The Significance of Tests on Fresh and Hardened Concrete

BY :

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What is Concrete ? CONCRETE 101

- Concrete is defined in the ASTM terminology relating to Concrete and Concrete Making Materials (C-125) as:
  - "a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates ;
  - In Hydraulic-cement concrete, " the binder is formed from a mixture of Hydraulic cement and water "
  - Hydraulic cement is defined (ASTM C-219) as " a cement that sets and hardens by chemical interaction with water and that is capable of doing so under water"

RAW MATERIALS

COMPONENT MATERIALS

- Portland Cement
- Water
- Fine and Coarse Aggregates
- Air
- Admixtures (Accelerators, plasticizers etc)

WATER

- NEXT TO PORTLAND CEMENT, WATER IS AN IMPORTANT INGREDIENT.
- WATER CONTROLS THE STRENGTH AND WORKABILITY OF THE MIX.
- THE WATER CEMENT RATIO IS A GOOD **approximate** INDICATOR OF THE PROBABLE STRENGTH OF THE HARDENED MIX. ITS CONTROL IS ESSENTIAL TO A PROPER MIX DESIGN WHICH WILL ADDRESS THE JOB REQUIREMENTS.
- TOO MUCH WATER IN THE MIX WILL:
  - CAUSE LARGE SHRINKAGES TO OCCUR IF CONCRETE IS ALLOWED TO CURE NORMALLY
  - RESULT IN LOW STRENGTHS
  - INCREASED WORKABILITY AND FLOWABILITY

WATER

- Reasons to use less water:
  - Increased strengths
  - Lower permeability
  - Increased resistance to the effects of weather
  - Better bonding with reinforcement
  - Less volume change from wetting and drying
  - Increased resistance to plastic shrinkage cracking
- If your job requires you to place concrete at a high slump you should either add more cement or use a superplasticizer in the mix. You might also consider using a concrete pump to place the concrete if doing so will allow you to place lower slump concrete.

WATER CONTENT VS COMPRESSIVE STRENGTH

Note:
Use as guide only. Based on American cement cube strengths !

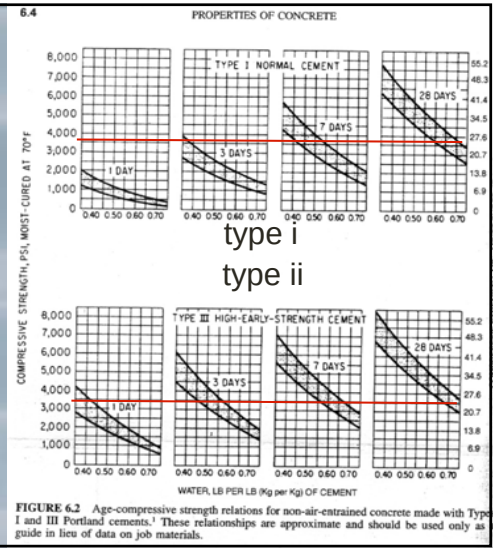
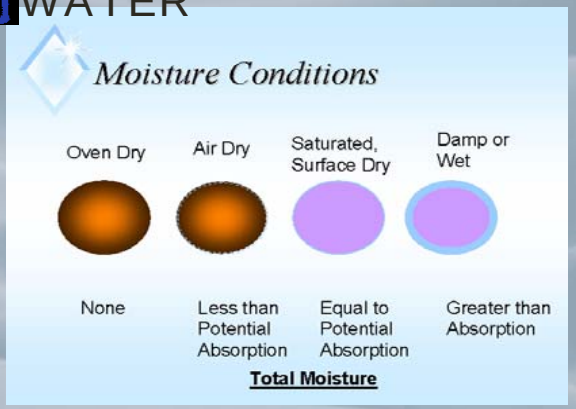


FIGURE 6.2 Age-compressive strength relations for non-air-entrained concrete made with Types I and III Portland cements.[1] These relationships are approximate and should be used only as a guide in lieu of data on job materials.

WATER IN AGGREGATES

WATER



Low Water/Cement Ratio

The water/cement ratio is the weight of the total amount of water relative to the weight of the total amount of cement used per cubic yard of concrete. In basic terms, the lower the water/cement ratio or the less water used, the better the concrete. This is true to a point. Enough water is needed to be able to place and consolidate the concrete.

