Concrete for Road Pavements

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Scope

- Strength
- Shrinkage
- Abrasion resistance
- Skid resistance
- Durability
- Plastic properties

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Scope (cont.)

- Materials
- Mix proportions
- Admixtures
- Handling and placing
- Curing
- Variability
- Specifications

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Concrete Strength

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General

- Compressive to SANS 5863
- Flexural to SANS 5864
- Indirect tensile to SANS 6253

- Most important is flexural but ITS plays role in cracking of CRCP

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Flexural strength

Flexural strength

- Often called Modulus of Rupture
- Can be single point or two-point (third-point) loading
- Single gives higher values and is more variable

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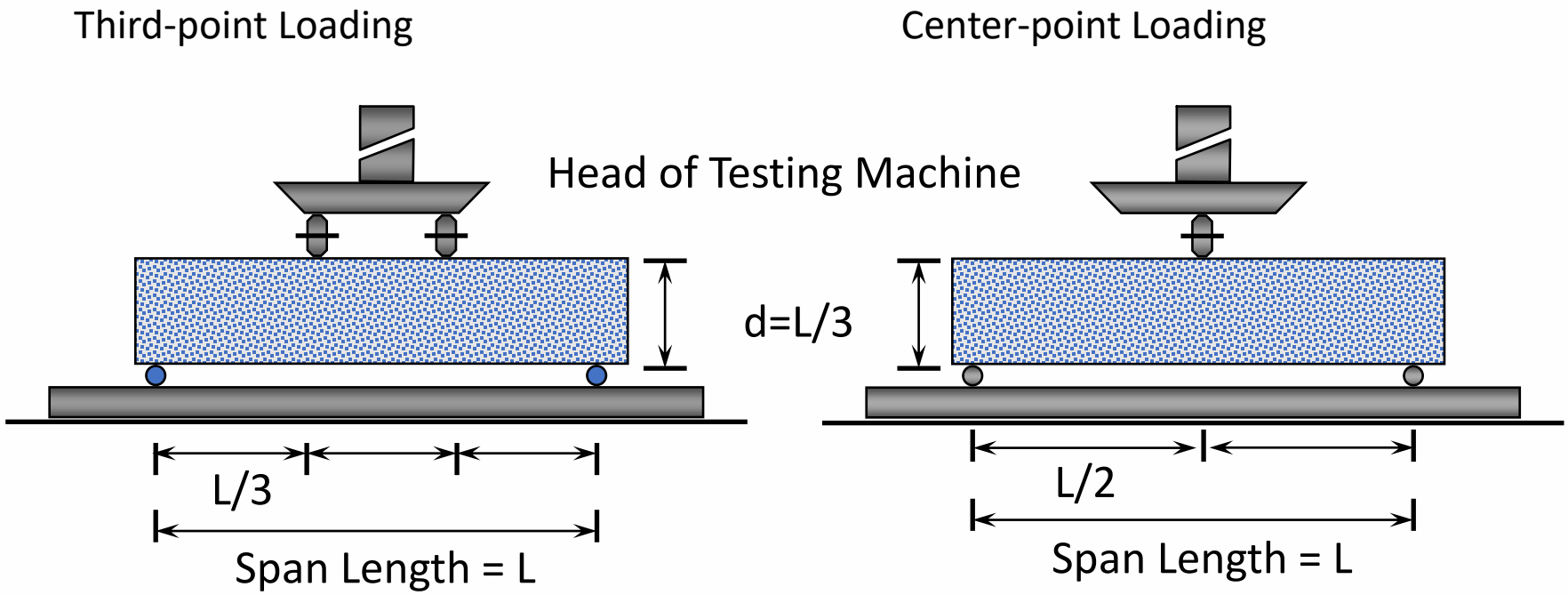
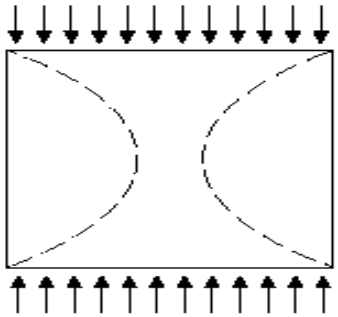
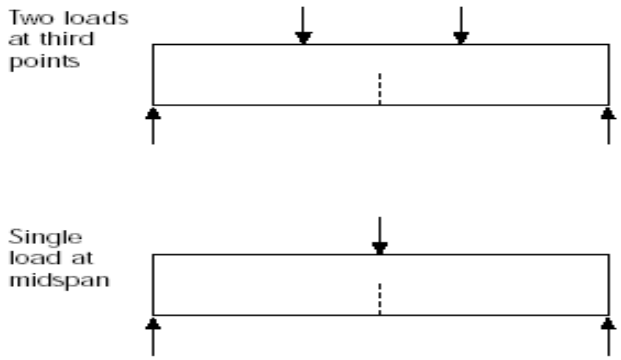
Flexural strength

