Properties of Fresh Concrete

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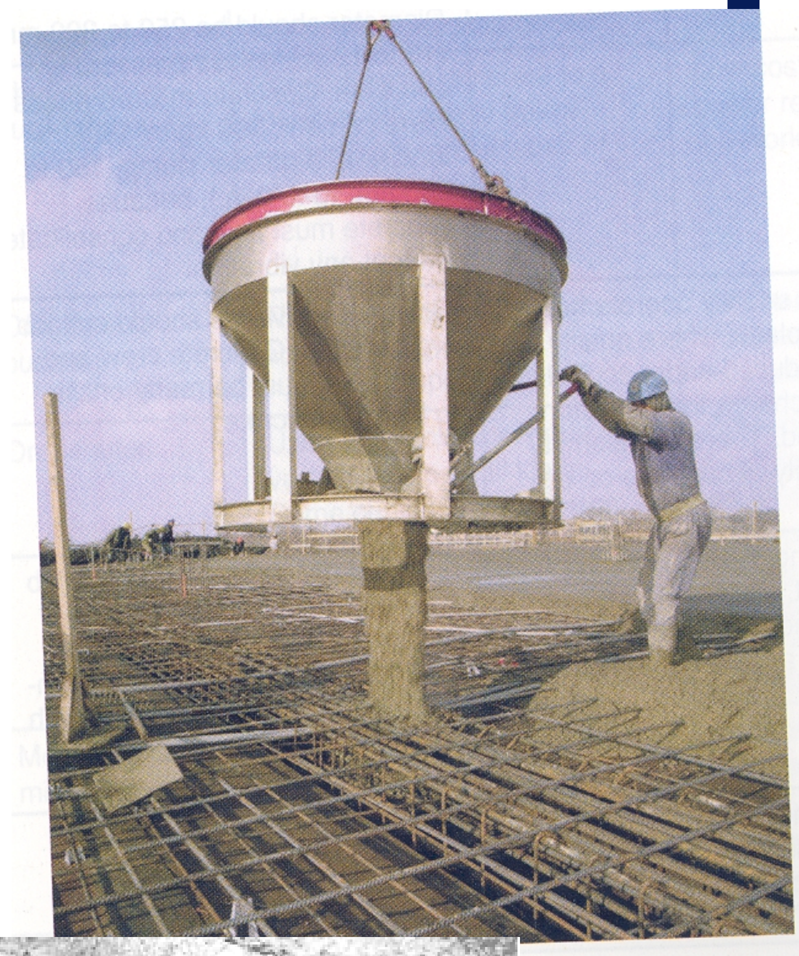
Overview

- Workability
- Factors affecting workability
- Measurements of workability
- Setting
- Early age deformation

Workability



Requirements for the period during mixing and initial placing:

- want a fluid-like material
- want a cohesive material

WORKABILITY (ASTM C125) - property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.

Qualitative property incorporating consistency (ease of flow) and cohesiveness (tendency to bleed or segregate)

Segregation

Segregation – separation of components in fresh concrete so that they are no longer uniformly distributed.

Often segregation of coarse aggregate from paste can be a result of

- too large an MSA
- too little fine aggregate or
- too coarse of a fine aggregate.

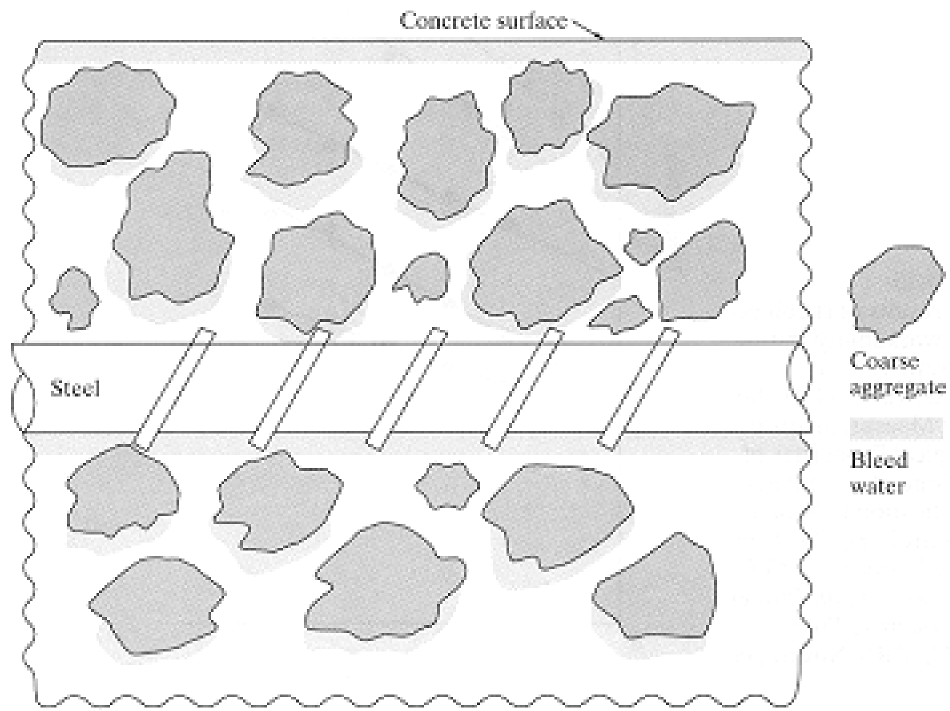
Can also be induced by dropping concrete from too great a height during placing.

Bleeding

Bleeding – a type of segregation where water appears at the concrete surface after placing and compacting, but before set. Water may also form a film under aggregate and reinforcing bar.