The binding quality of the cement-water paste is due to the chemical reaction achieved when water is mixed with cement.

This reaction is called hydration. Very little water is needed for hydration. In fact, most concrete would look like a pile of rocks and be unworkable if the only water added was to hydrate the cement. Most of the water in concrete is "water of convenience" to help ease the task of placing concrete.

The more water added to concrete the thinner the paste. The thinner the paste the less strength in the hardened concrete. The Portland Cement Association suggests using no more water than is absolutely necessary to make the concrete plastic and workable

THE WATER CEMENT RATIO

WC= **Weight of Cement**
Weight of Water

- PROBABLY THE MOST IMPORTANT CRITERION IN MIX DESIGN AND PROPORTIONING OF CONCRETE IS THE WATER CEMENT RATIO (WT OF WATER TO WT OF CEMENT).
- **The water cement ratio is a measure of the Workability of Fresh concrete.**

Use as guide only.
Based on American cement cube strengths !

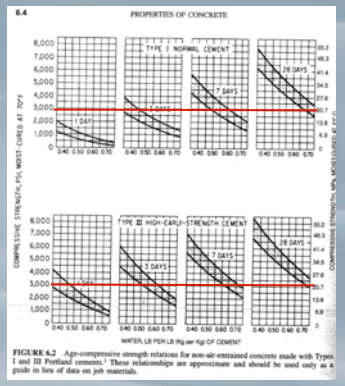


FIGURE 6.2 Age-compressive strength relations for non-air-entrained concrete made with Types I and III Portland cements.[1] These relationships are approximate and should be used only as a guide in lieu of data on job materials.

bleed effects

BLEEDING OCCURS WHEN OVER-TROWELING HAPPENS WHICH WORKS UP MORE WATER TO THE SURFACE.
THE INCREASED WATER AT THE SURFACE RESULTS IN HIGHER WC WHICH CAUSES A LOW STRENGTH LAYER THAT CAN DELAMINATE.

AIR CONTENT

- AIR CONTENT MEASUREMENT IS IMPORTANT PARTICULARLY FOR NON AIR ENTRAINED CONCRETE BECAUSE UNEXPECTED INCREASES IN AIR CONTENT CAN HAVE A RETROGRESSIVE EFFECT ON COMPRESSIVE AND FLEXURAL STRENGTHS
- IN TROPICAL CLIMATES, AIR ENTRAINMENT WOULD NORMALLY ONLE BE PRESCRIBED FOR MARINE EXPOSURES FOR INCREASED RESISTANCE TO WATER PERMEABILITY BUT MORE AND MORE THIS IS BEING REPLACED BY FLY ASH TO PROVIDE A DENSER LESS PERMEABLE MIX.
- AN AIR METER IS NORMALLY USED FOR MEASURING AIR CONTENT.

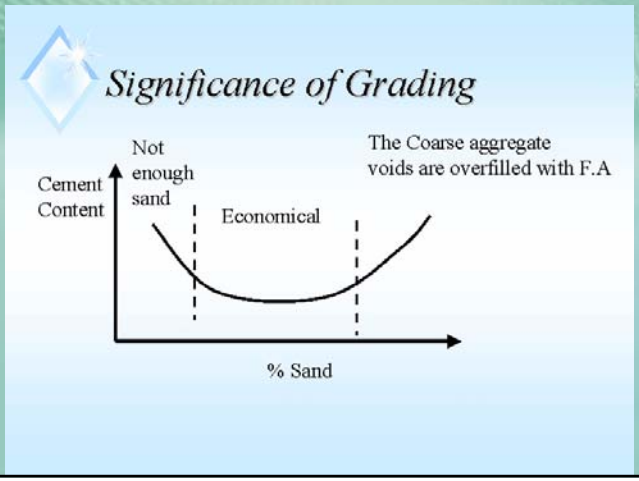
GRADATION TESTS

- GRADING IS THE PARTICLE DISTRIBUTION of GRANULAR MATERIALS AMONG VARIOUS SIZES. THIS IS USUALLY EXPRESSED IN TERMS OF CUMULATIVE PERCENTAGES LARGER OR SMALLER THAN EACH OF A SERIES OF SIZES OF STANDARD SIEVES.
- GRADING AND PARTICLE SIZE DISTRIBUTION AFFECTS CONCRETE AS FOLLOWS:
  - DETERMINES THE RELATIVE AGGREGATE PROPORTIONS
  - DETERMINES THE CEMENT AND WATER CONTENT
  - WORKABILITY
  - DURABILITY
  - POROSITY
  - POROSITY
  - SHRINKAGE
- THE WELL GRADED THE PARTICLES THE MORE ECONOMICAL IS THE MIX.
- VARIATIONS IN GRADING FROM BATCH TO BATCH CAN AFFECT THE UNIFORMITY OF
- CONCRETE

