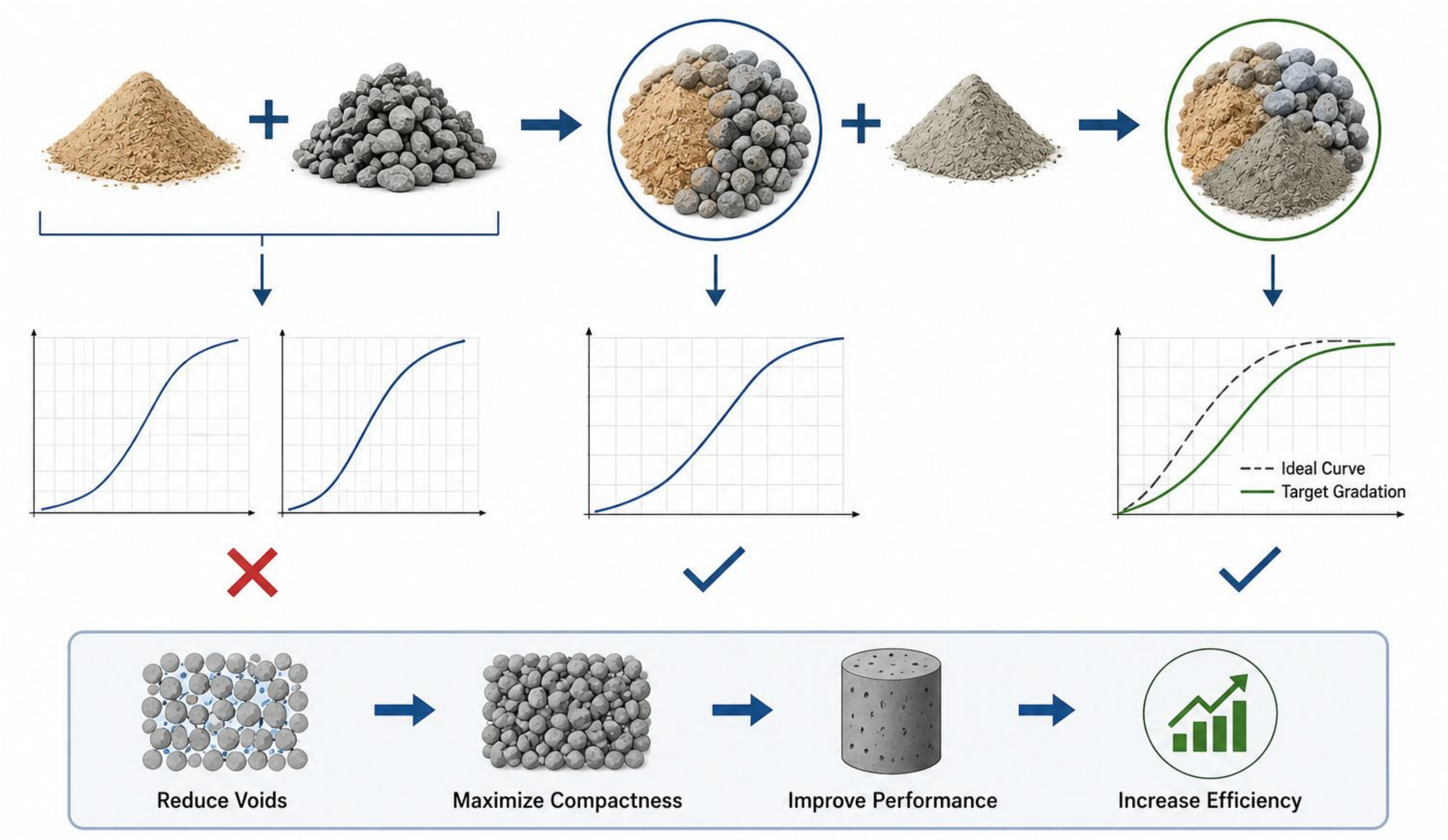
Moisture Correction

- Remaining steps follow same procedure as ACI method.
- Real aggregates rarely remain in SSD condition.
- Surface moisture changes effective mass and water content.
- Moisture correction ensures accurate field batching proportions.

Moist aggregate
Source: Suryakanta. (2015)