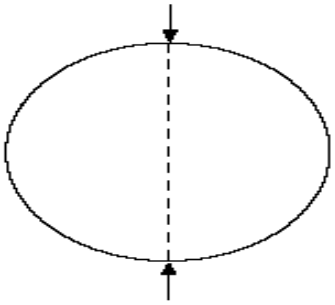




Cube test and core test



Beam test



Splitting test

Compressive strength

Tensile strength

COTO requirements

- 35 MPa @ 28 days
- $0{,}85f_{c1}$ where f_{c1} = comp strength = 4,5 MPa
- $0{,}85f_{c2}$ where f_{c2} = comp strength = w:c of 0,53
- $0{,}85f_{c3}$ where f_{c3} = comp strength = cement content of 320kg/m^3

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Factors affecting strength

- Age
- Temperature
- Aggregates and proportions
- Compaction
- Curing

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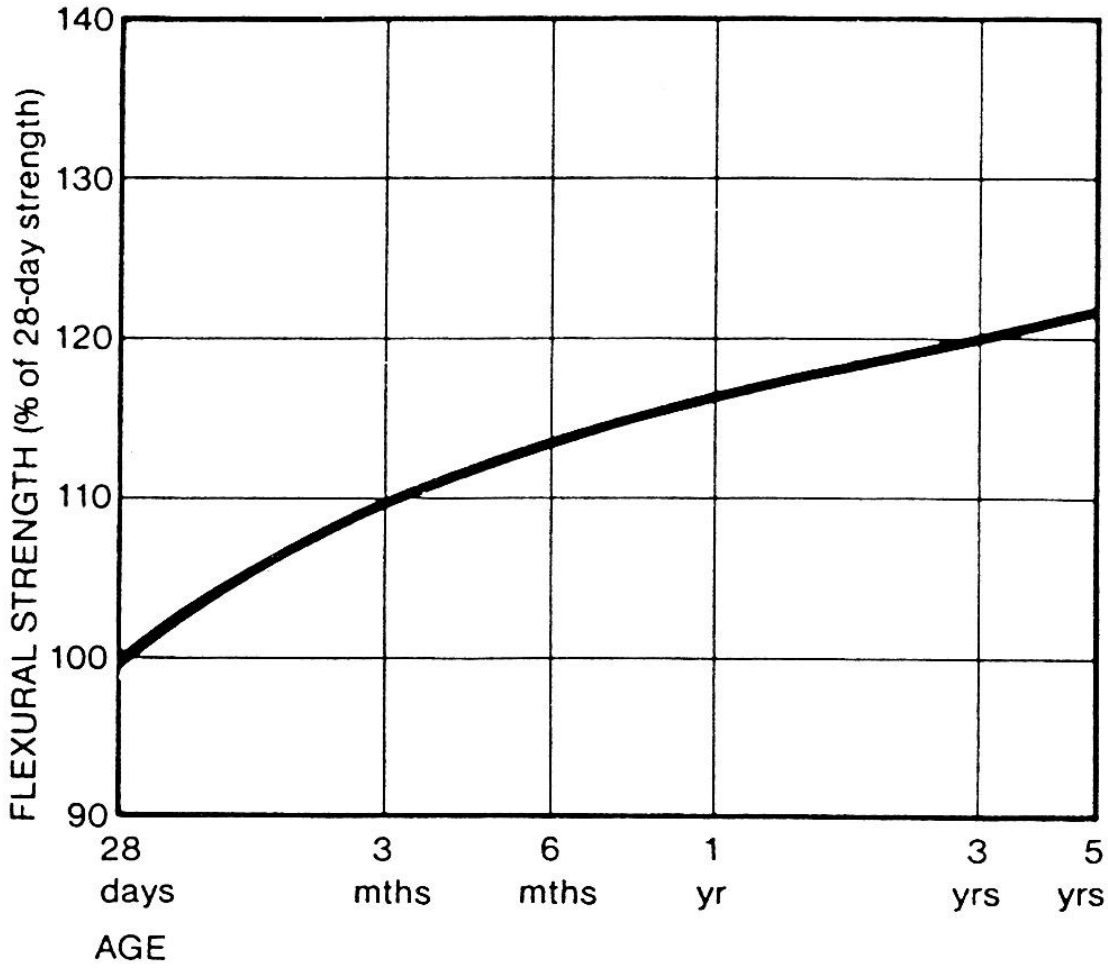
Age