Some bleeding is useful for finishing operations and to reduce plastic shrinkage cracking

- Leaner mixes bleed most
- Over-vibration/compaction can promote bleeding
- Finer cement, higher C_3A content, and air entrainment help reduce bleeding.
- SCMs also generally reduce bleeding



Factors Affecting Workability

Key factors are:

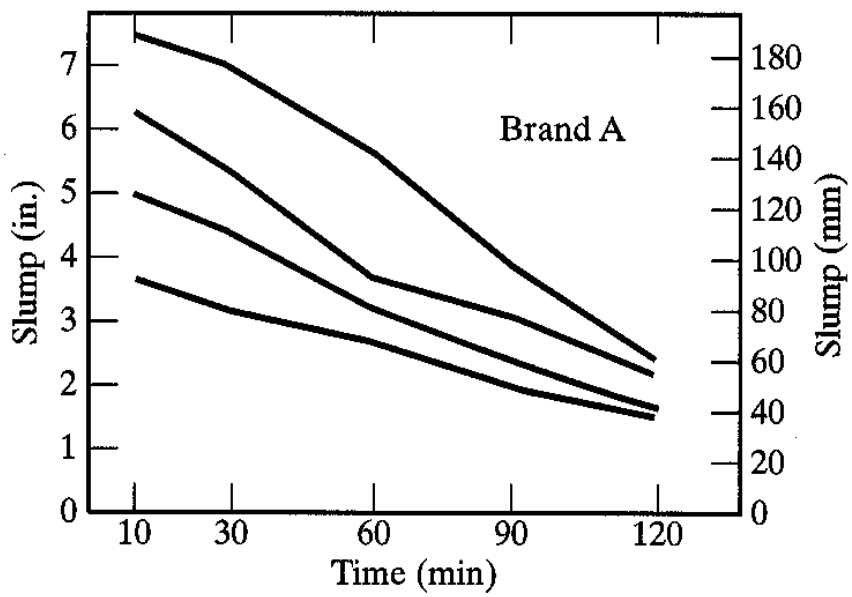
- Water and cement contents
- Aggregate characteristics
- Use and characteristics of SCMs and chemical admixtures
- Ambient conditions

Water and Cement Content

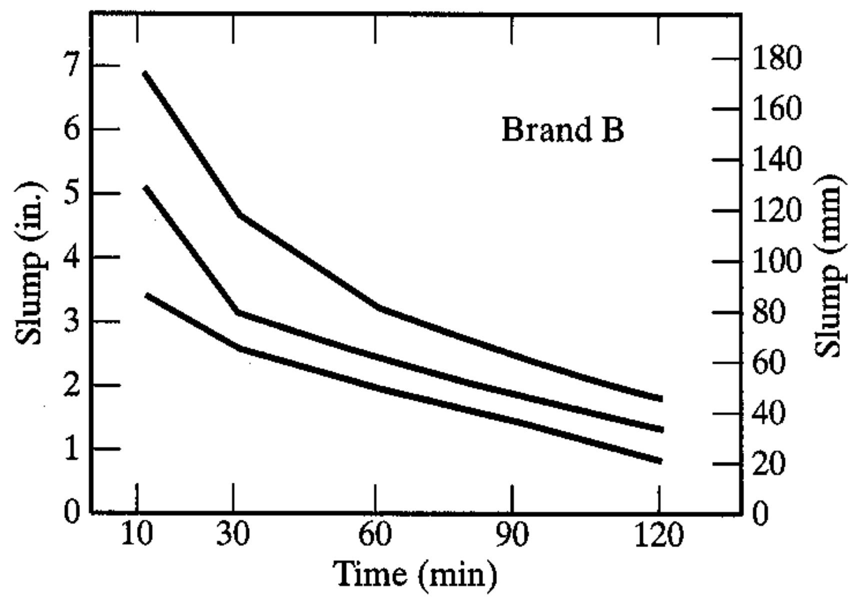
- Flowability increases as w/c increases
- Segregation and bleeding also increase as w/c increases
- Strength decreases as w/c increases
- Finer cement produces a less workable mix because of higher specific surface area and increase rate of hydration

Cement Composition

The cement composition is much less important than the aggregate characteristics and mix proportioning in determining workability.



(a)



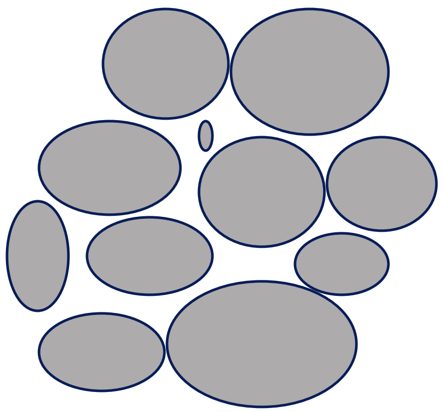
(b)

Aggregate Characteristics

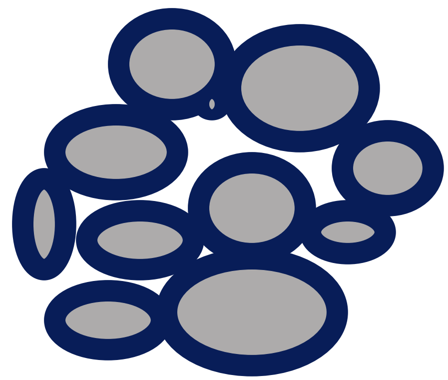
- Total surface area of the aggregate is important
- Workability decreases as surface area increases
- Workability is less in a lean mix (i.e., lower cement/aggregate) than in a rich mix
- Too little sand, however, produces a “harsh” mix, that is prone to segregation and difficult to finish
- Aggregate porosity may influence workability
- Roundness and smoothness of particles increases workability