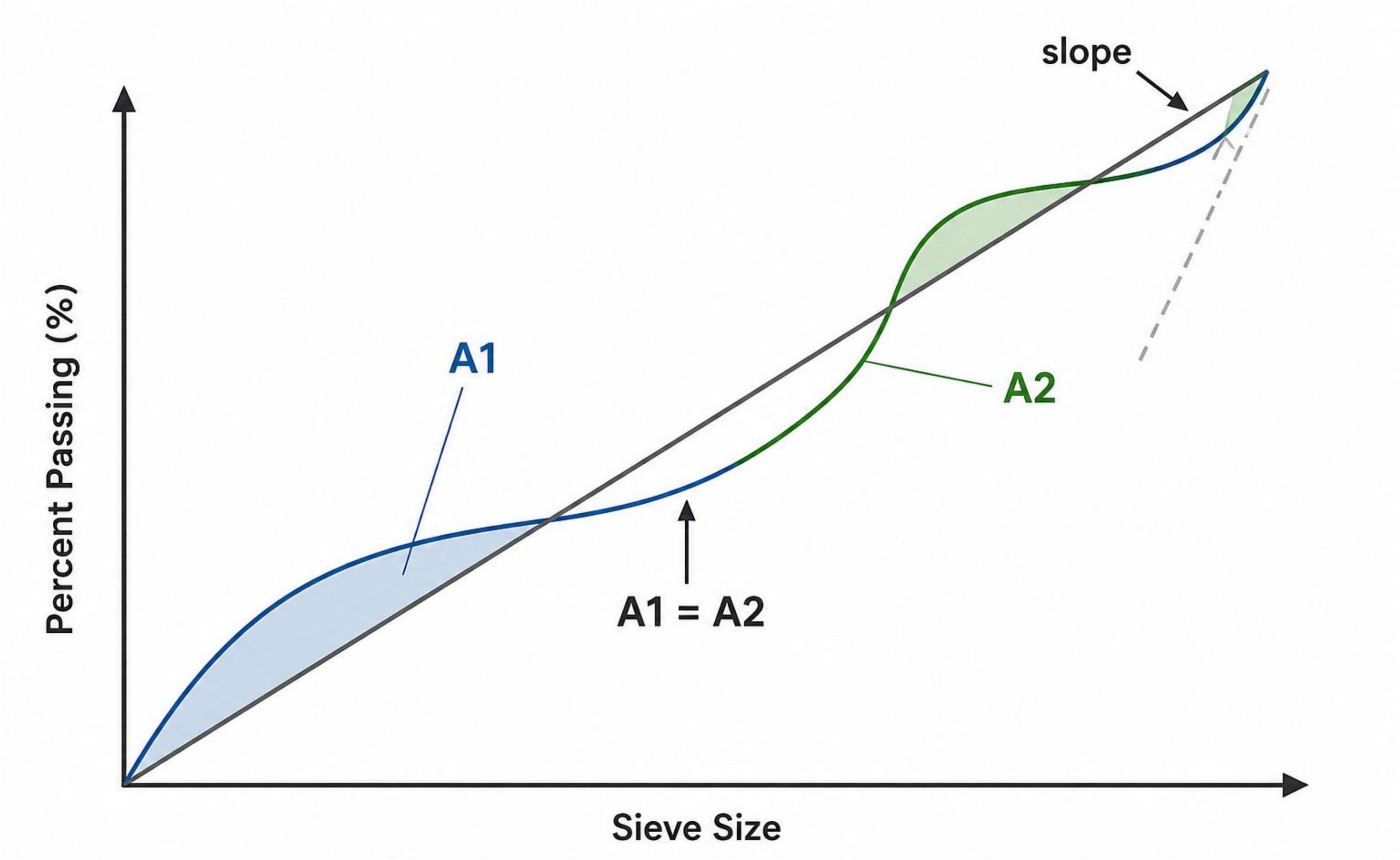
Theoretical curves method

Global Gradation Concept



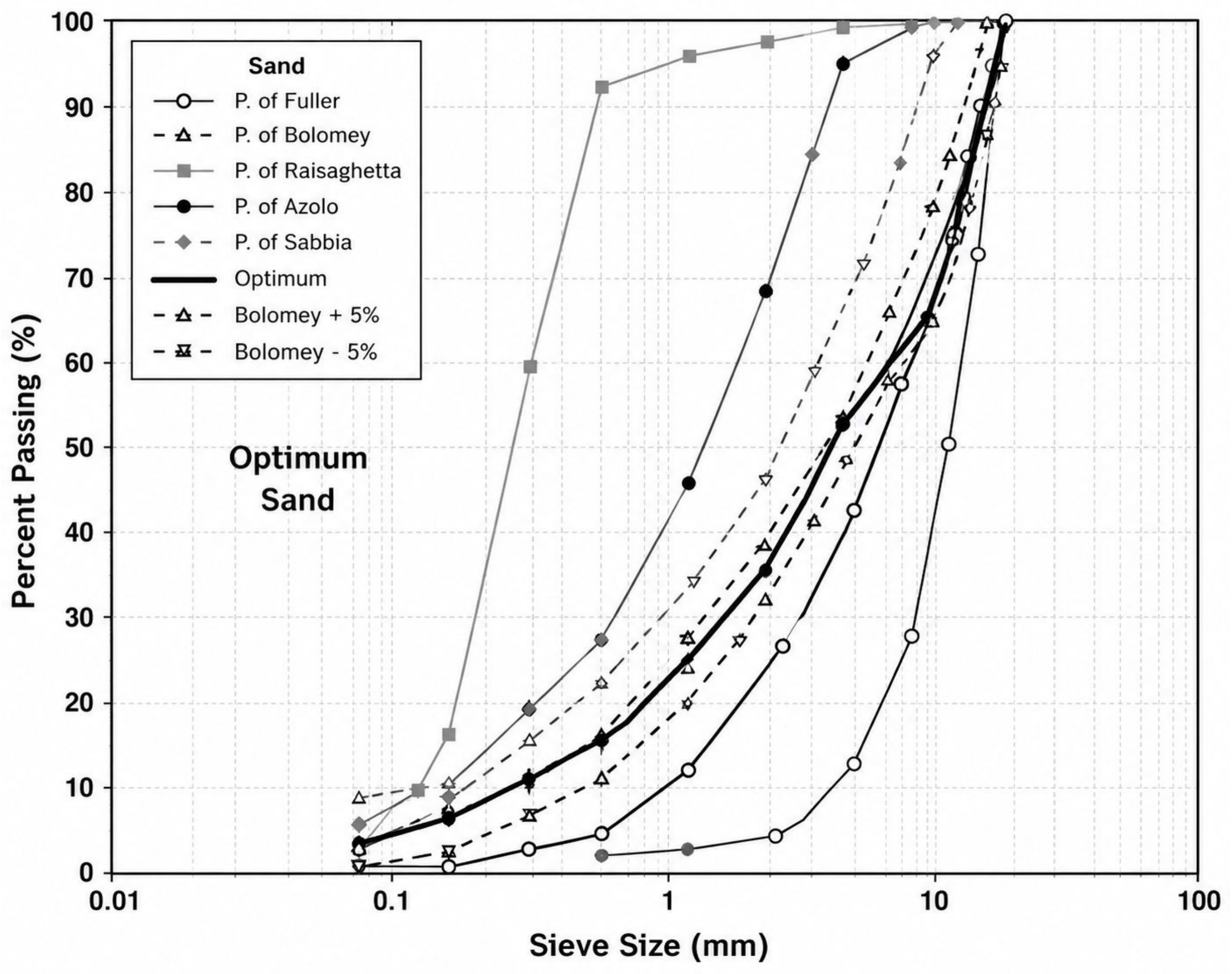
Source: Open AI (2026)

Area Compensation Principle



Source: Open AI (2026)

Theoretical Curve Contributors



Source: Neville, A. M. (2011)

Mathematical Formulation of Curves

Fuller	$y = 100 \times \sqrt{\dfrac{d}{D}}$
Bolomey	$y = 10 + 90 \times \sqrt{\dfrac{d}{D}}$
Popovics	$y = 15 + 85 \times \left(\dfrac{d}{D}\right)^{0.74}$

Source: Neville, A. M. (2011)

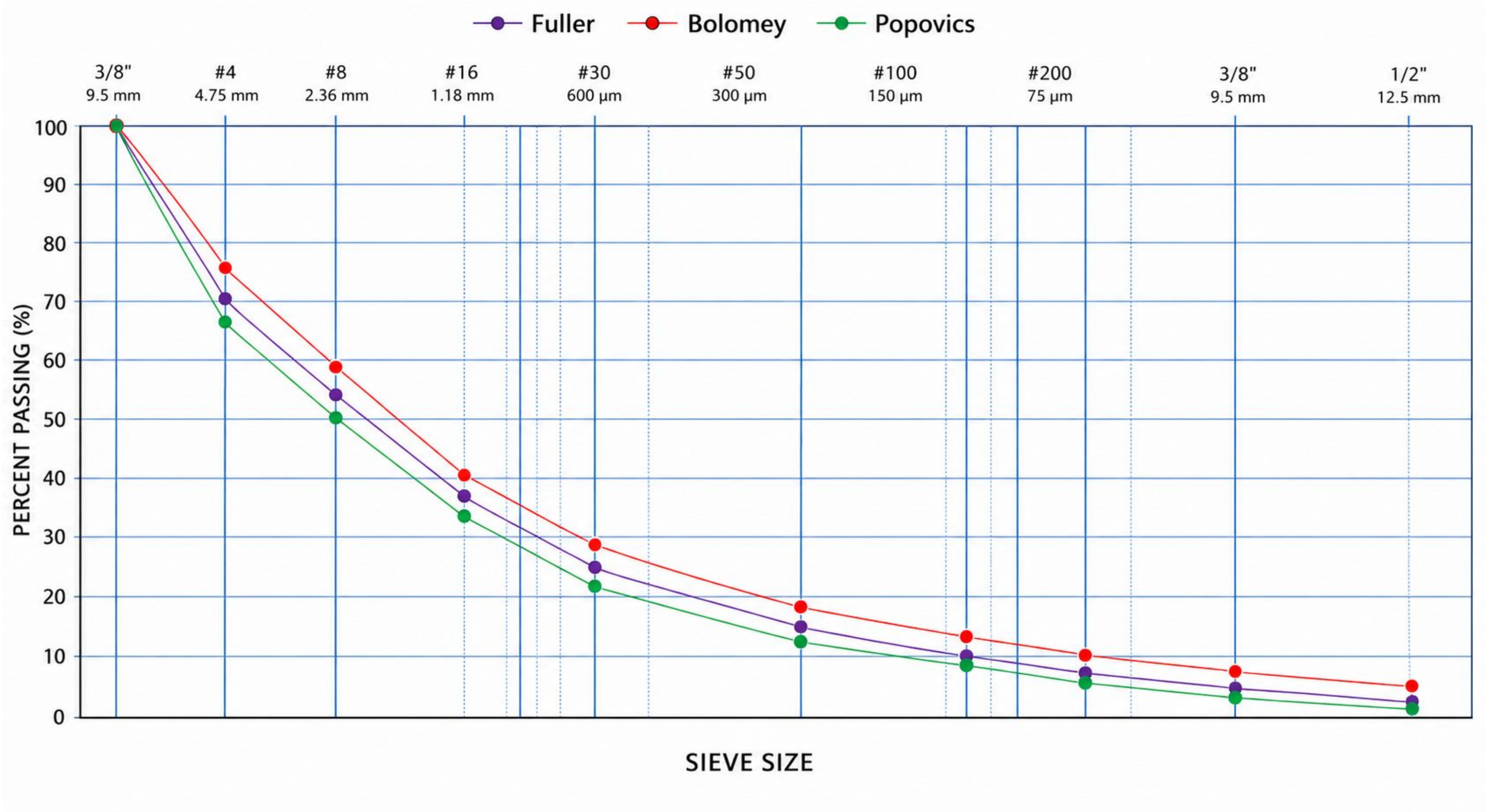
Where:

y : Cumulative percent passing

d : Sieve opening

D : Maximum aggregate size (TM)

Comparison of Theoretical Curves



Source: Author´s own ellaboration

Initial Design Sequence

- Begins identically to the traditional ACI procedure.
- First step determines required average compressive strength.
- Standard deviation used when historical data exists.
- Additional safety margin applied without prior database.

Maximum Aggregate Size Selection

- Theoretical curves method uses maximum aggregate size, not nominal maximum size.
- Maximum size defines equations for ideal gradation curve construction.
- Maximum size: smallest sieve passing 100% of aggregate sample.
- Usually one sieve larger than nominal maximum size.

Design Slump Selection

Type of Construction	Maximum	Minimum
Reinforced footings and foundation walls	3"	1"
Plain foundations, caissons, and wall substructures	3"	1"
Reinforced beams and walls	4"	1"
Building columns	4"	1"
Slabs and pavements	3"	1"
Cyclopean concrete	2"	1"

Source: ACI 211 Comittee

Design Water Content Determination

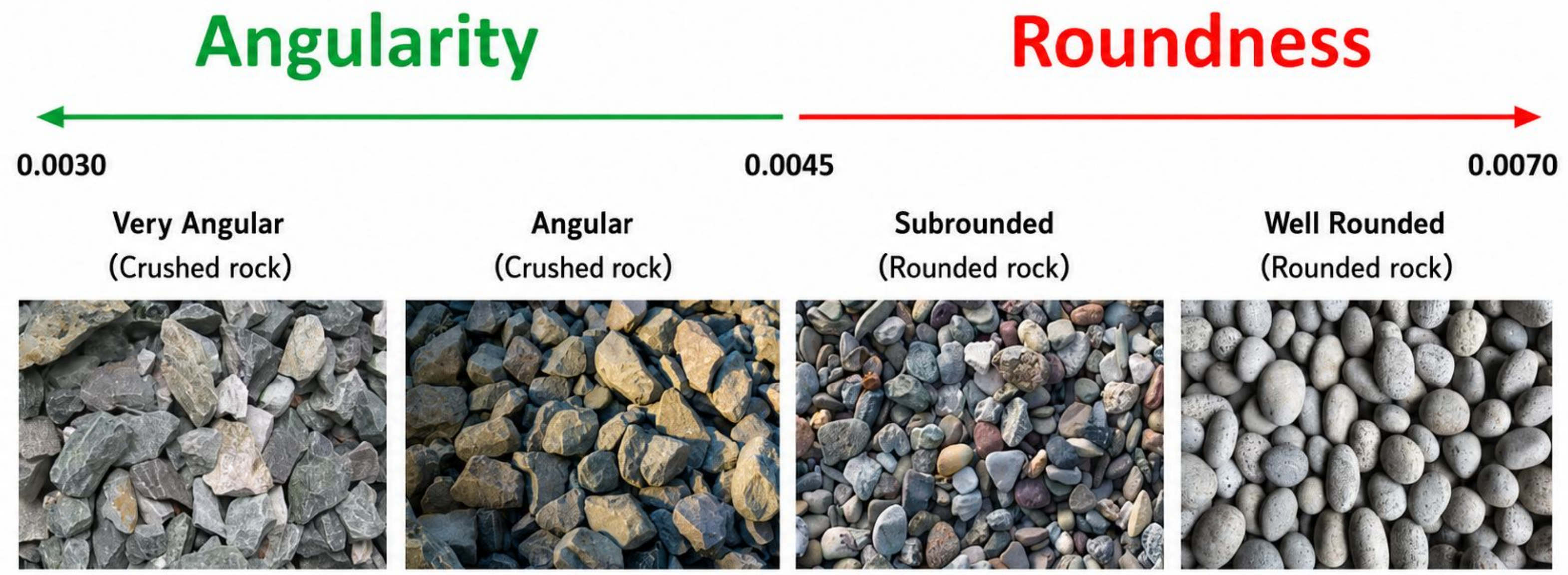
Approximate water content for different slumps and maximum aggregate sizes							
Water content in concrete							
Maximum Aggregate Size		Slump 25–50 mm		Slump 75–100 mm		Slump 150–175 mm	
		Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)	Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)	Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)
mm	in						
9,5	3/8	190	210	200	225	230	255
19	3/4	170	195	190	210	210	225
38,1	1 1/2	160	170	170	190	190	210
50,8	2	150	165	165	180	180	195
76,2	3	135	155	155	165	160	185

Source: Neville, A. M. (2011)

Water-Cement Ratio Using Parameter Z

$$Z = K_1 \times R_m + 0.5$$

K1: Shape factor	
Crushed rock	0.0030 to 0.0045
Rounded rock	0.0045 to 0.0070



Source: Author's own elaboration

Where:

Z: Cement/Water ratio

K_1: Shape factor

Rm: Required average strength = f'cr

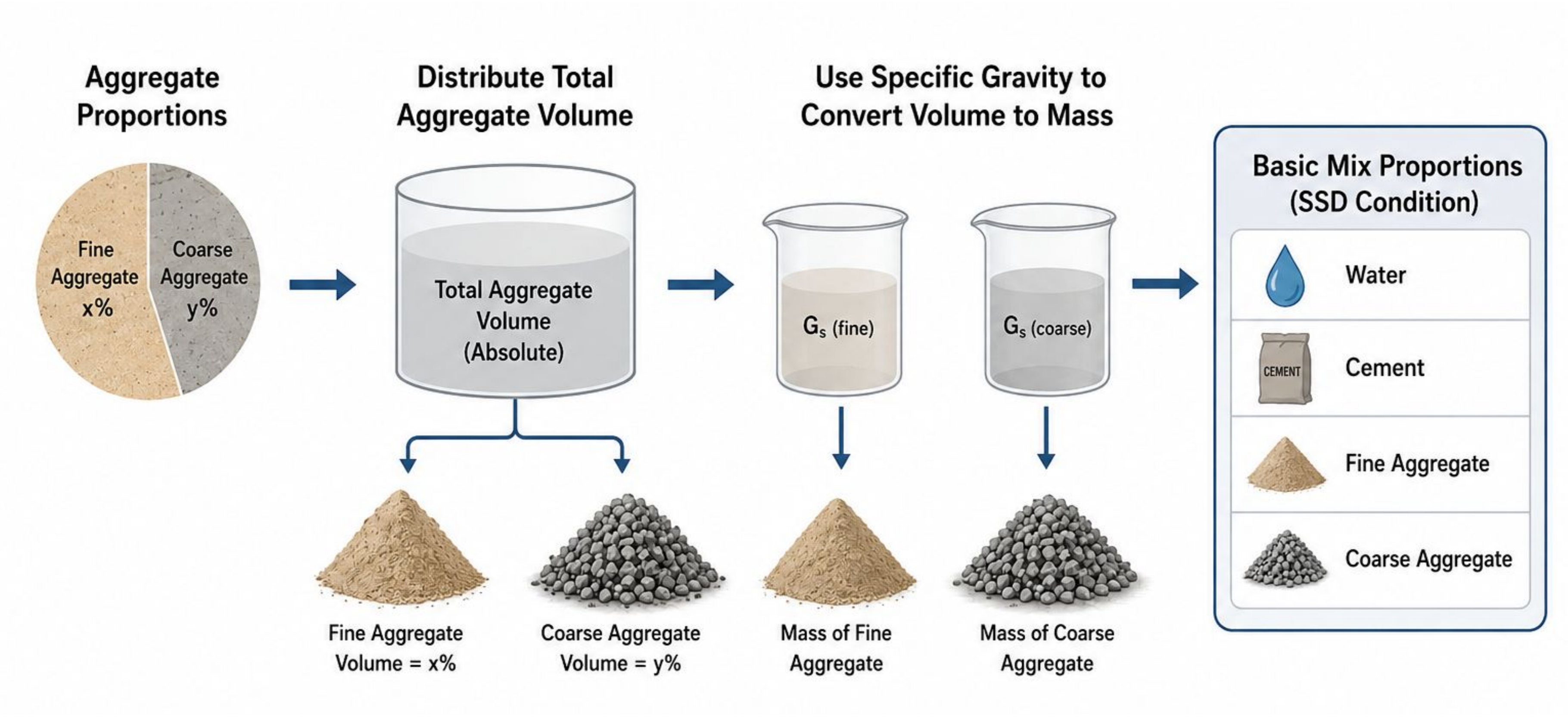
Air Content Selection

MNS	Entrained air
3/8"	3,0%
1/2"	2,5%
3/4"	2,0%
1"	1,5%
1 1/2"	1,0%
2"	0,5%
3"	0,3%
6"	0,2%

MNS	Total Air Content (%) (*)		
	Mild Exposure	Moderate Exposure	Severe Exposure
3/8"	4,50%	6,00%	7,50%
1/2"	4,00%	5,50%	7,00%
3/4"	3,50%	5,00%	6,00%
1"	3,00%	4,50%	6,00%
1 1/2"	2,50%	4,50%	5,50%
2"	2,00%	4,00%	5,00%
3"	1,50%	3,50%	4,50%
6"	1,00%	3,00%	4,00%
*	A tolerance of 1.5% is permitted		

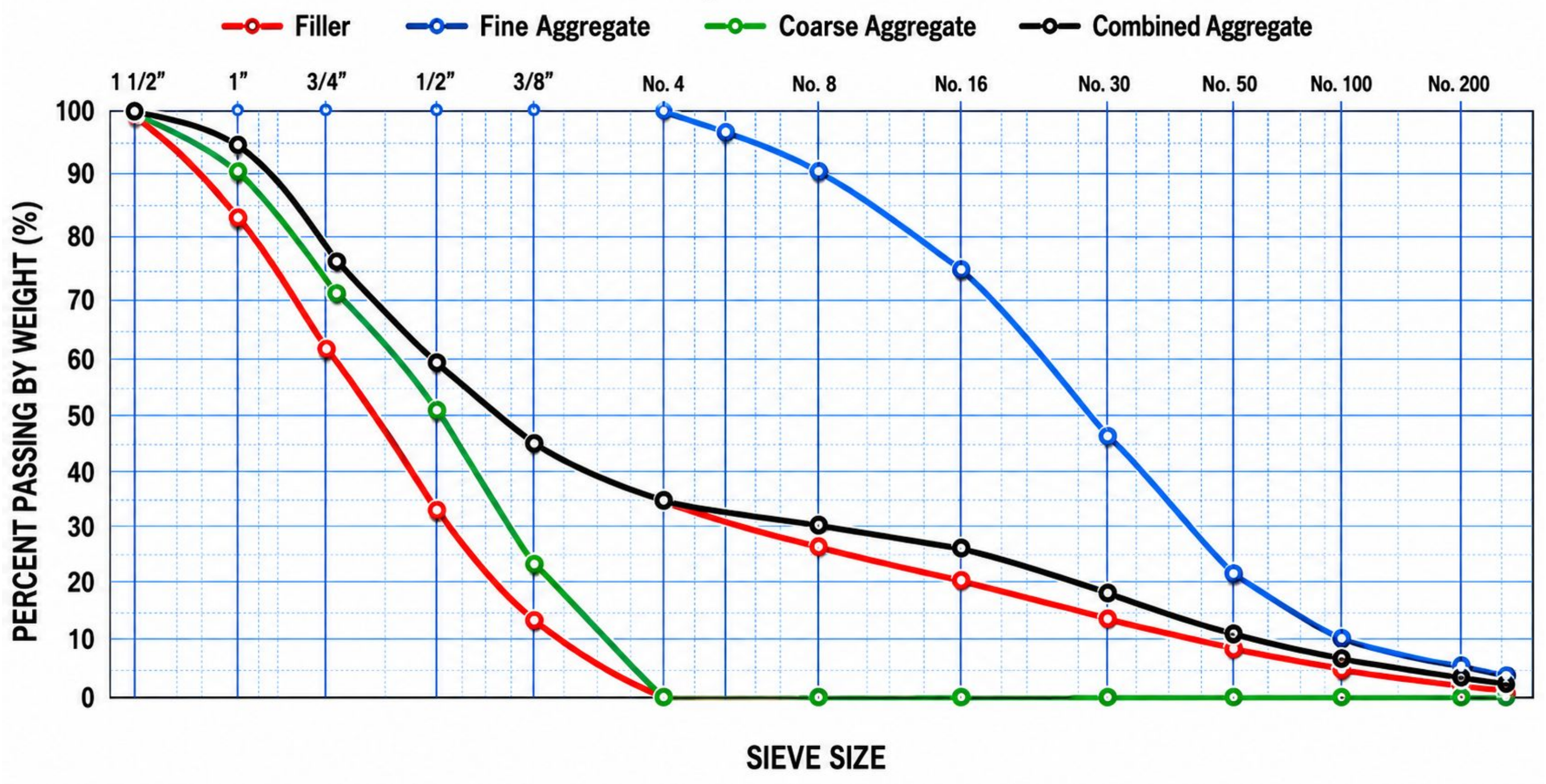
Source: ACI 211 Comittee

Total Aggregate Volume Calculation



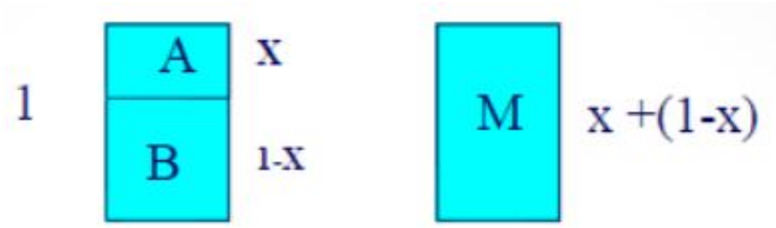
Source: Open AI (2026)