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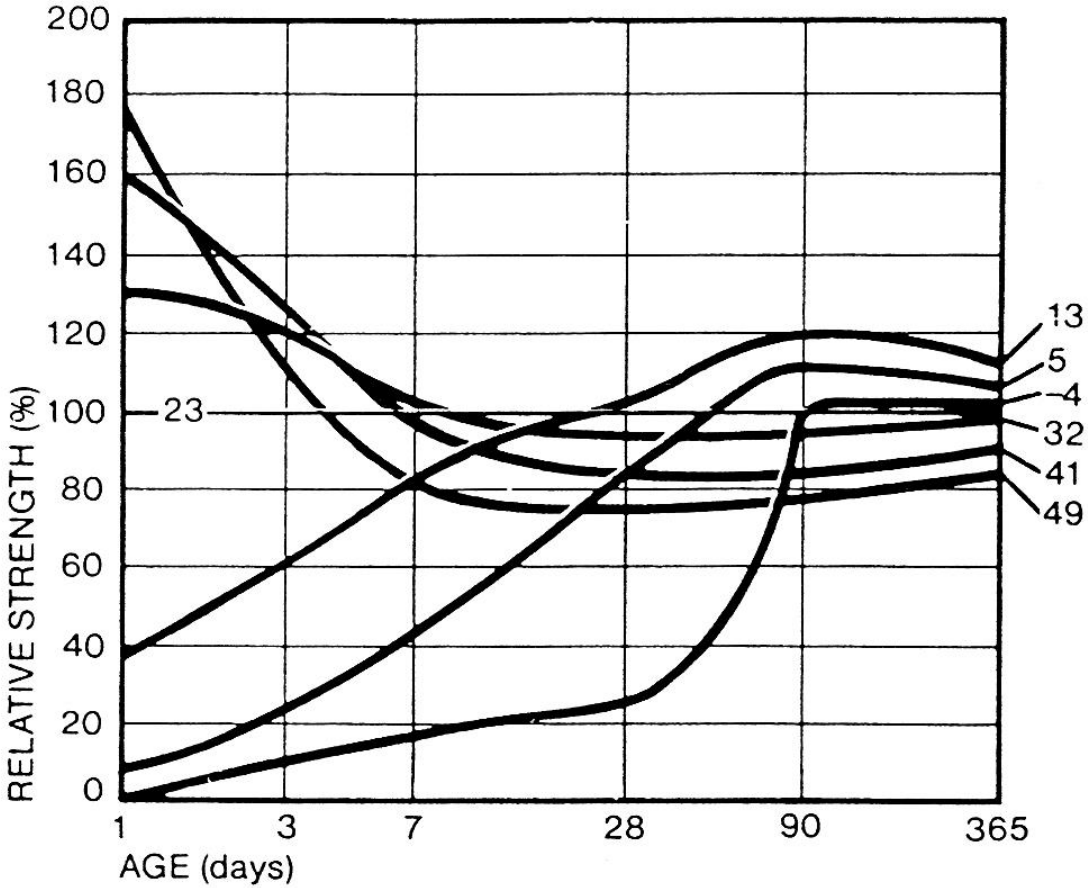