Aggregate Characteristics

Cement/Aggregate ratio is an important factor in determining workability



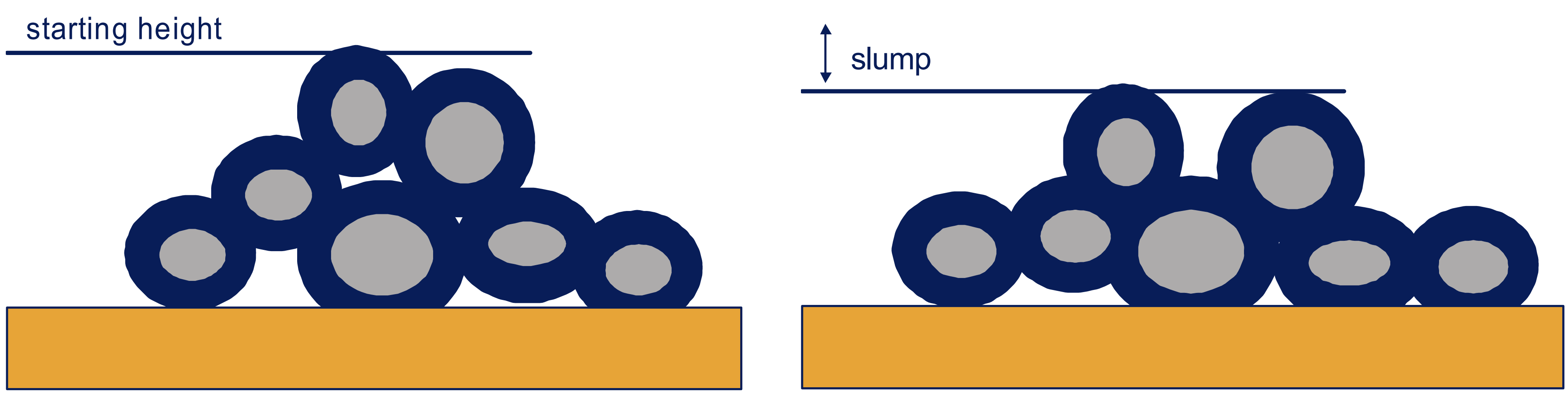
Low paste content
Lean mix



High paste content
Rich mix

Ball Bearing Effect

Near-spherical particles have a lower surface-to-volume ratio, requiring less mortar



Admixtures

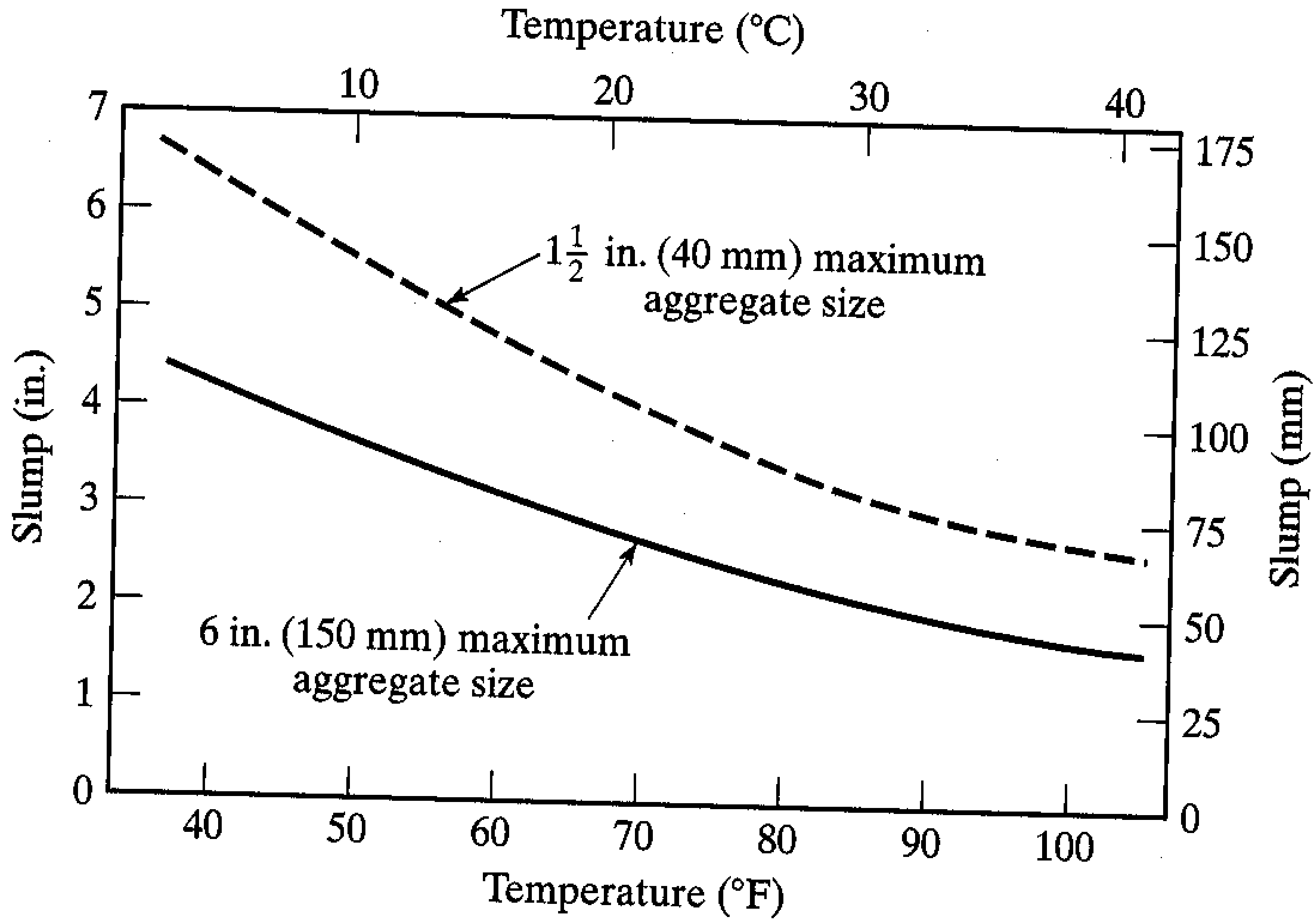
- Air entraining admixtures, water reducing admixtures, superplasticisers improve flowability and cohesiveness.
- SCMs can also improve cohesiveness and flow.
- The small particle size of some SCMs, particularly silica fume, may result in decreased flowabilty. Use a water reducing or superplasticizing admixture to improve workabililty.

Ambient Conditions

- For a given mix design, changes in workability are governed by the rate of cement hydration and the rate of water evaporation.
- Over time, more hydration and more water evaporation lead to loss in workability
- At higher T, hydration and evaporation occur more quickly.
- At lower RH and with wind, evaporation occurs more quickly.

