THE STATE OF TEXAS

CONSTRUCTION BULLETIN

C-11

TEXAS HIGHWAY DEPARTMENT
CONSTRUCTION DIVISION

FOREWORD

This Bulletin has been prepared by the Construction Division of the Texas Highway Department for the purpose of furnishing the field engineers, inspectors and contractors with the proper procedure to be followed in the design and control of Portland Cement Concrete Mixtures for structures and pavements in accordance with governing specifications.

The Bulletin gives rather detailed instructions and explanations for design and control of concrete. The arrangement for the bulletin has been made primarily for the experienced individual. For this reason, the definition of terms used in concrete design and control, the various test procedures, etc., with which he is familiar have been placed in the latter part of the Bulletin. For those individuals who are not familiar with concrete design, the section dealing with definition of terms should be carefully studied before beginning the other portions of the Bulletin.

ISSUED JANUARY 1964
SUPERSEDES BULLETIN C-11 REVISED JUNE 1956
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INTRODUCTION

In our standard specifications there are three items covering concrete pavement: Item 360, Item 364 and Item 366. These specifications require that concrete for each of these items be designed by the Absolute Volume Method (Specified Cement Content) in accordance with instructions of this bulletin. Items 360 and 366 require that pilot tests be made in accordance with instructions set forth for Pilot Tests for Strength (Concrete Pavement) prior to beginning paving operations. Item 364 requires the making of pilot tests if concrete admixtures are used, and in accordance with instructions set forth for Pilot Tests for Strength (Concrete for Structures, Natural Aggregates).

In addition to concrete pavement there is Item 421, Concrete for Structures (Natural Aggregates). This specification requires that concrete be designed by the Absolute Volume Method (Specified Cement Content) in accordance with instructions of this bulletin. This specification also requires the making of pilot tests if concrete admixtures are used, and in accordance with instructions outlined for Pilot Tests for Strength (Concrete for Structures, Natural Aggregates).

Item 423, Lightweight Concrete for Structures, requires that concrete be designed in accordance with instructions of this bulletin. Due to the peculiarities of lightweight aggregates, two design procedures are presented: the first is based on a Modified Absolute Volume Method and the second is based on the Trial-and-Error Method. This specification requires the making of of pilot tests prior to the use of the mixture and in accordance with instructions of this bulletin for Pilot Tests for Strength (Lightweight Concrete for Structures).

PRELIMINARY TESTS

PRELIMINARY TESTS ON MATERIALS

As soon as possible the inspector should send a representative sample of the coarse aggregate or aggregates, fine aggregate or aggregates, mineral filler, cement and water to the Austin or District Laboratory for testing. Water suitable for drinking need not be submitted. Sample these materials in the amounts and as directed under sampling.

The following tests are to be made by the plant or laboratory inspector and may be divided into two parts. The tests under Part One are made to determine whether the materials meet the governing specifications. The tests under Part Two are made to determine certain physical characteristics required to be known in the design of the concrete mixture.

I. The grading of the aggregates will be tested in accordance with Test Method Tex-401-A. The coarse aggregate and fine aggregate will be tested for loss by decantation in accordance with Test Method Tex-406-A. Fine aggregate will be tested for organic impurities in accordance with Test Method Tex-408-A.

II. Determine the specific gravity of each coarse aggregate, the specific gravity of each fine aggregate and mineral filler in accordance with Test Method Tex-403-A. The value used for each aggregate should be the average of not less than three tests. Should either fine or coarse aggregate be composed of a mixture of two or more materials, calculate the average specific gravity of the combined materials.

Determine the per cent solids in the coarse aggregate and in the fine aggregate in accordance with Test Method Tex-405-A. The value used for each aggregate should be the average of not less than three tests.

PRELIMINARY TESTS ON CONCRETE

This phase of testing may be divided into two groups. Small trial batches are made to determine the water-cement ratio to use with a specified cement factor to produce workable concrete and are made in the laboratory by the inspector. For concrete pavement, test batches will be made for pilot beam tests by the inspector in co-operation with the contractor and these batches will be mixed in the mixer furnished by the contractor in accordance with the governing specifications. Unless otherwise provided for in the specifications, the minimum size of the test batch shall not be less than the manufacturer's rated capacity of the mixer used for mixing test batches. For Concrete for Structures, Natural Aggregates (Item No. 421) small trial batches and pilot batches of sufficient size to make pilot beam or cylinder tests are to be made in the laboratory by the inspector unless other arrangements are made which are satisfactory to both the engineer and contractor. The specifications do not require the contractor to furnish a mixer for this mixing, but he must furnish the materials proposed for making the concrete for structures. Preliminary tests are not required by Item No. 421 unless concrete admixtures are used; Item No. 437.