GRADATION TESTS

- GENERALLY, AGGREGATES WHICH DO NOT CONTAIN A LARGE DEFICIENCY OR EXCESS OF ANY PARTICULAR SIZE AND GIVE A SMOOTH GRADATION CURVE, WITHIN THE PRESCRIBED GRADATION WILL PRODUCE A SATISFACTORY MIX.
- PROVIDING A WELL GRADED GRADATION(WHERE ALL PRESCRIBED PARTICLE SIZES ARE PRESENT) WILL REDUCE THE TOTAL VOLUME OF VOIDS WHICH OTHERWISE WILL BE OCCUPIED BY THE CEMENT PASTE.
- FOR FINE AND COARSE AGGREGATES THE FINENESS MODULUS (FM) IS DEFINED BY ASTM C-125. THE FINENESS MODULUS IS OBTAINED BY ADDING THE CUMULATIVE PERCENTAGES RETAINED (BY WEIGHT) ON EACH OF THE SPECIFIED SIEVE SIZES AND DIVIDING THE SUM BY 100. THE HIGHER THE FM, THE COARSER IS THE AGGREGATE.
- FM IS IMPORTANT IN ESTIMATING THE PROPORTIONS OF FINE AND COARSE AGGREGATE.

GRADATION TESTS



COARSE AGGREGATES

- THE STRENGTH OF AGGREGATES, AND HENCE ITS INFLUENCE ON THE CONCRETE, IS PRIMARILY DEPENDENT ON ITS MINERALOGY
- BEYOND THIS, A SMALLER SIZED AGGREGATE MAY HAVE STRENGTH ADVANTAGES IN THAT INTERNAL WEAK PLANES MAY BE LESS LIKELY TO EXIST OR WOULD BE SMALLER AND DISCONTINUOUS.
- THE BOND BETWEEN MORTAR AND COARSE AGGREGATES WILL BE STRONGER FOR SMALLER AGGREGATES .
- A ROUGH ANGULAR SURFACE SUCH AS IN CRUSHED AGGREGATES WILL INCREASE THE BOND STRENGTHS
- AS THE MAXIMUM SIZE OF AGGREGATE IS INCREASED FOR A GIVEN SLUMP,THE WATER AND CEMENT CONTENT PER CU METER OF CONCRETE ARE DECREASED.
- THE LARGER THE COARSE AGGREGATE PROPORTION IS IN THE TOTAL MIX, THE LESSER IS THE CEMENT NEEDED DUE TO THE LESSER SURFACE AREA COMPARED TO SMALLER AGGREGATES. HOWEVER, WORKABILITY IS AFFECTED AND THE MIX BECOMES HARSHER WITH INCREASING AGGREGATE SIZE.
- FLAT ELONGATED AND ANGULAR SHAPES REQUIRE MORE WATER TO PRODUCE WORKABLE CONCRETE. HENCE CEMENT DEMAND IS INCREASED TO MAINTAIN THE SAME WC RATIO.

COARSE AGGREGATES

- THE LARGER THE AGGREGATE SIZE, THE LESSER IS THE CEMENT DEMAND.
- FOR COARSE AGGREGATES, THE LARGER SIZE MATERIALS TEND TO AFFECT THE STRENGTH OF CONCRETE PARTICULARLY IF THE AGGREGATES HAVE WEAKENED PLANES OR DISCONTINUITIES.
- GAP GRADED AGGREGATES MAY SOMETIMES BE USED BECAUSE OF DEFICIENCY IN COARSE AGGREGATE SIZES WITHIN A CERTAIN SIEVE SERIES. THIS WOULD STILL BE ACCEPTABLE PROVIDED THE PERCENTAGE OF FINE AGGREGATES IS CONTROLLED . GAP GRADED MIXES CAN PRODUCE A HARSHER MIX BUT ADEQUATE VIBRATION MAY ADDRESS THE PROBLEM.
- SEGREGATION IS A PROBLEM AND THEREFORE OVER VIBRATION IS TO BE AVOIDED AND THE SLUMP LIMITED FROM 0 TO 3 INCHES.