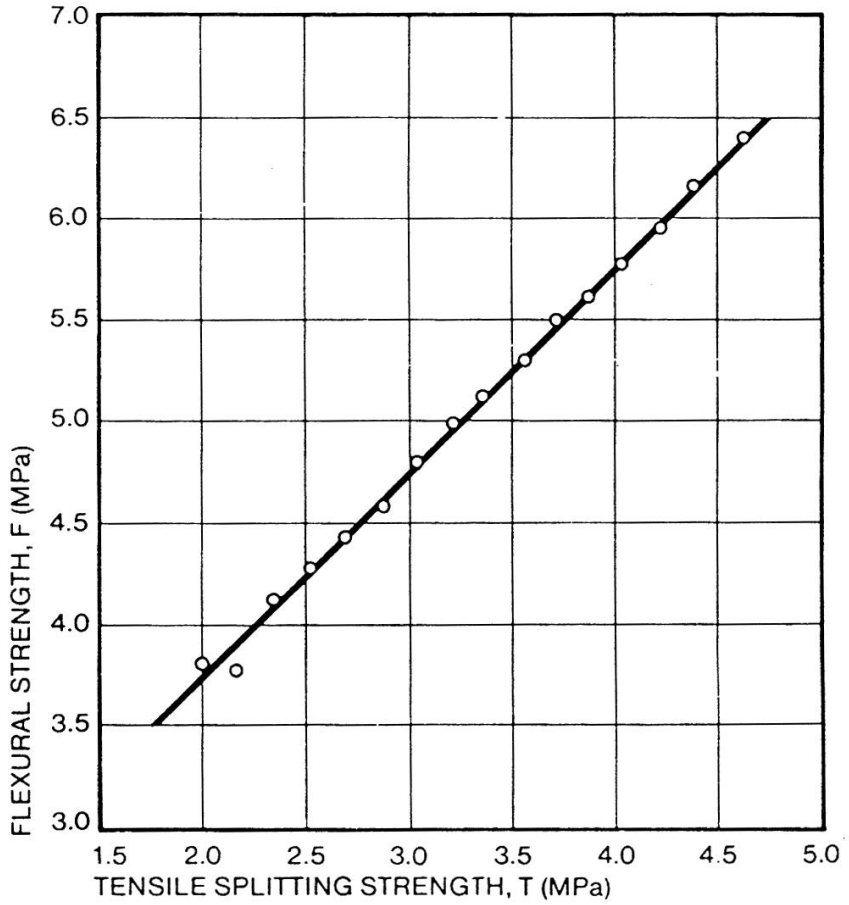
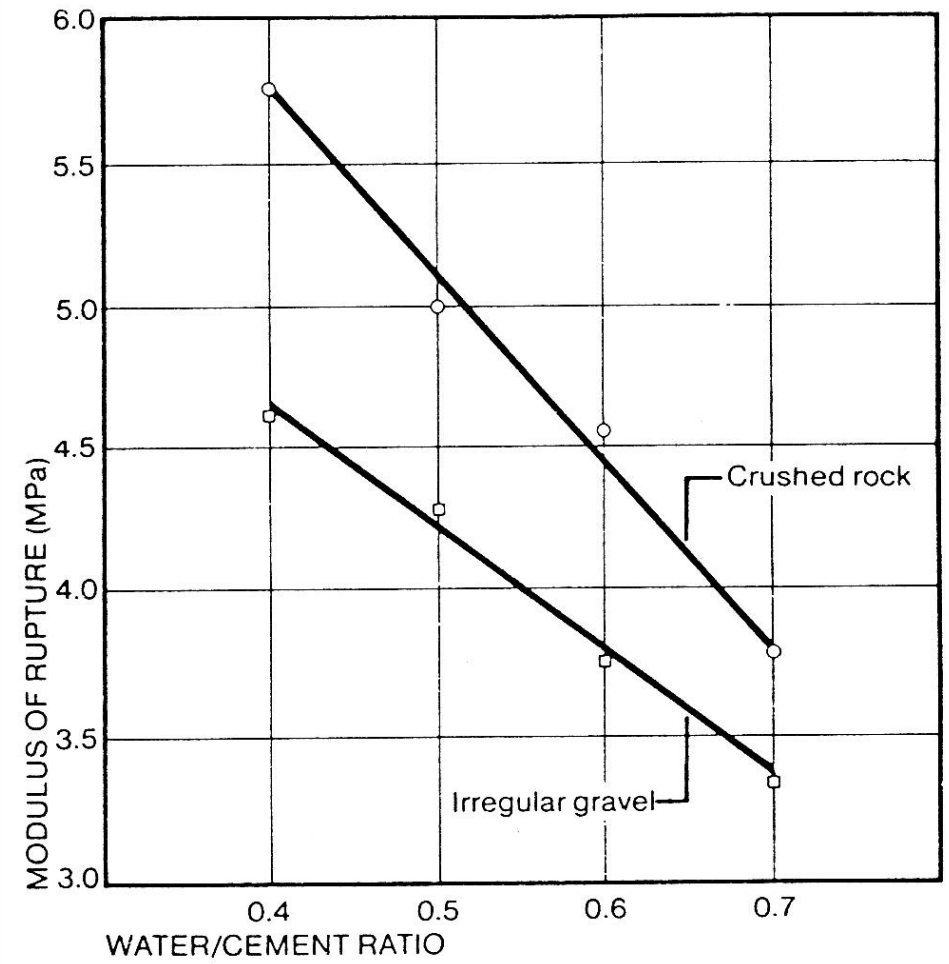
Temperature