For these preliminary tests, select a coarse aggregate factor which has proven to be satisfactory on previous projects and the one most likely to be used on the project under consideration. The first small trial batch will indicate whether or not the selected coarse aggregate factor is satisfactory.

Preliminary tests for Lightweight Concrete for Structures will be discussed under the section of this bulletin devoted to that particular item.

CONCRETE PAVEMENT
SECTION

CONCRETE PAVEMENT

SMALL TRIAL MIXES (CONCRETE PAVEMENT)

The primary purpose in making these small trial batches is to determine the water-cement ratio to use with a given cement factor that will produce concrete which meets the requirements for workability and consistency. The next objective is to determine if the selected coarse aggregate factor is satisfactory.

For the first small trial batch always select the minimum cement factor allowed in the specifications. The next step is to select a coarse aggregate factor based on previous experience. If entrained air is required by the specifications, four per cent will usually prove to be satisfactory and is the amount usually used. Assume a water factor which experience indicates will be reasonably close to the determined water factor, or use the maximum value allowed in the specifications. Once the water-cement ratio has been determined for the minimum cement factor, three additional small trial batches are to be made as explained under part 3 of the following discussion and example:

For this discussion and example, we have selected Item No. 366; Concrete Pavement (Continuously Reinforced). The principles are the same for any concrete item.

1. Design a mix in accordance with Example I of Mix Designs using a cement factor of 4.5 (Minimum); a coarse aggregate factor of 0.82 (Selected); a water-cement ratio of 6.8 (Maximum) and 4% entrained air (Selected). It must be remembered that the materials used in these small trial batches must be the same as the materials to be used in the pilot test batches and in the pavement or structure, whichever the case might be.

   Calculate a trial mix batch of 0.50 cubic foot (Suggested) by use of a factor derived as follows:

$$\text{Factor} = \frac{0.50}{\text{Yield}}$$

   The weights for a one sack batch multiplied by this factor will give the weights for a 0.50 cubic foot batch.

2. Make this mix in accordance with Test Method C-11-1, Part I.

3. Usually, but not always, the determined water-cement ratio will be less than the maximum allowed with the minimum cement factor. We will assume that the first trial batch resulted in a water-cement ratio of 6.4 gallons for a cement factor of 4.5, the minimum. This results in a total quantity of 28.8 gallons (6.4 gals. x 4.5 sacks) of water per cubic yard of concrete. This value of 28.8 gallons of water per cubic yard of concrete will remain constant (plus or minus one gallon) for any water-cement ratio times the cement factor within the limits of these tests. Calculate the other cement factors to use in the other three trial batches by the equation:

$$\text{Cement Factor} = \frac{\text{Total Gals. Water per Cu. Yd. Concrete}}{\text{Water-cement Ratio}}$$

For the second trial batch, calculate the cement factor by using a water-cement ratio of one-half gallon less water than the water-cement ratio as determined in the first trial batch. For the third trial batch, calculate the cement factor by using a water-cement ratio of one gallon less water than the water-cement ratio as determined in the first trial batch. For the fourth trial batch, calculate the cement factor by using a water-cement ratio of one gallon more water than the water-cement ratio as determined in the first trial batch. In making the last three trial batches, actually determine the water-cement ratios to use with the calculated cement factors. These determined water-cement ratios should check the water-cement ratios used for calculating the cement factors within 0.2 gallon, plus or minus. From the above, it is quite evident that these tests must be made with a high degree of accuracy. It must be remembered that the coarse aggregate factor must remain the same for all of the small trial batches, and the slump must be the same for all of the small trial batches in any one series of tests.