OFTEN THESE CANNOT BE CONTROLLED

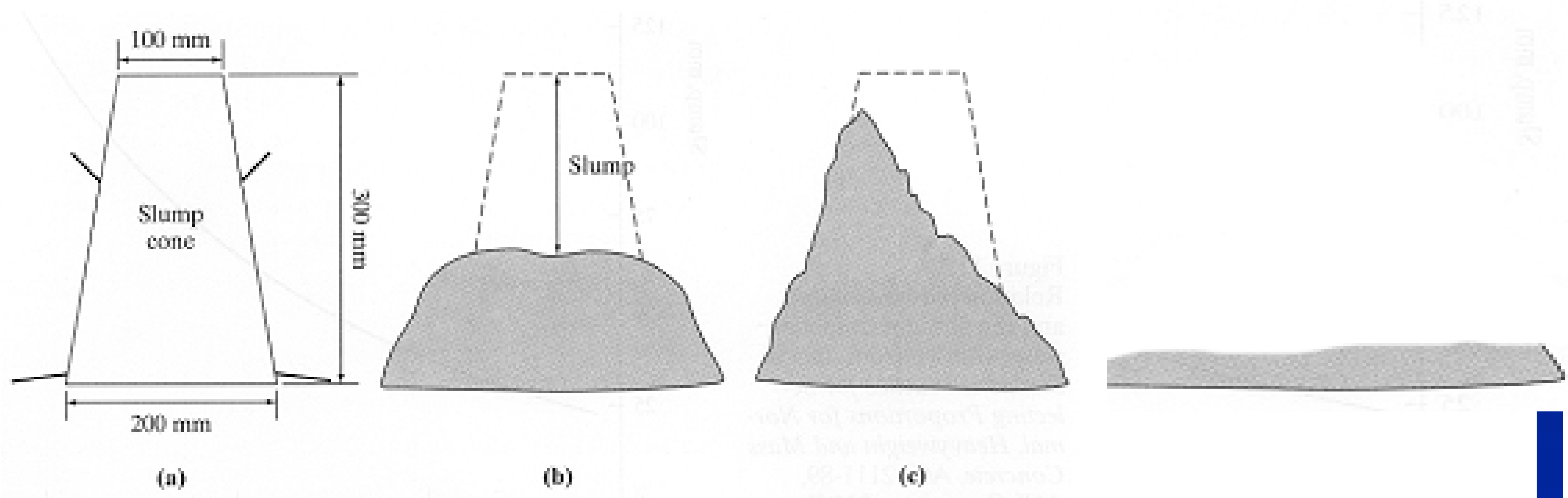
Effect of Temperature



Measurements of Workability: Slump

Measurements of Workability: Slump

- ASTM C143



Normal slump   Shear slump   Collapse slump

Slump

Stiff 0-2”

- massive sections, little reinforcement
- use vibration

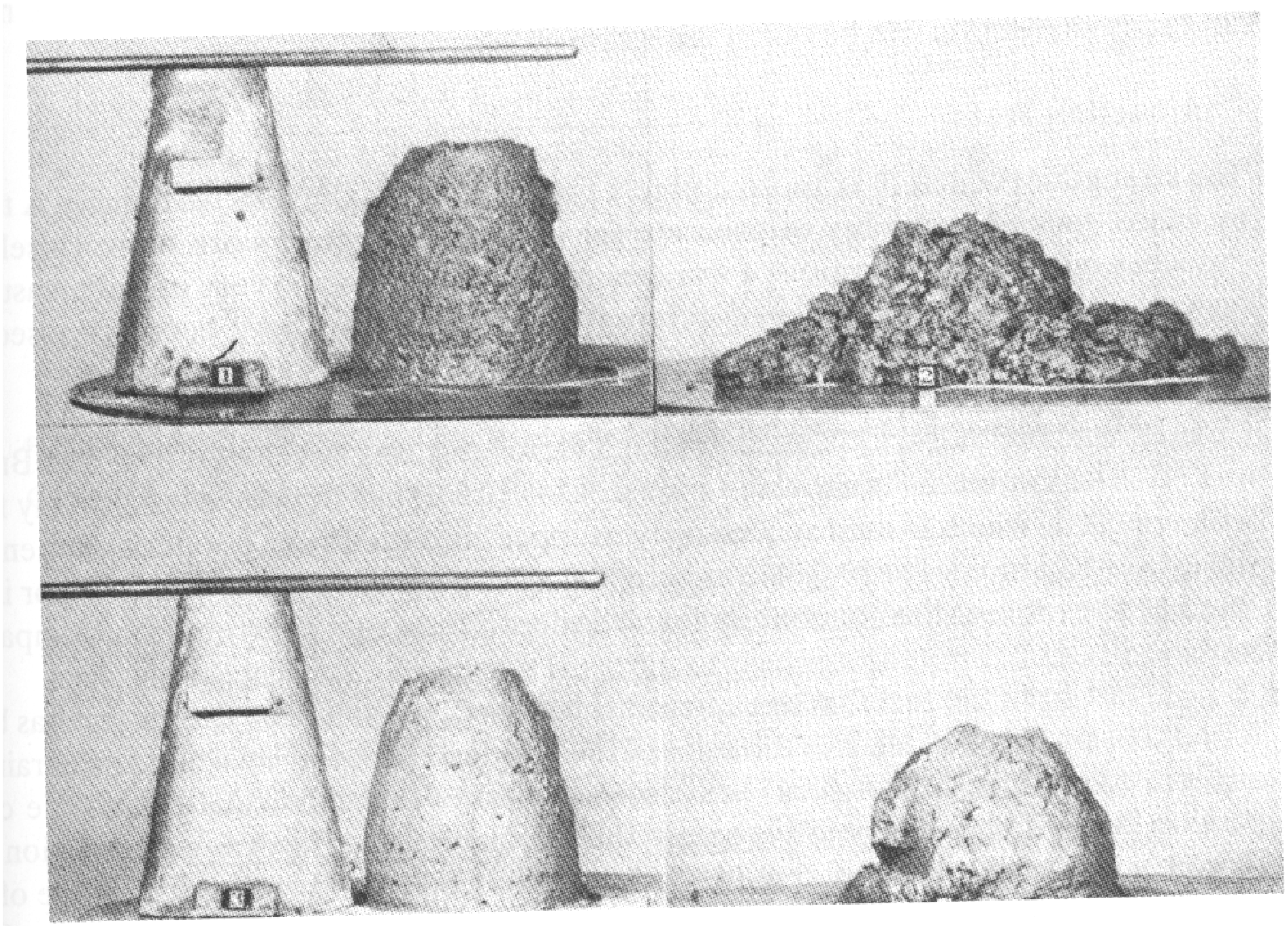
Medium 2-5”