Aggregate and proportions



Aggregate and proportions



Shrinkage

Factors affecting shrinkage

- Cement type and content
- Paste content
- Water:cement ratio
- Aggregate type

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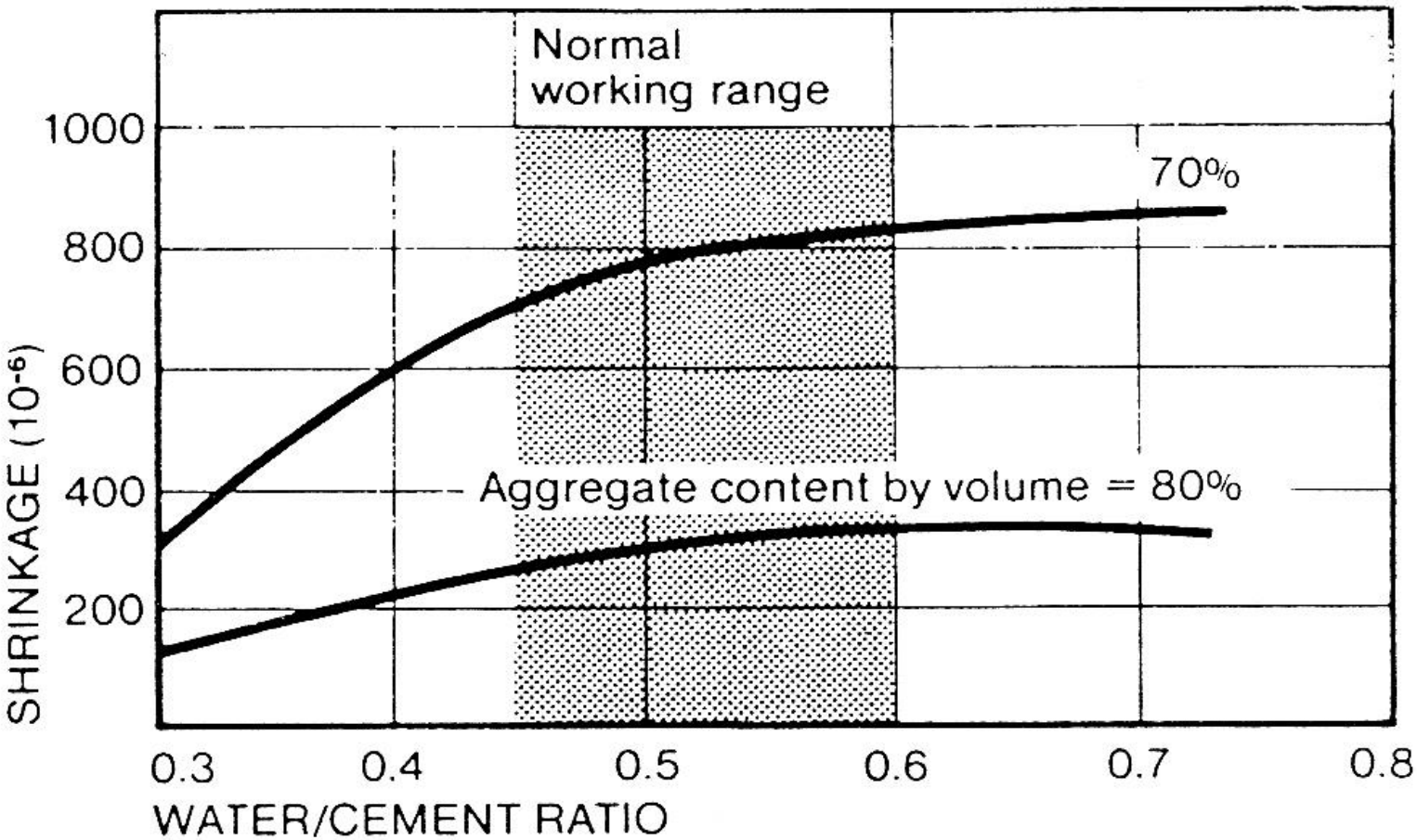
Effect of aggregate