4. Duplicate steps one and two in the second trial batch; however, design this mix using a water-cement ratio of 5.9; a cement factor of 4.9 $\left(\frac{28.8}{5.9}\right)$; a coarse aggregate factor of 0.82 and 4% entrained air. Actually determine the water-cement ratio to use with a cement factor of 4.9 which will produce the same slump as in the first small trial batch. This determined water-cement ratio should equal 5.9 (plus or minus 0.2 gallon) provided a high degree of accuracy has been maintained in making these tests.

5. Duplicate steps one and two in the third trial batch; however, design this mix using a water-cement ratio of 5.4; a cement factor of 5.3 $\left(\frac{28.8}{5.4}\right)$; a coarse aggregate factor of 0.82 and 4% entrained air. Actually determine the water-cement ratio to use with a cement factor of 5.3 which will produce the same slump as in the first trial batch. This determined water-cement ratio should equal 5.4 (plus or minus 0.2 gallon) provided a high degree of accuracy has been maintained in making these tests.

6. Duplicate steps one and two in the fourth trial batch; however, design this mix using a water-cement ratio of 7.4 gallons; a cement factor of 3.9 $\left(\frac{28.8}{7.4}\right)$; a coarse aggregate factor of 0.82 and 4% entrained air. Actually determine the water-cement ratio to use with a cement factor of 3.9 which will produce the same slump as in the first trial batch. This determined water-cement ratio should equal 7.4 (plus or minus 0.2 gallon) provided a high degree of accuracy has been maintained in making these tests.

7. Show the data obtained graphically, plotting the water-cement ratio values on the horizontal axis and the cement factor values on the vertical axis. This graph is used to determine the cement factor to use for any water-cement ratio between the values of 5.4 and 7.4, and in the method of mix design presented in this bulletin, this value must be known.

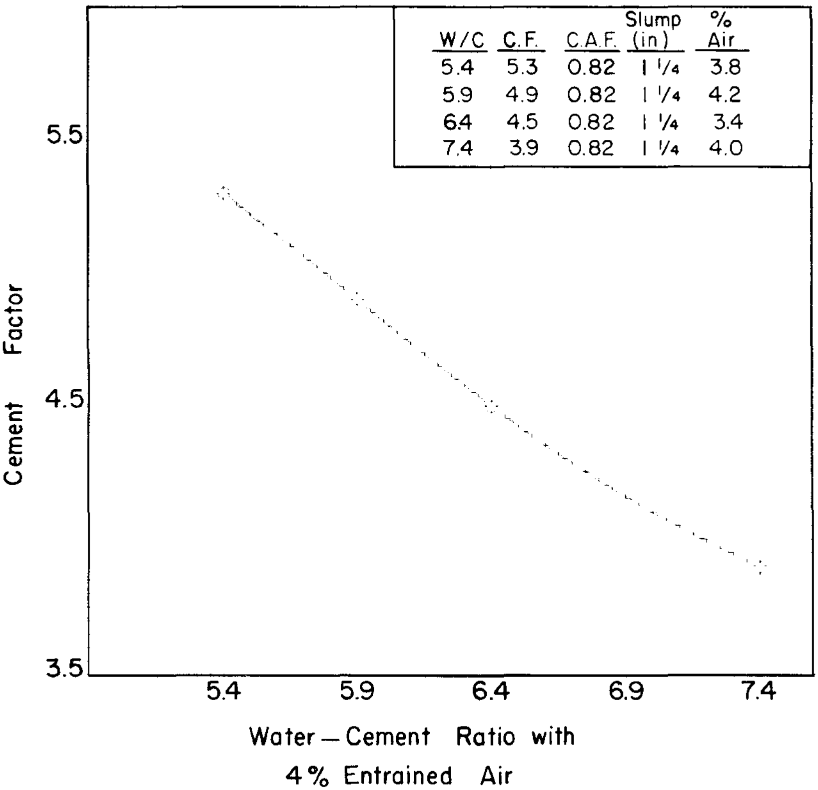
8. It may be well to emphasize that under this procedure of making small trial batches, the water-cement ratios determined are the correct values to use with the corresponding cement factor which, when using an air-entraining admixture, will produce 4% entrained air. There will not be any corrections made in these water-cement ratio values due to any reduction in water occasioned by the use of an air-entraining admixture since this procedure automatically does this.