COARSE AGGREGATES

Fineness Modulus for Coarse Aggregates

Sieve	Wt. ret, g	Ind. Ret %	Total ret %	Tot % Passing	Spec % passing
1"	0	0	0	100	100
¾"	300	3	3	97	90 – 100
½"	2870	29	32	67	-
3/8"	4000	40	72	28	20 – 55
#4	2800	28	100	0	0 – 10
#8	30	0	100	0	0
	10,000		500		

8	100
16	100
30	100
50	100
100	100
	500

Total = 675
F.M.= 6.75

1" and 0.5" are not Std. Size

FINE AGGREGATES

- SAND IS PRIMARILY A FILLER FOR THE VOIDS IN CONCRETE.
- INCREASING THE PROPORTION OF SAND IN THE TOTAL MIX INCREASES CEMENT DEMAND BECAUSE OF THE RELATIVELY VERY LARGE SURFACE AREA THAT NEEDS TO BE COATED BY CEMENT PASTE
- FLOWABILITY AND MOBILITY OF CONCRETE IS ENHANCED WITH LARGER SAND PROPORTIONS BUT INCREASES CEMENT DEMAND.
- FLAT ELONGATED AND ANGULAR SHAPED SANDS SUCH AS PRODUCTS FROM CRUSHED SAND, ALSO REQUIRE MORE WATER TO PRODUCE WORKABLE CONCRETE. HENCE CEMENT DEMAND IS INCREASED TO MAINTAIN THE SAME WC RATIO.
- GENERALLY, THE GRADATION FOR FINE AGGREGATES GIVEN BY ASTM C-33 WOULD BE ADEQUATE. HOWEVER, IT WOULD BE PREFERABLE TO LIMIT THE % PASSING FOR THE TWO SMALLEST SIEVE SIZES (#50 AND #100 TO 15% AND 3 % OR MORE RESPECTIVELY. THIS WOULD DEPEND ON WORKABILITY DURING PLACEMENT. THE HIGHER THE FINES CONTENT THE MORE WORKABLE IS THE CONCRETE BUT ALSO INCREASES CEMENT DEMAND.

FINE AGGREGATES

Sieve analysis and Fineness modulus of Sand

Sieve Size	% retained between sieves	Cum. % passing, by mass	Cum. % retained by mass
5 mm	2	98	2
2.5 mm	113	85	15
1.25 mm	20	65	35
630 microns	20	45	55
315 microns	24	21	79
160 microns	18	3	97
Fineness Modulus= 283/100=2.83			283

FINE AGGREGATES

Fineness Modulus

- Fineness Modulus a measure of fineness of the sand
- Sum of Cum % retained on Std Sieves divided by 100.
- In previous example , 285/100 = 2.85
- Std Sieves = 1 ½, 3/4, 3/8, 4, 8, 16, 30, 50, 100
- For Concrete Sands, FM range is 2.3 to 3.1 (fine to coarse)

THE SLUMP TEST

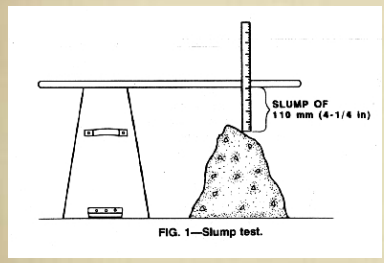


FIG. 1—Slump test.

The slump test is a measure of the workability of fresh concrete. It should NOT be used for predicting Strength even in an approximate way.