- Volume fraction of aggregate
- Mod E of aggregate
- Aggregate shrinkage

Effect of aggregate



Abrasion resistance

Factors affecting abrasion resistance

- High cement content
- Low water:cement ratio
- Placing and compaction
- Protection and curing

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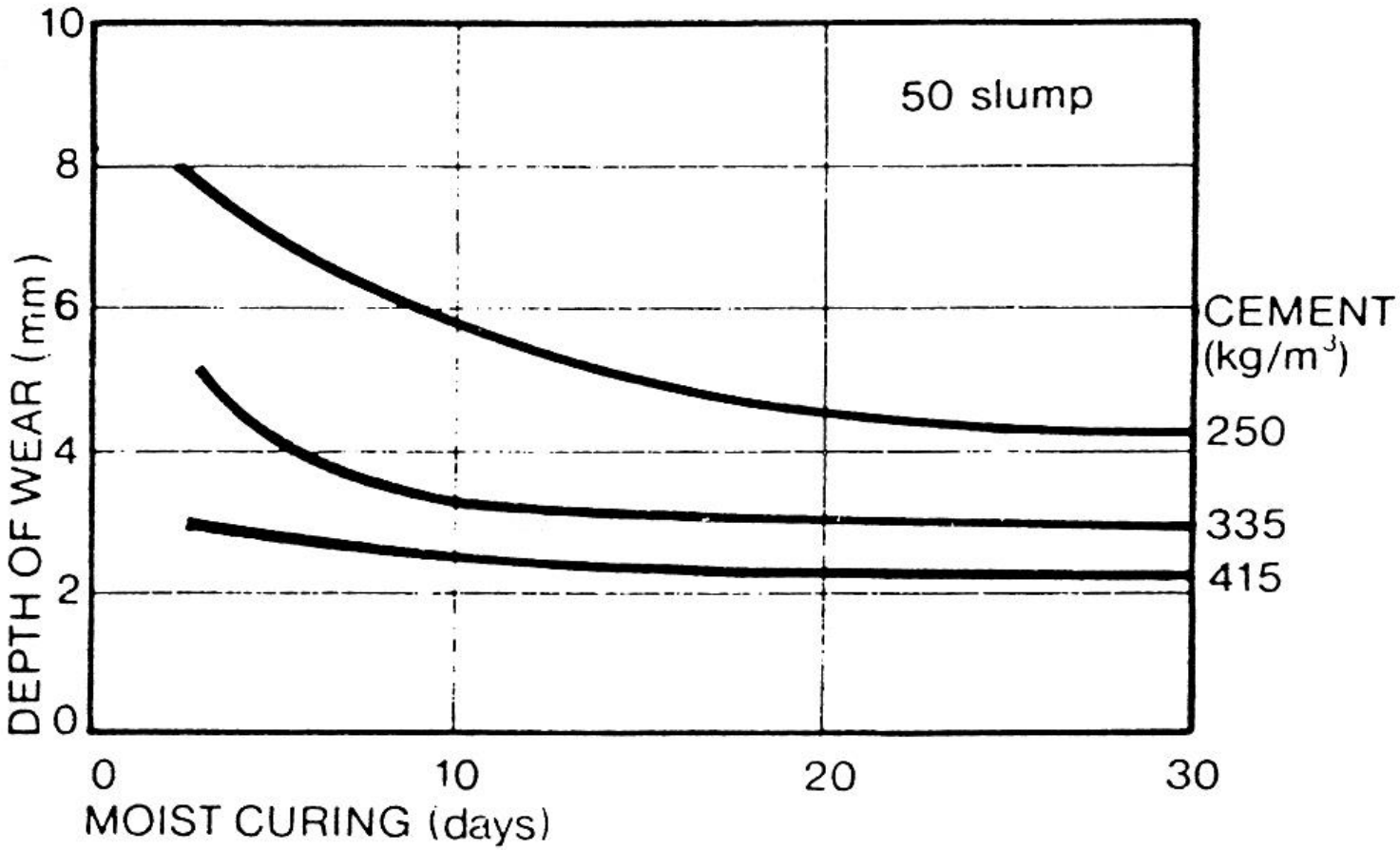
Factors affecting abrasion resistance