CEMENT FACTOR CURVE

Contractor	—	A&M Constr. Co.
Project No.	—	C 9-9-9
Hwy. No.	—	F.M. 1111
County	—	Montgomery
Date	—	8/27/63

Material	Source
Cement	El Burro — Trio, Texas
Coarse Agg.	Alto Pit — Soprano, Texas
Reg. Sand	Alto Pit — Soprano, Texas
* Fine Sand	Bass Property, Local
Water	Clear Creek, Sta 140
Air Ent. Admix	Hy-Air — Light, Texas

* 10% of Total Fine Aggregate



W/C	C.F.	C.A.F.	Slump (in)	% Air
5.4	5.3	0.82	1 1/4	3.8
5.9	4.9	0.82	1 1/4	4.2
6.4	4.5	0.82	1 1/4	3.4
7.4	3.9	0.82	1 1/4	4.0

John Jones
INSPECTOR

PILOT TESTS FOR STRENGTH (CONCRETE PAVEMENT)

Make the pilot tests (Mix Design Tests) for strength in accordance with the following example:

1. Design four mixes of the size required by the specifications by the Absolute Volume Method (Specified Cement Factor). All of these four mixes are designed with a coarse aggregate factor of 82 (optional) and for each of the four mixes a water-cement ratio of 5.4 with a cement factor of 5.3 and 4% entrained air; a water-cement ratio of 5.9 with a cement factor of 4.9 and 4% entrained air; a water-cement ratio of 6.4 with a cement factor of 4.5 and 4% entrained air and a water-cement ratio of 7.4 with a cement factor of 3.9 and 4% entrained air.

2. These batches are to be mixed in a mixer approved for the job or as provided in the governing specifications. In case two or more mixers are approved and used on the project, only one set (80 beams) of pilot test beams will be required. In case transit-mix mixers are used, the size and mixing of these batches will be as directed by the Engineer. The mixer should be located conveniently to the beam forms which are provided by the contractor. These forms must be properly oiled, checked for size and strength, leveled and in every way made ready for use. The cement and aggregates should be batched by the batching plant to be used on the job so this equipment will be checked and be ready for use.

3. Immediately prior to making the pilot batches, determine the free moisture and/or the absorption of the aggregates according to Test Method Tex-403-A and/or Tex-409-A. Calculate the proper bin weights and the gallons of mixing water to be used on the basis of these determinations.

4. Weigh out a batch with a water-cement ratio of 6.4 and a cement factor of 4.5. Run this batch through the mixer for the approved mixing time in order to thoroughly coat the drum and blades, but do not use this batch for making beams. Check the workability, slump and air content of this batch immediately after it is discharged from the mixer. Redesign and adjust, if necessary, before making the batch to be used for making beams having a water-cement ratio of 6.4 and a cement factor of 4.5. The slump should be approximately one-half inch greater than the slump of the first small trial batch.

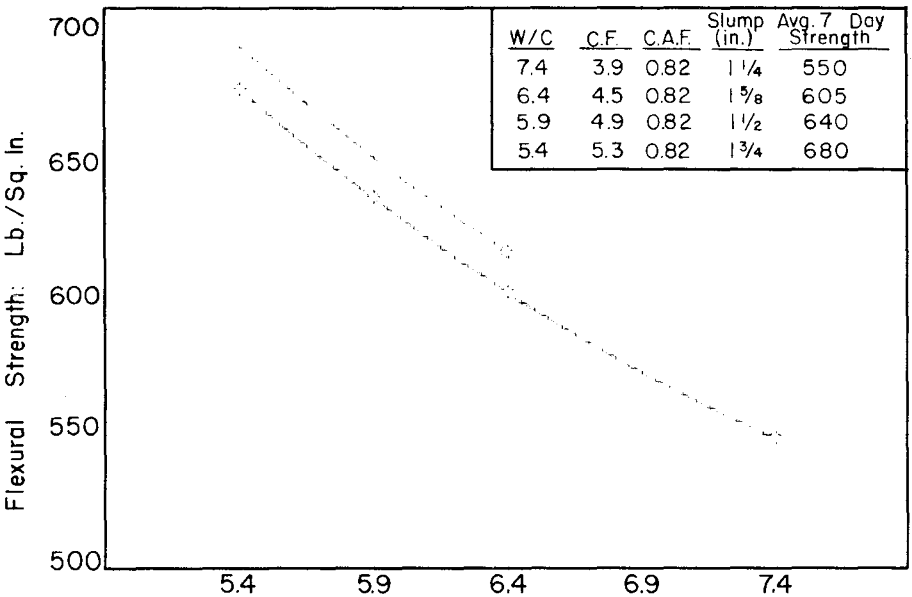
5. Weigh out and mix a batch designed with a water-cement ratio of 6.4, a cement factor of 4.5 and 4% entrained air. Check the workability of this batch, make a slump test according to Test Method Tex-415-A and determine the per cent of air according to Test Method Tex-416-A.