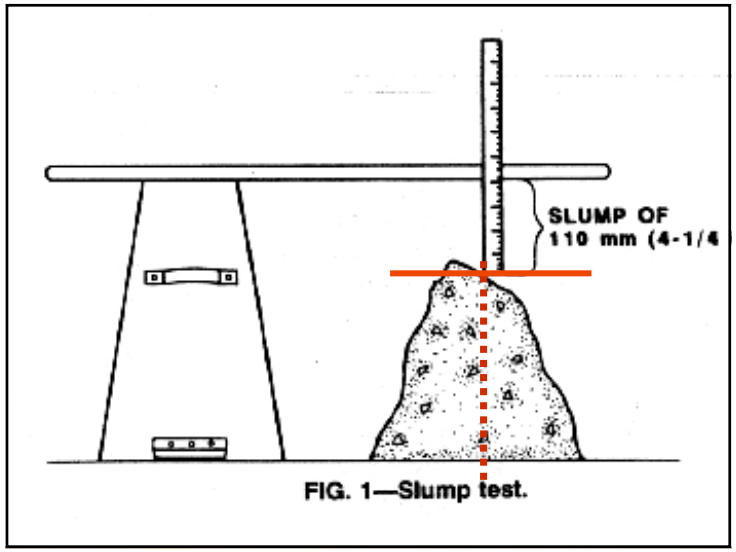


FIG. 1—Slump test.

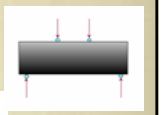
Additional Information from the Slump Test

- More information can be obtained from the Concluded Slump Test as Follows:
- After removing the slump cone and measuring the slump, the concrete is tapped on the side with the tamping rod.
- Two concretes with the same slump may behave differently as follows:
  - One may fall apart after tapping which indicates that it is a harsh mix with a minimum of fines. This may have sufficient workability ONLY for placement in pavements or Mass concrete
  - Another may be very cohesive with surplus of **workability,** this may be required for more difficult placement condition.

Ref 1.0 Klieger et al

Tests on hardened Concrete

- Concrete Compression test
- Concrete Flexural Tests
- Rebound hammer test

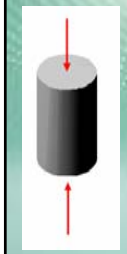

- ULTRASONIC METHODS TO DETERMINE ELASTIC PROPERTIES AND DISCONTINUITIES IN THE CONCRETE

The Schmidt Rebound Hammer

- What is it ?
- What does it do ?
- Is it Reliable?

The Schmidt Rebound Hammer

- **WHAT IS IT?** THE REBOUND HAMMER IS AN IMPACT DEVICE THAT INDICATES RELATIVE AND APPROXIMATE CONCRETE STRENGTH QUALITATIVELY THROUGH THE REBOUND OF THE PROBE WHICH HAS BEEN CALIBRATED AGAINST CONCRETE STRENGTHS
- **WHAT DOES IT DO ?** IT IS USEFUL IN DETERMINING OR LOCATING WEAKER OR STRONGER CONCRETE QUALITATIVELY OR LOCATING AREAS WITH DISCONTINUITIES
- **IS IT RELIABLE ?** IT IS NOT ACCURATE AND IS NOT INTENDED TO REPLACE THE COMPRESSION TEST. IT SHOULD NOT BE USED AS A BASIS FOR ACCEPTANCE OR NON-ACCEPTANCE OF A PARTICULAR POUR.



CONCRETE COMPRESSIVE STRENGTH

failure mechanism

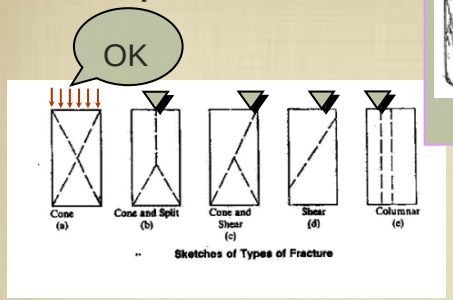
- Concrete Failure in the Compression Test or in service is a result of the development of microcracking through the specimen to the point where it can no longer resist any further load.
- The crack propagates through the weakest link whether it is through the aggregates or the cement matrix or both.
- for ultra high strength concrete aggregate strength becomes critical.
- in the compression test, because of scale effects, the planeness, perpendicularity and surface imperfections critically influence the results.

FACTORS AFFECTING COMPRESSIVE STRENGTH

- Retempering of the mix with water in the concrete can cause a decrease in the mortar strength due to uneven dispersion of the retempering waterwhich leads to pockets of mortar having a high water cement ratio.
- If concrete is allowed to dry rapidly, the available moisture for hydration reaction will be reduced and hydration ceases.
- A smaller sized aggregate may have strength advantages in that the internal weak planes may be less likely to exist.
- The bond between the mortar and coarse aggregate particles will be stronger for smaller sized aggregates which have a higher curvature.
- When concrete bleeds, the bleed water is often trapped beneath the coarse aggregate thus weakening the bond within the interfacial zone. Excessive bleeding will produce a high water cement ratio at the top portion leading to weakened wearing surfaces and dusting.