Skid resistance

Factors affecting skid resistance

- Fine roughness
- Coarse roughness
- Texturing
  - Brooming
  - Burlap or astro drag
  - Tining or combing

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Durability

Durability

- Biggest factor is permeability
- Permeability depends on pore size and distribution
- Voids are formed by
  - Excess water
  - Inadequate compaction
  - Incomplete curing

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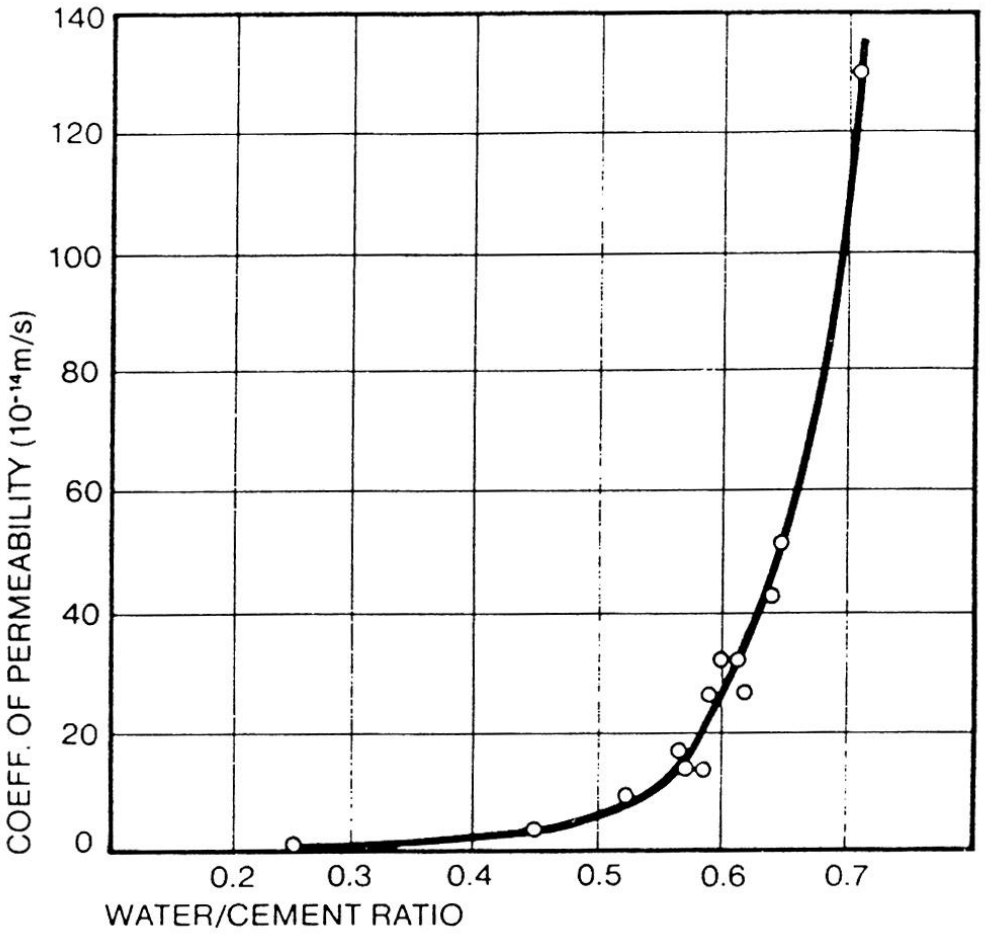
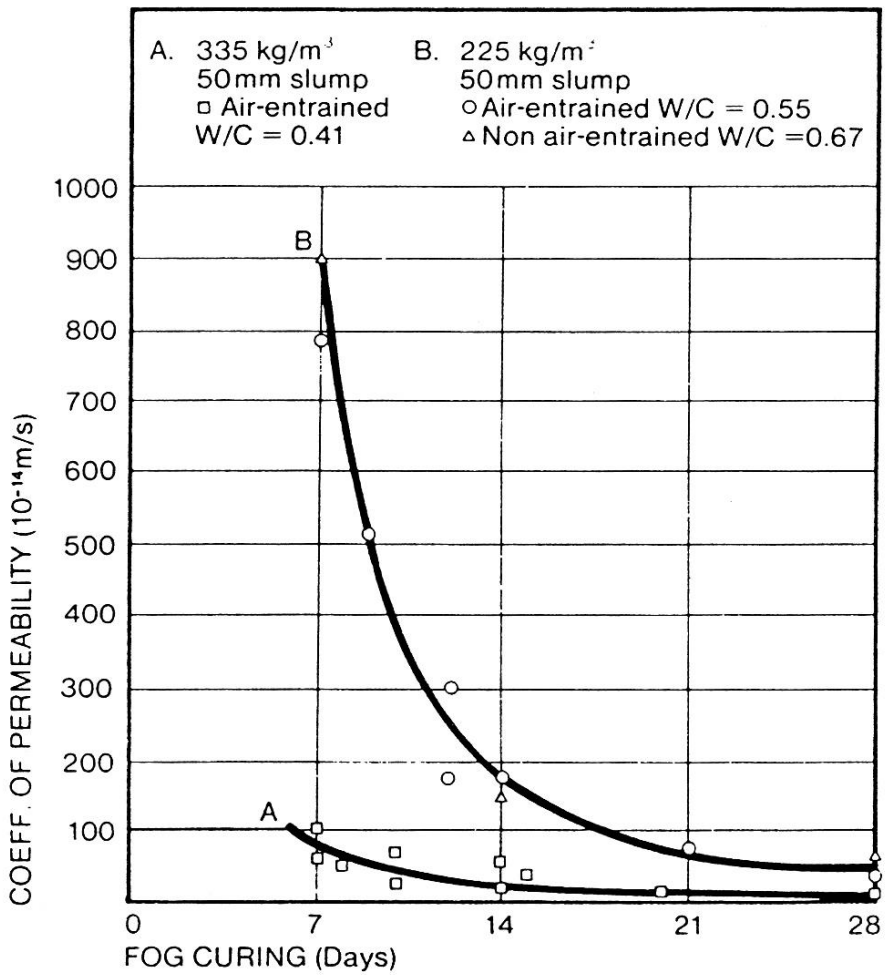
Durability