PILOT STRENGTH CURVE

Contractor — A&M Constr. Co.
Project No. — C 9-9-9
Hwy. No. — F.M. 1111
County — Montgomery
Date — 8 / 27 / 63

Material	Source
Cement	El Burro — Trio, Texas
Coarse Agg.	Alto Pit — Soprano, Texas
Reg. Sand	Alto Pit — Soprano, Texas
* Fine Sand	Bass Property, Local
Water	Clear Creek, Sta. 140
Air Ent. Admix.	Hy-Air — Light, Texas

* 10% of Total Fine Aggregate



W/C	C.F.	C.A.F.	Slump (in.)	Avg. 7 Day Strength
7.4	3.9	0.82	1 1/4	550
6.4	4.5	0.82	1 5/8	605
5.9	4.9	0.82	1 1/2	640
5.4	5.3	0.82	1 3/4	680

Water – Cement Ratio with
4% Entrained Air

John Doe
SUPERINTENDENT

John Jones
INSPECTOR

If the batch does not comply with all of the requirements for workability, slump and air content, discard the batch and redesign and/or adjust the amount of air-entraining admixture in order to produce concrete meeting the requirements. The slump should be approximately one-half inch greater than the slump of the first small trial batch. Providing the concrete is of satisfactory consistency and workability, make twenty beams according to Test Method Tex-420-A.

6. Repeat Step 5 with mixes designed on a water-cement ratio of 5.4, cement factor of 5.3 and 4% entrained air; a water-cement ratio of 5.9, cement factor of 4.9 and 4% entrained air; and a water-cement ratio of 7.4, cement factor of 3.9 and 4% entrained air. The slump should be approximately the same for all of the four batches.

7. Cover all test beams with saturated burlap or saturated cotton mats as soon as possible without unduly marring the surface of the concrete. Keep the burlap or cotton mats thoroughly saturated until the beams are removed from the forms.

8. From 24 to 30 hours after making, remove the beams from the forms, being careful not to damage them in any way, and immerse them in the curing tank. Keep them completely immersed and cured in accordance with Test Method Tex-420-A until they are tested. The contractor shall furnish and operate adequate facilities for curing all test specimens, together with satisfactory curing tanks equipped with heating or cooling devices that will maintain the temperature of the curing water at 70° to 90°F. at all times.

9. Seven days after the beams were made, test them in accordance with Test Method Tex-420-A and calculate the average flexural strength in pounds per square inch (Modulus of Rupture) produced by each water-cement ratio including all values in each group. Discard all individual test values in any group which vary from the average of that group by more than 10 per cent, and calculate a new average value with the remaining specimens.

10. Plot the data secured as illustrated by the graph titled, 'Pilot Strength Curve,' showing the flexural strengths along the vertical axis and the respective water-cement ratios along the horizontal axis. Produce a smooth curve which best fits all four points as illustrated in the graph, and, if necessary, give preference to the points which are within the specification requirements. Where the strength of one of the water-cement ratios is obviously out of line, it will be satisfactory to start paving operations using the curve obtained with the three remaining points with the understanding that a new batch with this water-cement ratio will be made, and twenty beams made on the first day of paving operations, so that a new average flexural strength value can be determined. If time permits, the check test should be run prior to beginning paving operations. Record all pertinent data as shown on the accompanying graph. The superintendent, or other duly authorized representative of the contractor, should sign this graph, thereby signifying he has checked and approved the work and the results obtained.

MIX DESIGNS

In order to design and control a concrete mixture properly, it is necessary to understand the definition or meaning of each term, each design constant (values which are always the same in any design) and each design factor, separately, as well as the interrelationship between them. Any change in one design factor value will automatically change the value of one or more of the other design factors. Absolute volume design may logically be divided into three steps:

Step 1. Determine the yield (Cu. Ft. Concrete produced with one sack of cement) by dividing one cubic yard (27 Cu. Ft.) by the cement factor (Sacks of Cement per Cu. Yd. Concrete). This value is called a one sack batch.