- columns, beams, retaining walls

Fluid 5-7”

- heavily reinforced section, flowable concrete

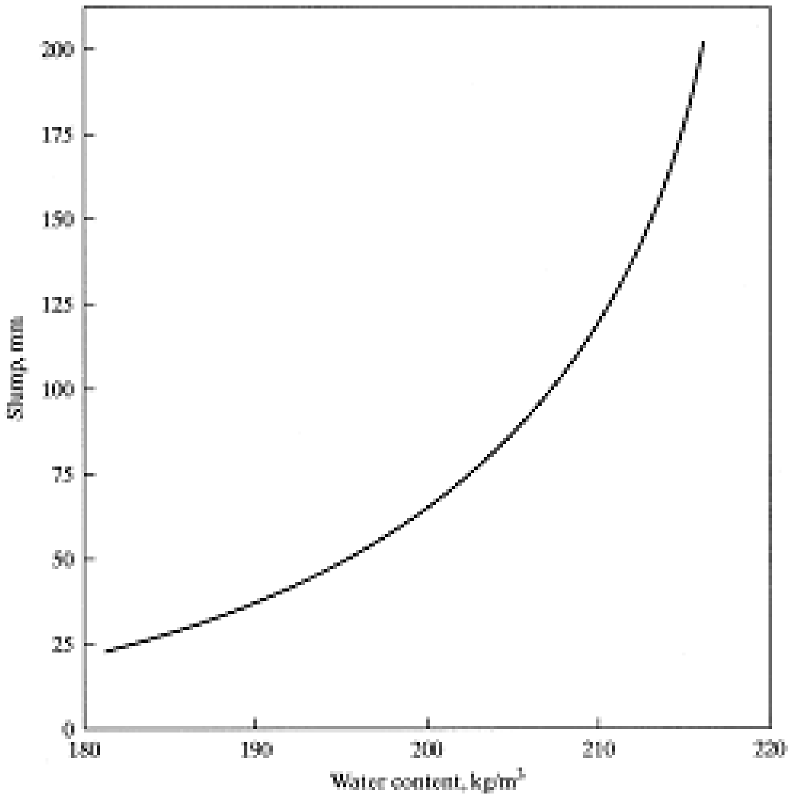
Slump

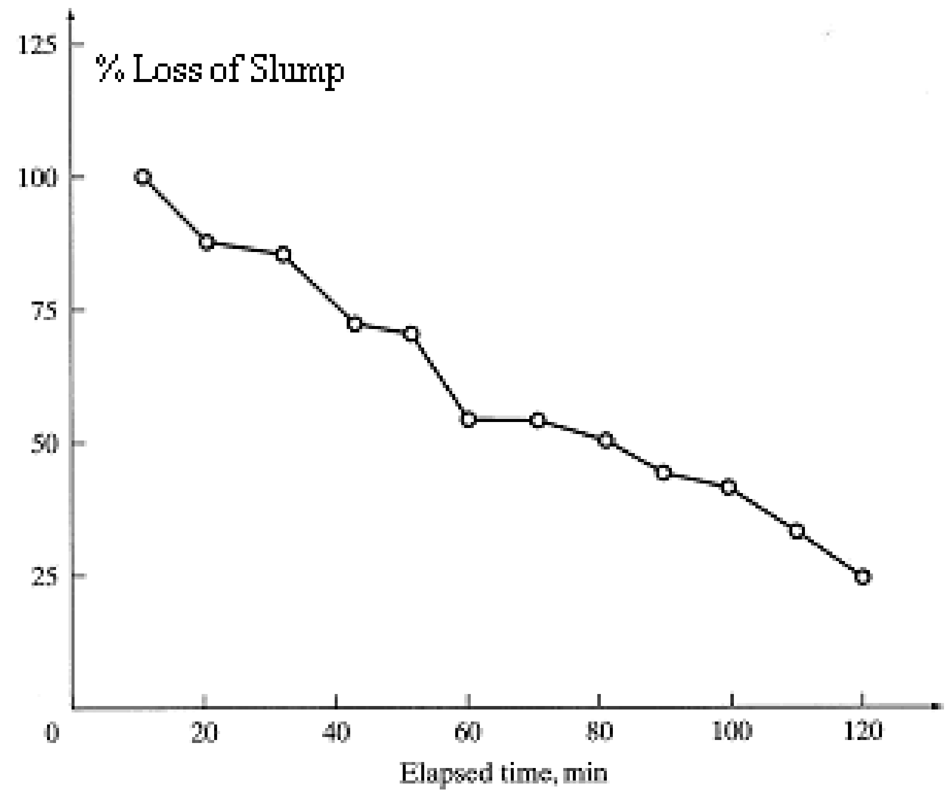


Slump Loss

- Loss of water by hydration, absorption (by the aggregate or by the forms), or evaporation leads to SLUMP LOSS.
- Slump loss is a measure of loss of consistency over time. Simply means that the slump measured after a period of time is less than the slump initially measured.
- To regain slump, concrete can be retempered by adding water and remixing just prior to placement. p

Slump


Slump, mm
200
175
150
125
100
75
50
25
0
180
190
200
210
220
Water content, kg/m³


% Loss of Slump
125
100
75
50
25
0
20
40
60
80
100
120
Elapsed time, min

Other Measurements of Workability

Table 4.5 Test Methods Apropriate to Mixes of Different Workability According to BS 1881 : 1983