140
120
100
80
60
40
20
0
COEFF. OF PERMEABILITY (10^{-14}m/s)
0.2
0.3
0.4
0.5
0.6
0.7
WATER/CEMENT RATIO

Durability


A. 335 kg/m³
50mm slump
□ Air-entrained
W/C = 0.41
B. 225 kg/m³
50mm slump
○ Air-entrained W/C = 0.55
△ Non air-entrained W/C =0.67
COEFF. OF PERMEABILITY (10⁻¹⁴m/s)
1000
900
800
700
600
500
400
300
200
100
B
A
0
7
14
21
28
FOG CURING (Days)

Plastic properties

Plastic properties

- Workability should allow full compaction without segregation
- Concrete should be free of excessive bleeding

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Workability

- Usually slump test
- Doesn’t measure workability but consistence
- For stiff mixes use Vebe test

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Workability

Workability

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Workability

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Workability

- Slipform - 25 to 35 mm
- Sideform - 35 to 50 mm
- Hand work - 50 to 70 mm

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Concrete Materials

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Cement

- Cement type
- Saw cutting
- Surface drying
- Can affect curing
- Can affect crack pattern

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Table 1.1: Common cements: SABS EN 197-1

Main types	Notation of products (types of common cement)		Composition, percentage by mass[a]										
			Clinker	Blast-furnace slag	Silica fume	Pozzolana		Fly ash		Burnt shale	Limestone		Minor additional constituents
						natural	natural calcined	siliceous	calcareous				
			K	S	D[b]	P	Q	V	V	T	L	LL	
CEM I	Portland cement	CEM I	95 - 100	-	-	-	-	-	-	-	-	-	0 - 5
CEM II	Portland-slag cement	CEM II A-S	80 - 94	6 - 20	-	-	-	-	-	-	-	-	0 - 5
		CEM II B-S	65 - 79	21 - 35	-	-	-	-	-	-	-	-	0 - 5
	Portland-silica fume cement	CEM II A-D	90 - 94	-	6 - 10	-	-	-	-	-	-	-	0 - 5
	Portland-pozzolana cement	CEM II A-P	80 - 94	-	-	6 - 20	-	-	-	-	-	-	0 - 5
		CEM II B-P	65 - 79	-	-	21 - 35	-	-	-	-	-	-	0 - 5
		CEM II A-Q	80 - 94	-	-	-	6 - 20	-	-	-	-	-	0 - 5
		CEM II B-Q	65 - 79	-	-	-	21 - 35	-	-	-	-	-	0 - 5
	Portland-fly ash cement	CEM II A-V	80 - 94	-	-	-	-	6 - 20	-	-	-	-	0 - 5
		CEM II B-V	65 - 79	-	-	-	-	21 - 35	-	-	-	-	0 - 5
		CEM II A-W	80 - 94	-	-	-	-	-	6 - 20	-	-	-	0 - 5
		CEM II B-W	65 - 79	-	-	-	-	-	21 - 35	-	-	-	0 - 5
	Portland-burnt shale cement	CEM II A-T	80 - 94	-	-	-	-	-	-	6 - 20	-	-	0 - 5
		CEM II B-T	65 - 79	-	-	-	-	-	-	21 - 35	-	-	0 - 5
	Portland-limestone cement	CEM II A-L	80 - 94	-	-	-	-	-	-	-	6 - 20	-	0 - 5
		CEM II B-L	65 - 79	-	-	-	-	-	-	-	21 - 35	-	0 - 5
		CEM II A-LL	80 - 94	-	-	-	-	-	-	-	-	6 - 20	0 - 5
		CEM II B-LL	65 - 79	-	-	-	-	-	-	-	-	21 - 35	0 - 5
	Portland-composite cement[c]	CEM II A-M	80 - 94	←	-	-	-	6 - 20	-	-	-	→	0 - 5
		CEM II B-M	65 - 79	←	-	-	-	21 - 35	-	-	-	→	0 - 5
CEM III	Blastfurnace cement	CEM III A	35 - 64	36 - 65	-	-	-	-	-	-	-	-	0 - 5
		CEM III B	20 - 34	66 - 80	-	-	-	-	-	-	-	-	0 - 5
		CEM III C	5 - 19	81 - 95	-	-	-	-	-	-	-	-	0 - 5
CEM IV	Pozzolanic cement[c]	CEM IV A	65 - 89	-	←	-	11 - 35	-	→	-	-	-	0 - 5
		CEM IV B	45 - 64	-	←	-	36 - 55	-	→	-	-	-	0 - 5
CEM V	Composite cement[c]	CEM V A	40 - 64	18 - 30	-	←	18 - 30	→	-	-	-	-	0 - 5
		CEM V B	20 - 39	31 - 50	-	←	31 - 50	→	-	-	-	-	0 - 5

Notes

(a) The values in the table refer to the sum of the main and minor additional constituents.

(b) The proportion of silica fume is limited to 10%.

(c) In portland-composite cements CEM II A - M and CEM II B - M, in pozzolanic cements CEM IV A and CEM IV B, and in composite cements CEM V A and CEM V B the main constituents other than clinker shall be declared by designation of the cement.

Factors to be considered when selecting cement type

- Cost of concrete
- 28-day compressive strength
- Early compressive strength development
- Ability to resist aggressive environment
- Sensitivity to poor site practices and extent of supervision
- Other properties (colour, heat development, control of ASR, etc.)

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Aggregates

- Meet SABS 1083
- Add:
  - Drying shrinkage
  - 10% FACT
  - Acid Insolubility
  - ASR
  - Flakiness

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Admixtures

- Water reducers/Plasticiser
- Superplasticisers
- Accelerators
- Retarders

- Check as part of mix design for unwanted effects

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Mix Proportioning

Mix proportioning

- Lowest slump possible - adequate compaction
- Maximum aggregate size
- Adequate strength
- Adequate durability

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Mix proportioning

- Flexure: compressive ratio at 3 water:cement ratios
- Effect of admixture on setting and sawing times
- Effect of three water contents on consistence

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Mix proportioning

- Check for the following:
  - Dowel/tiebar insertion
  - Paste on surface
  - Edge slump
  - Tining
- Trial pavement

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Curing and protection

Curing

- Vitally important:
- Plastic sheeting
- Water sprays or ponding
- Curing compounds - comply with COTO White pigmented resin based

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Concrete variability

Variability

- Vitally important for input to cncPave
- cncPave indicates which items are critical
- Need input for determining distribution

Ultra Thin requirements

- The cement shall be a CEM I A 42,5
- Only high-performance polymer-based superplasticizers may be used
- The maximum W/C ratio shall not exceed 0.40. The W/C ratio shall be based on the total cementitious binder, i.e. cement, fly ash and condensed silica fume
- The cement type CEM I 42.5 content shall be less than 500 kg/m^3.
- Condensed silica fume shall form 10% to 15% of the binder.
- Fly ash shall form 15% to 20% of the binder

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Ultra Thin requirements

- The steel fibres should meet the following requirements:
  - Cold-drawn low carbon steel wire, with deformed hooked ends.
  - Conformance: ASTM A 820/A 820M, Type I.
  - Tensile Strength: Minimum 1,000 MPa.
  - Fibre Length (l): Minimum 30 mm.
  - Fibre Diameter (d): Minimum 0.5 mm.
  - Aspect Ratio (l/d): Maximum 70.

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Ultra Thin requirements

The specification also contains the following performance requirements:

- The 28-day compressive strength (inclusive of fibres) must be at least 90 MPa.
- 24-hour compressive strength (inclusive of fibres) of at least 40 MPa.
- 28-day Flexural strength (inclusive of fibres) must be at least 10 MPa.
- The maximum bending moment recorded on rectangular panels should be more than 3 kNm and the energy absorption of the panels should be at least 120 kNm.
- The maximum energy absorption recorded in joule for deflection of up to 25 mm should be more than 1000 joule when tested on circular panels in a modified ASTM C1550-05

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