Step 2. Calculate the absolute volumes (Expressed in Cu. Ft.) of each ingredient involved for a one sack batch; namely, cement, water, coarse aggregate, fine aggregate and entrained air in case an air-entraining admixture is used. The sum of these values should equal the yield value.

Step 3. Convert the absolute volume of each ingredient into saturated surface dry weight, expressed in pounds, by multiplying the absolute volume by the specific gravity (saturated surface dry) times 62.5 (Wt. of one Cu. Ft. Water). These three steps will produce the required values for a one-sack batch which is the basic unit of the design. Any size batch can now be calculated by using the above values and will be illustrated in the four examples presented later.

DESIGN CONSTANTS

The values shown under this heading are always the same, any where and at any time. Even though these values may actually vary a very small amount they are so nearly correct for all cases that deviations therefrom have no practical influence on the design or mix. These Design Constants are as follows:

Weight of one sack of cement = Weight of one cu. ft. cement (loose)	=	94.0 lbs.
Specific Gravity of Cement	=	3.10
Weight of one cu. ft. water	=	62.5 lbs.
Weight of one gallon water	=	8.33 lbs.
Gallons in one cu. ft.	=	7.5
Specific Gravity of Water	=	1.00

DESIGN FACTORS

These factors are four in number when designing ordinary concrete, and consist of the cement factor, water-cement ratio or water factor, the coarse aggregate factor and fine aggregate factor. The fine aggregate factor is not used in the design proper but is calculated. When an air-entraining admixture is used, an additional design factor is introduced and is expressed as a percentage of the total absolute volume of the mix and will be called the Air Factor. The primary function of these Design Factors is to control the proportion of the various ingredients, which in turn controls the strength, workability and durability of the concrete. Each Design Factor has a specific function, or the direct control of one ingredient, but all of them are so interrelated that a change in one automatically causes a change in one or more of the others. The specifications place certain limitations on all of the Design Factors with the exception of the Fine Aggregate Factor.

Concrete has often been defined as a mixture of coarse aggregate, water, cement and fine aggregate. Lately, the use of air has been introduced and its use has now become quite prevalent, in which case another ingredient is added. Even though air is weightless, it occupies space or volume and must be considered in the Absolute Volume theory of design.

In order to help understand the function and interrelation of the Design Factors, it becomes desirable to divide concrete into various components which correspond with the respective steps in the Absolute Volume method of design. Thus, concrete is a mixture of two ingredients; Coarse Aggregate and Mortar. The mortar not only fills the voids in the coarse aggregate, but separates the coarse aggregate particles. The extent of this separation is one of the factors influencing workability.

Now, Mortar is also a mixture of two ingredients; Fine Aggregate and Paste. The paste not only fills the voids in the fine aggregate but separates the fine aggregate particles. The extent of this separation is another factor influencing workability.

Next, Paste is a mixture of three ingredients; Air, Cement and Water. The air and water not only fill the voids in the cement but separate the cement particles. The extent of this separation is also a factor affecting workability, and, in addition, influences the strength and durability of the concrete, providing the concrete is of a workable consistency.

In the Absolute Volume Method (Specified Cement Factor) of design, all of the Design Factors except the Fine Aggregate Factor, must be known, either from determinations previously made in the small trial mixes, or, assumed as in the first small trial mix.

A logical procedure, following the above mentioned steps, for calculating the absolute volumes of the various ingredients is illustrated in the following four examples:

EXAMPLE I

ABSOLUTE VOLUME METHOD, SPECIFIED CEMENT FACTOR WITH AIR-ENTRAINING ADMIXTURE

Example design of a one-sack batch follows:

Fine Aggregate	--	SSD specific gravity	2.65
Fine Aggregate	--	Wt. per Cu.Ft. saturated surface dry loose	101.8
Fine Aggregate	--	Per cent of solids	61.4
Coarse Aggregate	--	SSD specific gravity	2.61
Coarse Aggregate	--	Wt. per Cu.Ft. saturated surface dry loose	98.8
Coarse Aggregate	--	Per cent of solids	60.6
Cement Factor	--	Sacks per cu. yd. of concrete	4.5*
Water Factor	--	Gals. per sack of cement (From Water-Cement Ratio - Cement Factor Curve or Assumed)	6.8*
Coarse Aggregate Factor (CAF, Optional)			.82*
Air Factor	--	(AF, Optional from 3% to 6%)	4.0*
Fine Aggregate Factor (FAF, to be determined)			