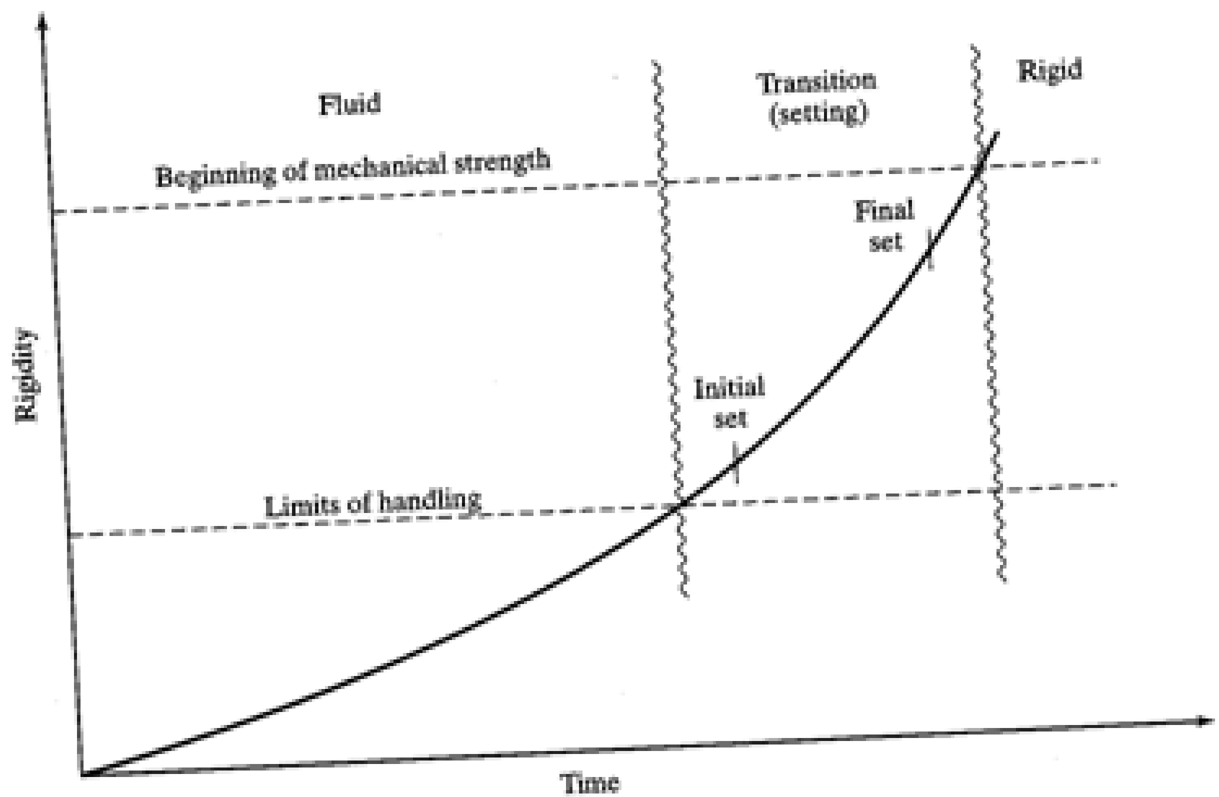
Workability	*Method*
Very low	Vebe time
Low	Vebe time, compacting factor
Medium	Compacting factor, slump
High	Compacting factor, slump, flow
Very high	Flow

Other Tests on Fresh Concrete

- Setting time
- Air Content
  - Gravimetric method (will do in lab)
  - Volumetric method
  - Pressure method
- Unit Weight and Yield

Setting Time

- Determine the time elapsed between addition of water and when the paste ceases to be fluid and plastic (initial set)
- Determine the time required for the paste to achieve a certain degree of hardness (final set)



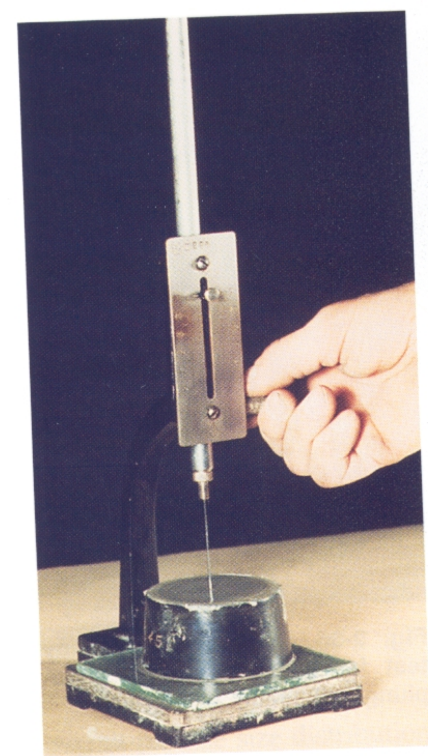
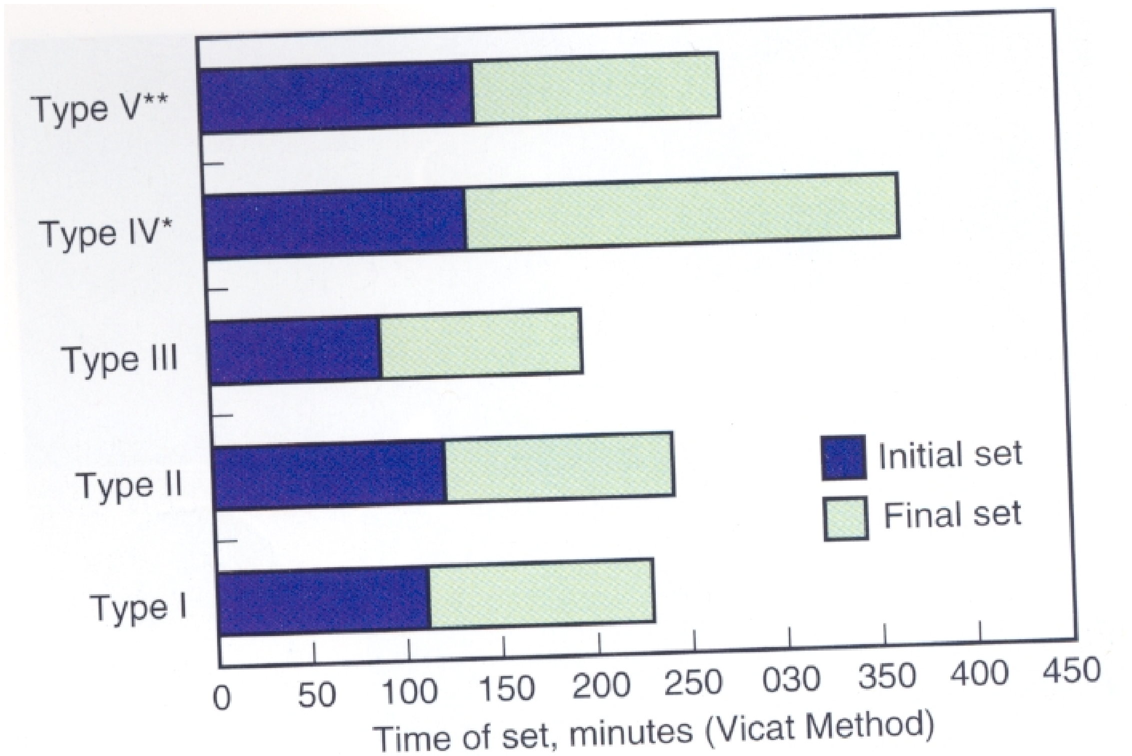


Fig. 2-38. Time of set test for paste using the Vicat needle. (23890)

Setting Time



*Average of two values for initial set; one value for final set
**Average of two values for final set

Fig. 2-40. Time of set for portland cements (Gebhardt 1995 and PCA 1996).