Applying the Theoretical Curve Principle



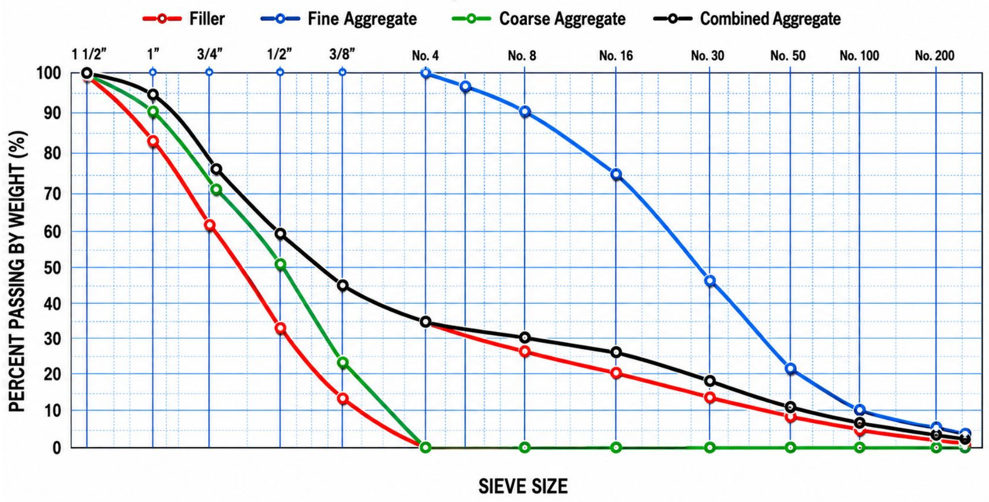
Source: Author´s own ellaboration

Aggregate Combination Procedure



- A: Fine aggregate
- B: Coarse aggregate

$$m = a.x + (1 - x).b$$



$$X = \frac{b - m}{b - a}$$

Where:

m: % of material passing the No. 4 sieve → Combination: Theoretical curve

a: % of material passing the No. 4 sieve → Fine Aggregate

b: % of material passing the No. 4 sieve → Coarse Aggregate

X: % of fine aggregate in the combination

Aggregate Weight Determination

- Aggregate percentages applied to total aggregate absolute volume.
- Specific gravity converts volumes into aggregate mass values.
- Basic concrete proportioning is now fully established.
- Moisture correction required to obtain actual field proportions.

Moist aggregate
Source: Suryakanta. (2015)

Applied case studies

1st Applied case: ACI mix design method

Data

Element: Beams and columns

There is no risk of freezing and thawing, sulfate attack, or presence of chloride ions.

- $f'c = 210\,\mathrm{kgf/cm^2}$
- $s = 20\,\mathrm{kgf/cm^2}$

Materials

Portland Cement

Type I

Specific gravity: 3.15 g/cm³

Potable Water

Fine Aggregate

- Specific gravity: 2.64 g/cm³
- Absorption: 0.70%
- Moisture content: 6.00%
- Fineness modulus (FM): 2.8

Coarse Aggregate

- Nominal maximum size (NMS): 1 1/2"
- Dry rodded unit weight: 1600.00 kg/m³
- Specific gravity: 2.68 g/cm³
- Absorption: 0.50%
- Moisture content: 2.00%

Select the average strength $(f'cr)$ based on the specified compressive strength $(f'c)$ and the standard deviation (s)

- $f'c = 210\,\mathrm{kgf/cm^2}$
- $s = 20\,\mathrm{kgf/cm^2}$

Equation 1

$$f'cr = f'c + 1.34s$$

$$f'cr = 236.8\,\mathrm{kgf/cm^2}$$

Equation 2

$$f'cr = f'c + 2.33s - 35$$

$$f'cr = 221.6\,\mathrm{kgf/cm^2}$$

Selected value:

$$f'cr = 237\,\mathrm{kgf/cm^2}$$

1st Applied case: ACI mix design method

Since it is intended for **columns and beams**, and the concrete is required to be **plastic**, the selected **slump** will be: **3" to 4"**.

Slump	Water (L/m³) for the indicated maximum nominal size (MNS) of coarse aggregate and consistency							
	3/8"	1/2"	3/4"	1"	1 1/2"	2"	3"	6"
Non-air-entrained								
1" to 2"	207	199	190	179	166	154	130	113
3" to 4"	228	216	205	193	181	169	145	124
6" to 7"	243	228	216	202	190	178	160	-
Air-entrained								
1" to 2"	181	175	168	160	150	142	122	107
3" to 4"	202	193	184	175	165	157	133	119
6" to 7"	216	205	197	184	174	166	154	-

MNS	Entrained air
3/8"	3,0%
1/2"	2,5%
3/4"	2,0%
1"	1,5%
1 1/2"	1,0%
2"	0,5%
3"	0,3%
6"	0,2%

1st Applied case: ACI mix design method

Since it is not exposed to factors that could compromise its durability, the water-cement ratio (w/c) will be calculated based on the required strength.

f'cr (28 days)	Design w/c ratio, by weight	
	Non-air-entrained concrete	Air-entrained concrete
150	0,8	0,71
200	0,7	0,61
250	0,62	0,53
300	0,55	0,46
350	0,48	0,4
400	0,43	-
450	0,38	-

It does not contain entrained air. Therefore, the value is:

Interpolating…

- *x = 237 f'cr*
- $x_1 = 200$
- $x_2 = 250$
- $y_1 = 0.70$
- $y_2 = 0.62$
- ***y = 0.6408*** **w/c ratio (water-cement ratio)**

$$y = \frac{(x - x_1)}{(x_2 - x_1)}(y_2 - y_1) + y_1$$

Determine the cement factor:

- **w/c = 0.6408**
- **Water = 181**
- **Cement = 282.46 = 6.6 bags**

1st Applied case: ACI mix design method

MNS of Coarse Aggregate	Volume of coarse aggregate, dry-rodded, per unit volume of concrete, for various fineness moduli			
	2,4	**2,6**	**2,8**	**3**
3/8"	0,50	0,48	0,46	0,44
1/2"	0,59	0,57	0,55	0,53
3/4"	0,66	0,64	0,62	0,60
1"	0,71	0,69	0,67	0,65
1 1/2"	0,76	0,74	0,72	0,70
2"	0,78	0,76	0,74	0,72
3"	0,81	0,79	0,77	0,75
6"	0,87	0,85	0,83	0,81