*By way of explanation, regarding the selection of the design factors, the water factor is assumed at the beginning in making the first small trial batch, Test Method C-11-1, and is usually the maximum allowed in the governing specification. It will be satisfactory to assume a lower value than the maximum if experience on previous projects so indicates. At this same time, the minimum cement factor required in the governing specification is selected. The exact water factor to use with the minimum cement factor will be determined in the first small trial batch. Once this relationship is established and the water-cement ratio - cement factor curve is drawn, based on data from all four small trial batches, it will be quite obvious what cement factor to use with any water-cement ratio, or vice versa. It must be remembered that the water factor must include the liquid of the air-entraining admixture. See Part I of Small Trial Batches for an example as to how this is done.

The coarse aggregate factor is usually selected on the basis of what has proved to be satisfactory on previous projects. Once this selection is made and found to be satisfactory in the first small trial batch, it must remain constant throughout any series of preliminary tests.

Batch Design
Abs. Vol. in
Cu. Ft. per
Sack Cement

Step 1. Concrete Yield:

Abs. Vol. = $\frac{27 \text{ (Cu. Ft. in 1.0 Cu. Yd.)}}{4.5 \text{ (Sacks Cement per Cu. Yd.)}}$ = 6.000

Step 2. A coarse aggregate factor of 0.82 is used in this example, which means that each unit volume of concrete contains 82% of coarse aggregate saturated surface dry loose volume.

Coarse Aggregate (Loose Volume) = 6.0 (Yield) x 0.82 (CAF) = 4.920 Cu. Ft. Coarse Aggregate Loose Volume.

Since the Coarse Aggregate Solids per Cu. Ft. is 60.6%, we calculate the absolute volume in 4.920 Cu. Ft. Coarse Aggregate Loose Volume thusly:

4.920 (Cu. Ft. Loose Volume) x .606 $\left(\frac{\text{\% solids per cu. ft.}}{100}\right)$ = 2.982

Mortar (Absolute Volume) = 6.000 (Yield) - 2.982 (Abs. Vol. Coarse Aggregate) = 3.018 Cu. Ft.

Water: $\frac{\text{Water Factor per Sack of Cement (Gallons)}}{\text{Water per Cu. Ft. (Gallons)}} = \frac{6.8}{7.5}$ = 0.907

Cement: $\frac{94 \text{ (Pounds per Cu. Ft. Loose)}}{3.10 \text{ (Sp. Gr.) x } 62.5 \text{ (Pounds Water per Cu. Ft.)}}$ = 0.485

Air (Abs. Vol) = .04 $\left(\frac{4\%}{100}\right)$ x 6.000 (Yield) = 0.240

Paste: 0.907 (Abs. Vol. Water) + 0.485 (Abs. Vol. Cement) + 0.240 (Abs. Vol. Air) = 1.632 Cu. Ft.

Fine Aggregate: 3.018 (Mortar) - 1.632 (Paste) = 1.386

Yield = Total Concrete Produced per Sack Cement = Coarse Aggr. + Water + Cement + Fine Aggr. + Air = 6.000

Fine Aggregate Factor =

$$\frac{1.386 \text{ (Cu. Ft. Abs. Vol. Fine Aggr.)}}{0.614\left(\frac{\text{\% F.A. Solids}}{100}\right) \text{ x } 3.018 \text{ (Cu. Ft. Abs. Vol. Mortar)}} = 0.75$$

Step 3.

Since the job control of the various ingredients comprising the concrete is by weight, it will be necessary to convert Absolute Volume to pounds. This is done by the simple formula:

Wt. in lbs. = Abs. Vol. x (Wt. of one Cu. Ft. Water x Specific Gravity)

Water	= 0.907 (62.5 x 1.0)	=	56.7 lbs.
Cement	= 0.485 (62.5 x 3.1)	=	94.0 lbs.
Fine Aggregate	= 1.386 (62.5 x 2.65)	=	229.6 lbs.
Coarse Aggregate	= 2.982 (62.5 x 2.61)	=	486.4 lbs.
Air	= 0.240 (62.5 x 0)	=	0.0 lbs. *

*The specifications require that admixtures be dispensed in a liquid state and the amount of liquid which is required to produce the design per cent of air is included in the amount of mixing water.