Air Content

Table 8-6. Recommended Total Target Air Content for Concrete

Nominal maximum size aggregate, mm (in.)	Air content, percent*		
	Severe exposure**	Moderate exposure†	Mild exposure††
<9.5 (⅜)	9	7	5
9.5 (⅜)	7½	6	4½
12.5 (½)	7	5½	4
19.0 (¾)	6	5	3½
25.0 (1)	6	4½	3
37.5 (1½)	5½	4½	2½
50 (2)‡	5	4	2
75 (3)‡	4½	3½	1½

* Project specifications often allow the air content of the concrete to be within -1 to +2 percentage points of the table target values.

** Concrete exposed to wet-freeze-thaw conditions, deicers, or other aggressive agents.

† Concrete exposed to freezing but not continually moist, and not in contact with deicers or aggressive chemicals.

†† Concrete not exposed to freezing conditions, deicers, or aggressive agents.

‡ These air contents apply to the total mix, as for the preceding aggregate sizes. When testing these concretes, however, aggregate larger than 37.5 mm (1½ in.) is removed by handpicking or sieving and air content is determined on the minus 37.5 mm (1½ in.) fraction of mix. (Tolerance on air content as delivered applies to this value.)

ASTM C173: Volumetric Method

ASTM C231: Pressure Method

Air Content: Gravimetric Method

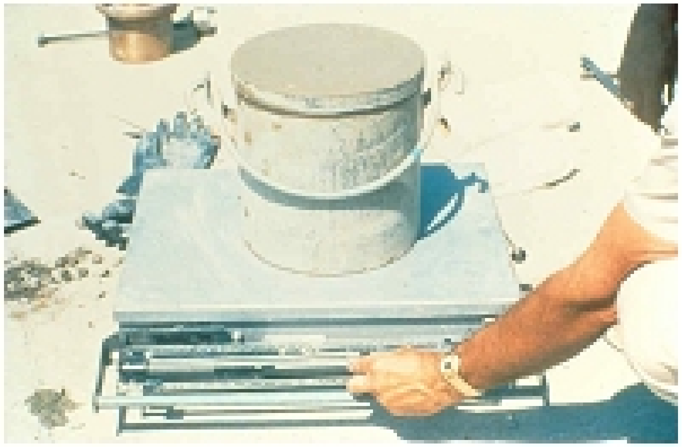
- ASTM C138
- Compares the unit weight of concrete as batched to the calculated unit weight of air-free concrete
- Can also determine "yield" or the volume of fresh concrete produced from a known quantity of mix ingredients
- Also used to determine unit weight
- Requires specific knowledge of specific gravity, moisture contents, and mix proportions
- Suitable for laboratory work

Air Content: Gravimetric Method

A = (T-W)/Tx100

T= theoretical unit weight

W= actual unit weight



Early Age Volume Change

- Prehardening shrinkage, presetting shrinkage, plastic shrinkage cracks
- <12 hrs age
- Cracks develop due to reduction of volume in the fresh state
- Plastic shrinkage cracks are typically run parallel 1-3 ft. apart and are 1-2 inches deep; can also be irregular
- Makes concrete vulnerable to other forms of attack

Plastic Shrinkage

- Happens because loss of water at surface occurs faster than bleed water becomes available. (function of T, RH, wind)
- Absorption of water by subgrade or aggregate
- Rapid water loss by evaporation (exacerbated by high concrete temp, low RH, high winds)
- At this age, the concrete is too stiff to flow, but does not yet have enough strength to exceed tensile stress generated by shrinkage.