- NMAS (Nominal Maximum Aggregate Size) = 1 1/2"
- Fine Aggregate FM (Fineness Modulus) = 2.8
- Coarse Aggregate Volume = 0.72 m^3
- Dry Rodded Unit Weight of Coarse Aggregate = 1600.00 kg/m^3

Coarse Aggregate Weight = Coarse Aggregate Volume × Dry Rodded Unit Weight of Coarse Aggregate

Coarse Aggregate Weight = 1152 kg

1st Applied case: ACI mix design method

Determine the sum of the absolute volumes of cement, design water, air, and coarse aggregate:

Material	Weight per m³ of concrete	Specific Gravity / Unit Weight	Absolute Volume
Cement	282 kg	3150 kg/m³	0.090 m³
Water	181 L	1000 L/m³	0.181 m³
Air	1.0%	—	0.010 m³
Coarse Aggregate	1152 kg	2680 kg/m³	0.430 m³
Total			**0.711 m³**

Determine the absolute volume of fine aggregate:

Fine Aggregate Volume = 1 m³ − sum of the remaining components = 0.289 m³

Determine the dry weight of fine aggregate:

Fine Aggregate Weight = Fine Aggregate Volume × Specific Gravity of Fine Aggregate

Fine Aggregate Weight = 764 kg

Determine the design values for cement, water, air, fine aggregate, and coarse aggregate:

Weights per m³ of Concrete

- **Cement: 282 kg**
- **Water: 181 L**
- **Dry Fine Aggregate: 764 kg**
- **Dry Coarse Aggregate: 1152 kg**

1st Applied case: ACI mix design method

Correct the values for aggregate moisture:

Wet aggregate weights → Dry weight × moisture content

- Fine Aggregate = 810 kg
- Coarse Aggregate = 1175 kg

Surface moisture → Moisture content − Absorption

- Fine Aggregate = 5.30%
- Coarse Aggregate = 1.50%

Moisture contribution from aggregates → Dry weight × surface moisture

- Fine Aggregate = 41 L
- Coarse Aggregate = 17 L
- **Total = 58 L**

Corrected weights per m³ of concrete

- **Cement = 282 kg**
- **Water = 123 L**
- **Fine Aggregate (wet) = 810 kg**
- **Coarse Aggregate (wet) = 1175 kg**

	Fine Aggregate	Coarse Aggregate
Moisture Content	6.00%	2.00%
Absorption	0.70%	0.50%

2nd Applied case: Global fineness modulus mix design method

Data

Element: Stadium bleachers

Specified compressive strength (f'c): 245 kgf/cm²

Standard deviation (s): 28 kgf/cm²

Materials

Portland Cement (Type I):

Specific gravity: 3.12 g/cm³.

Water:

Well water (meets the required specifications)

Fine Aggregate:

- Specific gravity: 2.68 g/cm³
- Absorption: 1.20%
- Moisture content: 3.00%
- Fineness modulus: 2.75

Coarse Aggregate:

- Nominal maximum aggregate size (NMAS): 1"
- Dry rodded unit weight: 1650.00 kg/m³
- Specific gravity: 2.62 g/cm³
- Absorption: 0.40%
- Moisture content: 1.30%
- Fineness modulus: 7.02

Select the average strength (f'cr) based on the specified compressive strength (f'c) and the standard deviation (s):

f'c = 245 kgf/cm²
s = 28 kgf/cm²

Equation 1
fcr′=fc′+1.34sf'_{cr}=f'_c+1.34sfcr′=fc′+1.34s

f'cr = 282.52 kgf/cm²

Equation 2
fcr′=fc′+2.33s−35f'_{cr}=f'_c+2.33s-35fcr′=fc′+2.33s−35

f'cr = 275.24 kgf/cm²

Choose the higher value:
f'cr = 283 kgf/cm²

2nd Applied case: Global fineness modulus mix design method

Since it is intended for **stadium bleachers**, and the concrete is required to be **plastic**, the selected **slump** will be: **3" to 4"**.

Slump	Water (L/m³) for the indicated maximum nominal size (MNS) of coarse aggregate and consistency							
	3/8"	1/2"	3/4"	1"	1 1/2"	2"	3"	6"
Non-air-entrained								
1" to 2"	207	199	190	179	166	154	130	113
3" to 4"	228	216	205	193	181	169	145	124
6" to 7"	243	228	216	202	190	178	160	-
Air-entrained								
1" to 2"	181	175	168	160	150	142	122	107
3" to 4"	202	193	184	175	165	157	133	119
6" to 7"	216	205	197	184	174	166	154	-

MNS	Entrained air
3/8"	3,0%
1/2"	2,5%
3/4"	2,0%
1"	1,5%
1 1/2"	1,0%
2"	0,5%
3"	0,3%
6"	0,2%

2nd Applied case: Global fineness modulus mix design method

Since it is not exposed to factors that could compromise its durability, the water-cement ratio (w/c) will be calculated based on the required strength.

f'cr (28 days)	Design w/c ratio, by weight	
	Non-air-entrained concrete	Air-entrained concrete
150	0,8	0,71
200	0,7	0,61
250	0,62	0,53
300	0,55	0,46
350	0,48	0,4
400	0,43	-
450	0,38	-

It does not contain entrained air. Therefore, the value is:

Interpolating…

- *x = 283   f'cr*
- *x_1 = 250*
- *x_2 = 300*
- *y_1 = 0.62*
- *y_2 = 0.55*
- ***y = 0.5738   w/c ratio (water-cement ratio)***

$$y = \frac{(x - x_1)}{(x_2 - x_1)}(y_2 - y_1) + y_1$$

Determine the cement factor:

- **w/c ratio: 0.5738**
- **Water: 193 L**
- **Cement: 336.35 kg**
- **Equivalent to: 7.9 bags of cement**

2nd Applied case: Global fineness modulus mix design method

Material	Weight per m³ of concrete	Specific Gravity / Unit Weight	Absolute Volume
Cement	336 kg	3120 kg/m³	0.108 m³
Water	193 L	1000 L/m³	0.193 m³
Air	1.5%	—	0.015 m³
Total			**0.316 m³**

Determine the sum of the absolute volumes of cement, design water, and air:

Determine the absolute volume of total aggregate:

Total Aggregate Volume = 1 m³ − sum of the remaining components = 0.684 m³

MNS of Coarse Aggregate	Fineness modulus of the aggregate combination with optimum workability for the indicated cement contents (bags/m³).			
	6	7	8	9
3/8"	3,96	4,04	4,11	4,19
1/2"	4,46	4,54	4,61	4,69
3/4"	4,96	5,04	5,11	5,19
1"	5,26	5,34	5,41	5,49
1 1/2"	5,56	5,64	5,71	5,79
2"	5,86	5,94	6,01	6,09
3"	6,16	6,24	6,31	6,39

It does not contain entrained air. Therefore, the value is:

Interpolating…

$$y = \frac{(x - x_1)}{(x_2 - x_1)}(y_2 - y_1) + y_1$$

- *x = 7.9 Bags*
- *x_1 = 7*
- *x_2 = 8*
- *y_1 = 5.34*
- *y_2 = 5.41*
- ***y = 5.403 Total FM = m***