The Compression Test ASTM C-39

break patterns



surface imperfections in the sample or the test platform can cause uneven break patterns which signal lower strength results normally.

Factors Affecting the Compressive Strength test results:

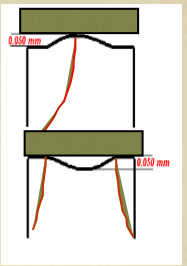
- specimen geometry
- size
- end conditions condition of loading appaatus
- rate of load application
- specimen moisture conditions

FACTORS AFFECTING COMPRESSIVE STRENGTH

The purpose of specifying end condition requirements of planeness and perpendicularity is to achieve a uniform transfer of load to the test specimen.

Surface irregularities will cause localized load concentrations of stress even if specimens are capped.

Non conforming specimens generally cause lower strength test results and the degree of strength reduction increases for higher strength concrete.



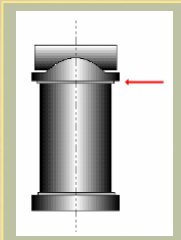
planeness and perpendicularity

specimen size and aspect ratio

- the ASTM Standard test specimen is a 6” Diameter x 12” high cylinder.
- Compressive strength generally varies inversely with increasing cylinder size with the 6” dia cylinder as the reference size.
- the ratio of specimen diameter to max aggregate should be 3 : 1. the accuracy of the strength test results decrease as the diameter to aggregate ratio decreases.
- the L :D (aspect ratio) requirements is 2. The strength increases with decreasing l/d ratio due to end restraint.However correction factors are allowed

Requirements for testing machine properties

- Must be capable of smooth and continuous load application
- Must have accurate load sensing and load indication
- Must have two bearing blocks one fixed and the other spherically seated both satisfying planness and rigidity requirements.
- Distortion of testing machine or of the bearing plates due to inadequate rigidity can cause strength reductions.

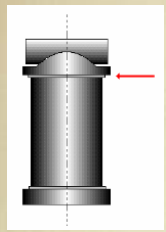


Ensure uniform seating - by rotating movable portion gently by hand as the spherically seated block is brought to bear on the specimen.

axis of specimen aligned with center of thrust of the spherically seated block

Note: Wipe clean the bearing faces of the upper and lower bearing blocks of the testing machine and test specimen prior to placement

Bearing Plate



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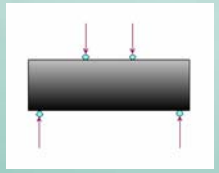
axis of specimen aligned with center of thrust of the spherically seated block

Note: Wipe clean the bearing faces of the upper and lower bearing blocks of the testing machine and test specimen prior to placement

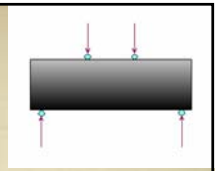
Rate of Loading

- ASTM C-39 requires that the loading rate for hydraulically operated test frames be controlled to within 20 to 50 PSI.
- The apparent strength of the concrete increases with increasing loading rate and therefore the loading rate must conform to the required standard to produce consistent and accurate results.
- Higher strength concrete are more affected by the loading rate.
- This dependence on loading rate has been found out to be due to the Mechanism of creep and Microcracking. Thus it has also been found out that when subjected to a sustained load of 75% its ultimate strength, concrete will eventually fail without any further load increases.

CONCRETE FLEXURAL STRENGTH



FACTORS AFFECTING FLEXURAL STRENGTH



- **a) Specimen size**
- **b) Preparation**
- **c) Moisture condition**
- **d) Curing**
- **e) Where the beam has been molded or sawed to size**
- **f) Aggregate size**

CONCRETE SHRINKAGE

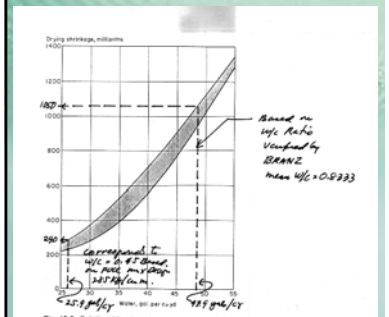


Fig. 13-9. Relationship of total water content and drying shrinkage. A large number of mixtures with various proportions is represented within the area of the band curves. Drying shrinkage increases with increasing water contents. 1 gal = 8.34 lb of water.