Tensile Strength

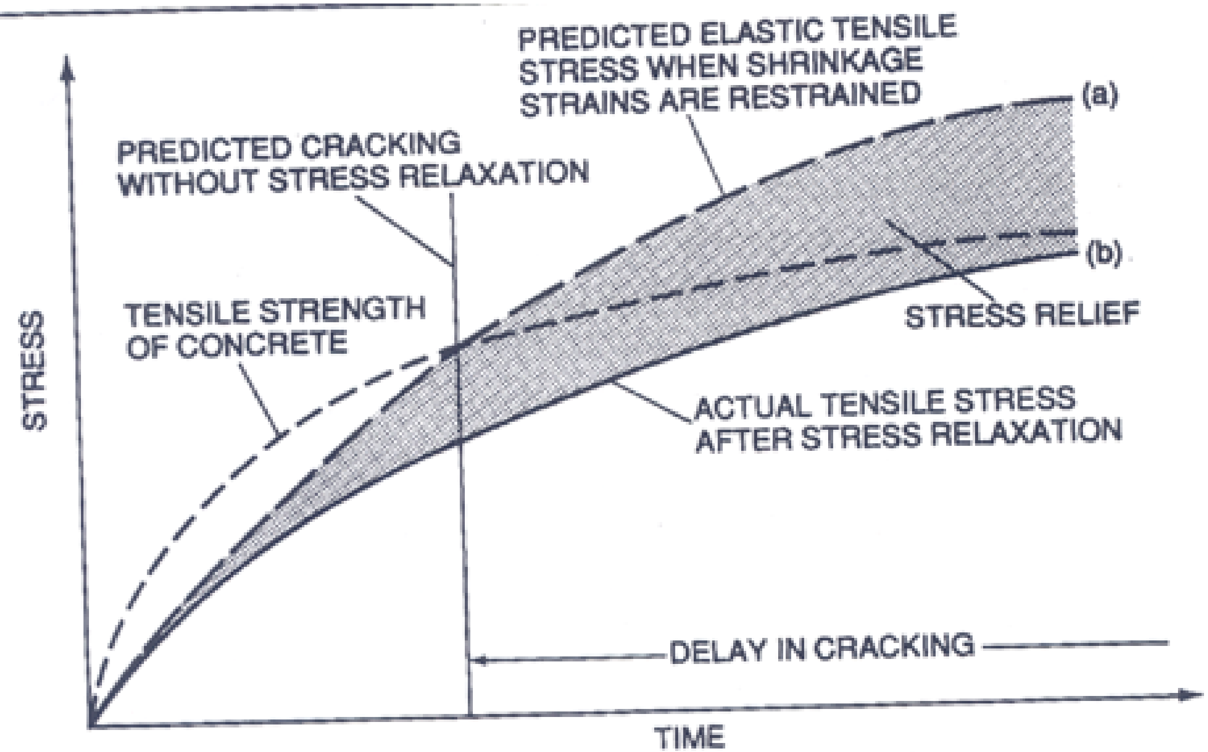
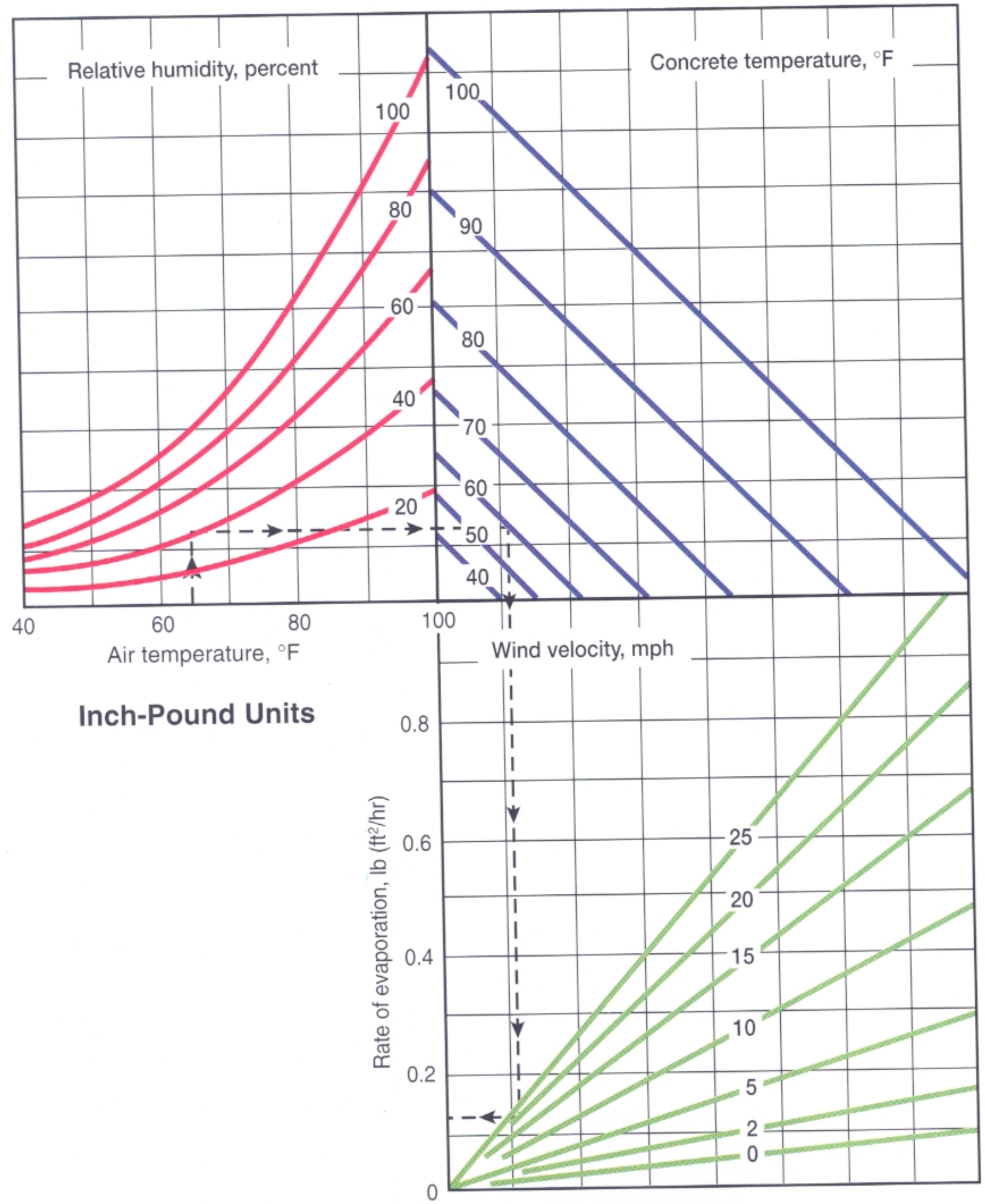


Figure 4–1 Influence of shrinkage and creep on concrete cracking. (Adapted from a presentation by J. W. Kelly at the Associated General Contractor's meeting in San Francisco, June 20, 1963.)

Under restraining conditions in concrete, the interplay between the elastic tensile stresses induced by shrinkage strains and the stress relief due to viscoelastic behavior is at the heart of deformations and cracking in most structures.

Can try to predict plastic shrinkage cracking using nomographs and T, RH, wind speed, and concrete T data.

PCA recommends that the rate of evaporation be less than 0.2 lb/ft^2 per hour



Plastic Shrinkage Cracking

To avoid plastic shrinkage cracking:

- Moisten subgrade and forms
- Avoid absorptive aggregate
- Erect temporary wind breaks and sunshades
- Cool aggregate and mix water
- Cover concrete with PE sheeting after placing but before finishing
- Cover with wet burlap, fog spray, or curing compound after finishing
- Adjust mix design – retarders can reduce early tensile strength…
- Use fibers in the mixture – polypropylene, nylon, or cellulose at a rate of 1 –1.5 lb/cu yd. (50-70 million fibers/lb) to increase early tensile strength and crack resistance