2nd Applied case: Global fineness modulus mix design method

Calculate **rf** (percentage of fine aggregate relative to the total absolute volume of aggregate):

m = 5.403
mf = 2.75
mg = 7.02
rf = **37.87%**

$$r_f = \frac{m_g - m}{m_g - m_f} \times 100$$

Determine the absolute volumes of the aggregates:

Total Aggregate Volume = 0.684 m³
Fine Aggregate Percentage = 37.87%

Fine Aggregate Volume = Total Aggregate Volume × Fine Aggregate Percentage = **0.259 m³**

Coarse Aggregate Volume = Total Aggregate Volume − Fine Aggregate Volume = **0.425 m³**

Determine the dry weights of fine and coarse aggregates:

- Cement = 336 kg
- Water = 193 L
- Dry Fine Aggregate (specific gravity = 2680 kg/m³) = **694 kg**
- Dry Coarse Aggregate (specific gravity = 2620 kg/m³) = **1114 kg**

	Fine Aggregate	**Coarse Aggregate**
Moisture Content	3.00%	1.30%
Absorption	1.20%	0.40%

Correct the values for aggregate moisture:

Wet aggregate weights → Dry weight × moisture content

- Fine Aggregate = **715 kg**
- Coarse Aggregate = **1128 kg**

Surface moisture → Moisture content − Absorption

- Fine Aggregate = **1.80%**
- Coarse Aggregate = **0.90%**

Moisture contribution from aggregates → Dry weight × surface moisture

- Fine Aggregate = **12 L**
- Coarse Aggregate = **10 L**
- **Total = 23 L**

Corrected weights per m³ of concrete

- **Cement = 336 kg**
- **Water = 170 L**
- **Fine Aggregate (wet) = 715 kg**
- **Coarse Aggregate (wet) = 1128 kg**

3rd Applied case: Theoretical curves mix design method

Data

Element: Building columns.

Exposure conditions: No risk of freezing and thawing, sulfate attack, or presence of chloride ions.

Specified compressive strength (f'c): 210 kgf/cm².

Standard deviation (s): No data available.

Materials

Portland Cement (Type IPM):

Specific gravity: 2.92 g/cm³

Water:

Potable water

Fine Aggregate:

- Specific gravity: 2.439 g/cm³
- Absorption: 1.67%
- Moisture content: 0.10%
- Fineness modulus: 2.7

Angular Coarse Aggregate:

- Nominal maximum aggregate size (NMAS): 1"
- Dry rodded unit weight: 1414.00 kg/m³
- Specific gravity: 2.500 g/cm³
- Absorption: 0.40%
- Moisture content: 0.05%

Select the average strength (f'cr) based on the specified compressive strength (f'c) and the standard deviation (s):

f'c = 210 kgf/cm²
s = No data available

Since the standard deviation is not available, we must use the following table:

f'c (Mpa)	f'cr
Less than 21	f'c + 7.0
21 to 35	f'c + 8.5
More than 35	1.1*f'c + 5.0

Since f'c = 210 kgf/cm² ≈ 21 MPa, the resulting value is: f'**cr = 295 kgf/cm².**

3rd Applied case: Theoretical curves mix design method

SIEVE SIZE	D (mm)	FINE AGGREGATE			
		RET. WEIGHT	% RET.	CUM. % RET.	% PASSING
1 1/2"	38.1	0.000	0.000	0.000	100.000
1"	25.400	0.000	0.000	0.000	100.000
3/4"	19.000	0.000	0.000	0.000	100.000
1/2"	12.700	0.000	0.000	0.000	100.000
3/8"	9.510	0.000	0.000	0.000	100.000
No. 4	4.750	5.200	0.954	0.954	99.046
No. 8	2.380	65.800	12.067	13.020	86.980
No. 16	1.190	94.300	17.293	30.314	69.686
No. 30	0.595	150.000	27.508	57.821	42.179
No. 50	0.297	100.000	18.338	76.160	23.840
No. 100	0.147	85.000	15.588	91.748	8.252
No. 200	0.074	30.000	5.502	97.249	2.751
PAN	0.000	15.000	2.751	100.000	0.000
		545.300			

3rd Applied case: Theoretical curves mix design method

SIEVE SIZE	D (mm)	COARSE AGGREGATE			
		RET. WEIGHT	% RET.	CUM. % RET.	% PASSING
1 1/2"	**38.1**	0.000	0.000	0.000	100.000
1"	25.400	2.000	12.937	12.937	87.063
3/4"	19.000	3.820	24.709	37.646	62.354
1/2"	12.700	3.560	23.027	60.673	39.327
3/8"	9.510	3.200	20.699	81.371	18.629
No. 4	4.750	2.780	17.982	99.353	0.647
No. 8	2.380	0.100	0.647	100.000	0.000
No. 16	1.190	0.000	0.000	100.000	0.000
No. 30	0.595	0.000	0.000	100.000	0.000
No. 50	0.297	0.000	0.000	100.000	0.000
No. 100	0.147	0.000	0.000	100.000	0.000
No. 200	0.074	0.000	0.000	100.000	0.000
PAN	0.000	0.000	0.000	100.000	0.000
		15.460			

3rd Applied case: Theoretical curves mix design method

Since it is intended for **columns** and the concrete is required to be **plastic**, the selected **slump** will be: **3" to 4"**.

Approximate water content for different slumps and maximum aggregate sizes							
Water content in concrete							
Maximum Aggregate Size		Slump 25–50 mm		Slump 75–100 mm		Slump 150–175 mm	
mm	in	Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)	Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)	Rounded Aggregate (kg/m³)	Angular Aggregate (kg/m³)
9,5	3/8	190	210	200	225	230	255
19	3/4	170	195	190	210	210	225
38,1	1 1/2	160	170	170	190	190	210
50,8	2	150	165	165	180	180	195
76,2	3	135	155	155	165	160	185

3rd Applied case: Theoretical curves mix design method

Calculate the cement/water ratio → **Z**

K1: Shape factor	
Crushed rock	0.0030 to 0.0045
Rounded rock	0.0045 to 0.0070

Selected value: **K_1 = 0.00375**

Average strength: **Rm = 295 kgf/cm²**

$$Z = K_1 \times R_m + 0.5$$

Result:
Z = **1.60625**
w/c = **0.62**

Determine the cement factor:

- **w/c ratio: 0.62**
- **Water: 190 L**
- **Cement: 305.19 kg**
- **Equivalent to: 7.2 bags of cement**

Select the entrapped and/or entrained air content.

Since **no air-entraining admixture is specified**, the concrete is assumed to have **entrapped air only**.