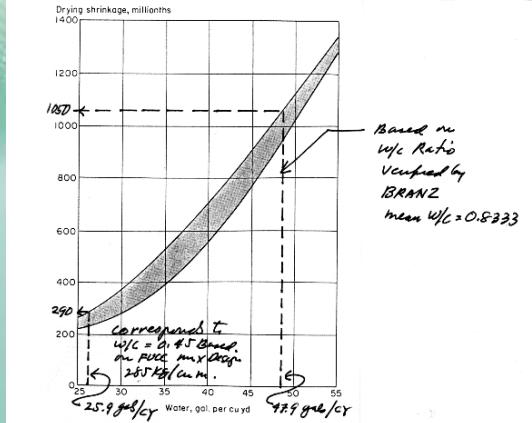
Based on these charts, and with the following actual Data:

W/C Ratio As Specified 0.42	
Resulting Water Content is	**25.9 gallons/CY**
W/C Ratio actually poured determined from average of BRANZ test W/C = 0.8333	
The resulting Water Content is	**47.9 gallons/CY**
(Computed from FUCC submittal of Mix Design).	

From these values, the Upper Band of the curve is entered to yield the following shrinkage magnitudes:

	Shrinkage Value in millionths
As specified W/C = 0.42	**290**
As poured by FUCC and determined by BRANZ W/C_{Ave} = 0.8333	**1,020**

There is, significantly, a lesser shrinkage value based on the specified W/C of 0.42 over **"normal"** concrete and a very large increase in the case of excessive W/C as provided by FUCC *(w/c=0.833 provided Vs. w/c=0.42 specified).*



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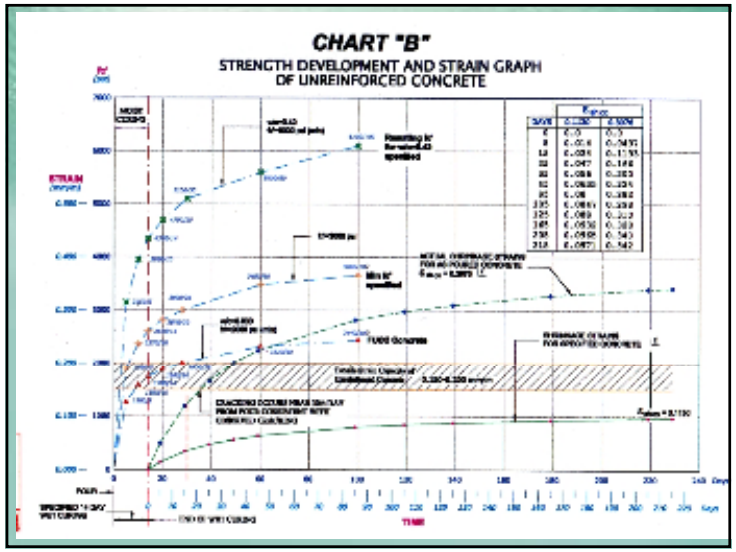

FACTORS INFLUENCING SHRINKAGE

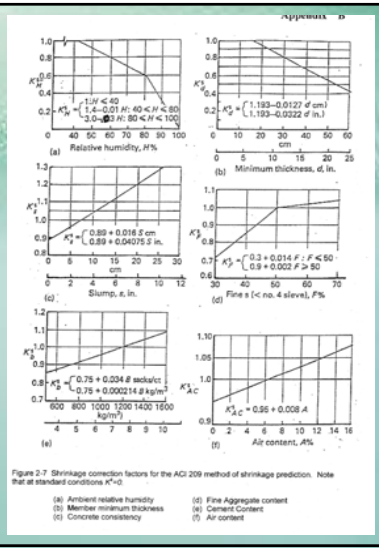

Figure 2-7 Shrinkage correction factors for the ACI 209 method of shrinkage prediction. Note that at standard conditions $K^s_i = 0$.

(a) Ambient relative humidity
(b) Member minimum thickness
(c) Concrete consistency
(d) Fine Aggregate content
(e) Cement Content
(f) Air content