MNS	Entrained air
3/8"	3,0%
1/2"	2,5%
3/4"	2,0%
1"	1,5%
1 1/2"	1,0%
2"	0,5%
3"	0,3%
6"	0,2%

3rd Applied case: Theoretical curves mix design method

Determine the sum of the absolute volumes of cement, design water, and air:

Material	Weight per m^3 of concrete	Specific Gravity / Unit Weight	Absolute Volume
Cement	305.188 kg	2920 kg/m^3	0.105 m^3
Water	190 L	1000 L/m^3	0.190 m^3
Air	1.5%	—	0.015 m^3
Total			**0.310 m^3**

Determine the **Absolute Volume of Aggregates (A.V.A.)**:

Absolute Volume of Aggregates = 1 m^3 − sum of the remaining components = **0.690 m^3**

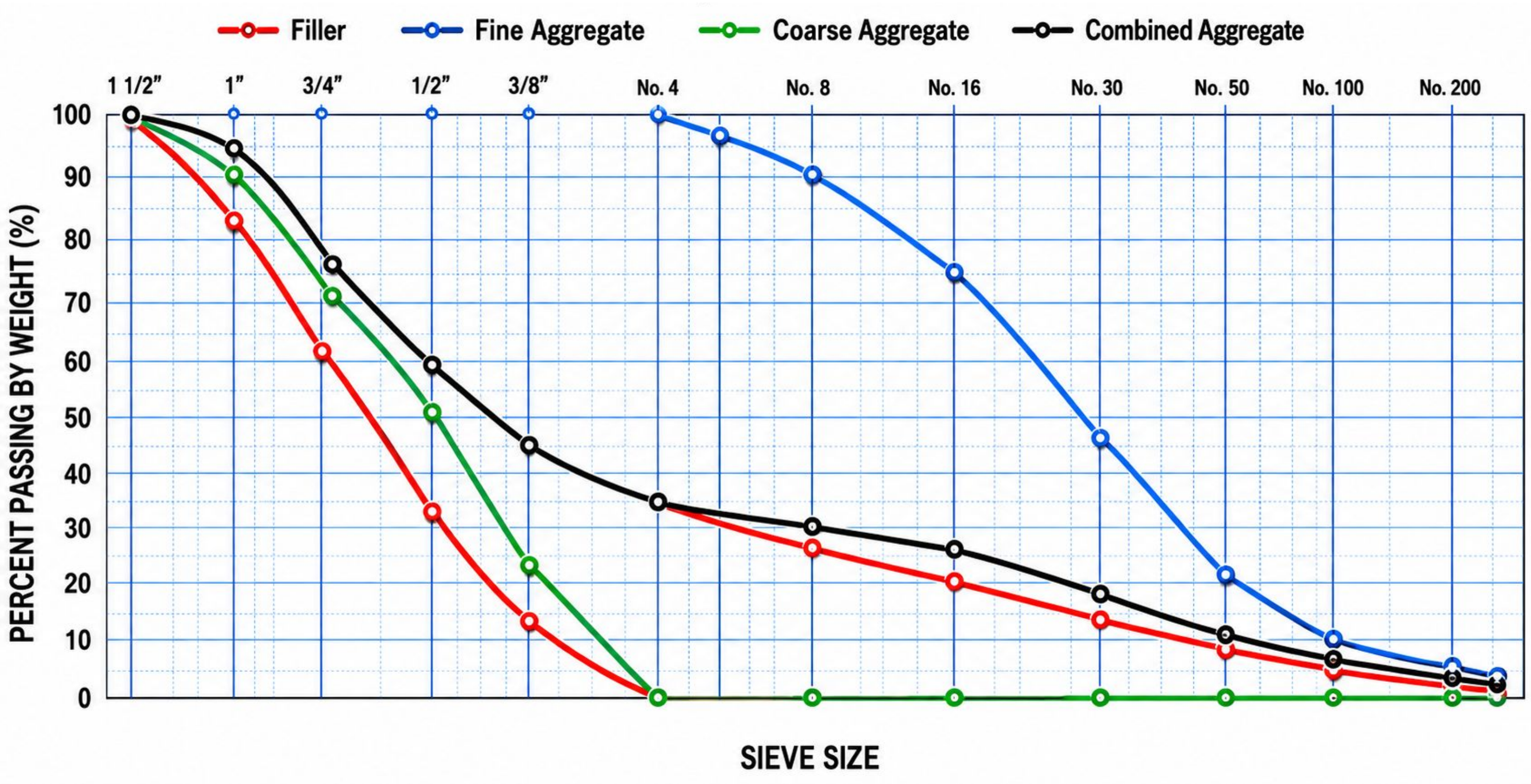
3rd Applied case: Theoretical curves mix design method

$$X = \frac{b - m}{b - a}$$

- a = 99.05%
- b = 0.65%
- m = 35.31%
- **X = % Fine Aggregate = 35.22%**
- **% Coarse Aggregate = 64.78%**

SIEVE SIZE	D (mm)	COARSE AGGREGATE % PASSING	FINE AGGREGATE % PASSING	COMBINATION OF AGGREGATES
1 1/2"	38.1	100.00	100.00	**100.00**
1"	25.400	87.06	100.00	**91.62**
3/4"	19.000	62.35	100.00	**75.62**
1/2"	12.700	39.33	100.00	**60.70**
3/8"	9.510	18.63	100.00	**47.29**
No. 4	4.750	0.65	99.05	**35.31**
No. 8	2.380	0.00	86.98	**30.64**
No. 16	1.190	0.00	69.69	**24.55**
No. 30	0.595	0.00	42.18	**14.86**
No. 50	0.297	0.00	23.84	**8.40**
No. 100	0.147	0.00	8.25	**2.91**
No. 200	0.074	0.00	2.75	**0.97**
PAN	0.000	0.00	0.00	**0.00**

3rd Applied case: Theoretical curves mix design method



3rd Applied case: Theoretical curves mix design method

Calculation of Aggregate Weights

Fine Aggregate Volume = 0.243 m³
Dry Fine Aggregate Weight = 593 kg

Coarse Aggregate Volume = 0.447 m³
Dry Coarse Aggregate Weight = 1118 kg

Determine the design values for cement, water, air, fine aggregate, and coarse aggregate

Weights per m³ of Concrete

- **Cement = 305 kg**
- **Water = 190 L**
- **Dry Fine Aggregate = 593 kg**
- **Dry Coarse Aggregate = 1118 kg**

	Fine Aggregate	**Coarse Aggregate**
Moisture Content	0.10%	0.05%
Absorption	1.67%	0.40%

Correct the values for aggregate moisture:

Wet aggregate weights → Dry weight × moisture content

- Fine Aggregate = **594 kg**
- Coarse Aggregate = **1119 kg**

Surface moisture → Moisture content − Absorption

- Fine Aggregate = **−1.57%**
- Coarse Aggregate = **−0.35%**

(*Negative values indicate the aggregates will absorb water from the mix.*)

Moisture contribution from aggregates → Dry weight × surface moisture

- Fine Aggregate = **−9 L**
- Coarse Aggregate = **−4 L**
- **Total = −13 L**

Corrected weights per m³ of concrete

- Cement = **305 kg**
- Water = **203 L**
- Fine Aggregate (wet) = **594 kg**
- Coarse Aggregate (wet) = **1119 kg**

Conclusions

- Concrete mix design is an empirical, iterative, and adaptable engineering process.
- ACI, global fineness modulus, and theoretical curves share the same foundation.
- Their main difference lies in how aggregate proportions are determined.
- Aggregate gradation optimization improves workability, compactness, and design efficiency.
- No single method is universally superior; selection depends on project conditions.
- Proper moisture correction is essential to achieve expected field performance.
- Effective mix design requires understanding material interaction, not only calculations.

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Course: Concrete Technology

Lecture 11: Alternative Mix Design Methods

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