Since we have the weights for a one-sack batch, we need to calculate the weights for the amount of concrete desired.

For example, we need to know the batch weights to be used for a 34-E Concrete Paver. The specifications allow a 20% overload; therefore, the size of the batch is 34.0 cu. ft. + 20% of 34.0 (6.8), which equals 40.8 cu. ft., the size of the batch. Then, $\left(\frac{40.8}{6.000\ (\text{Yield})}\right)$ = 6.800 sacks of cement per batch.

The specifications will not permit the use of a fraction of a sack of cement unless bulk cement is used. In the following example, if sacked cement is used, you would calculate for a 6-sack batch.

To calculate the weights for a 40.8 cu. ft. batch, we multiply the weights for a one-sack batch by 6.800.

Water	56.7 lbs. x 6.800	=	386 lbs.
Cement	94.0 lbs. x 6.800	=	639 lbs.
Fine Aggregate	229.6 lbs. x 6.800	=	1,561 lbs.
Coarse Aggregate	486.4 lbs. x 6.800	=	3,308 lbs.
Air	0.0 lbs. x 6.800	=	0 lbs. *

*The specifications require that admixtures be dispensed in a liquid state and the amount of liquid which is required to produce the design per cent of air is to be included in the amount of mixing water.

To convert pounds of water into gallons, divide by 8.33.

The above mineral aggregate weights were calculated on saturated surface dry materials. For actual bin weights, corrections are made on these weights to compensate for free water contained in the aggregates or for absorption. See Test Methods Tex-403-A and Tex-409-A. It must be remembered that a corresponding correction must be made in the amount of mixing water used to compensate for the amount of free water in the aggregates, or for the amount of absorption in the aggregates.

EXAMPLE II

ABSOLUTE VOLUME METHOD
SPECIFIED CEMENT FACTOR
NO CONCRETE ADMIXTURES

Example design of a one-sack batch follows:

Fine Aggregate	--	SSD specific gravity	2.65
Fine Aggregate	--	Wt. per Cu.Ft. saturated surface dry loose	101.8
Fine Aggregate	--	Per cent of solids	61.4
Coarse Aggregate	--	SSD specific gravity	2.61
Coarse Aggregate	--	Wt. per Cu.Ft. saturated surface dry loose	98.8
Coarse Aggregate	--	Per cent of solids	60.6
Cement Factor	--	Sacks per Cu.Yd. of Concrete	5.0*
Water Factor	--	Gals. per sack of cement	6.5*
Coarse Aggregate Factor (CAF, Optional)			0.76*
Fine Aggregate Factor (FAF, to be determined)			

*By way of explanation regarding the selection of the design factors, the water factor is assumed at the beginning in making the first small trial batch, Test Method C-11-1, and is usually the maximum allowed in the governing specification. It will be satisfactory to assume a lower value than the maximum if experience on previous projects so indicates. At this same time, the minimum cement factor required in the governing specification is selected. The exact water factor to use with the minimum cement factor will be determined in the first small trial batch. Once this relationship is established and the water-cement ratio - cement factor curve is drawn, based on data from all four small trial batches, it will be quite obvious what cement factor to use with any water-cement ratio, or vice versa.

The coarse aggregate factor is usually selected on the basis of what has proved to be satisfactory on previous projects. Once this selection is made and found to be satisfactory in the first small trial batch, it must remain constant throughout any series of preliminary tests.

Batch Design
Abs. Vol. in
Cu. Ft. per
Sack Cement

Step 1. Concrete Yield:

$$\text{Abs. Vol.} = \frac{27 \text{ (Cu. Ft. in 1.0 Cu. Yd.)}}{5 \text{ (Sacks Cement per Cu. Yd.)}} = 5.400$$

Step 2. A coarse aggregate factor of 0.76 is used in this example, which means that each unit volume of concrete contains 76 per cent of coarse aggregate saturated surface dry loose volume.

Coarse aggregate (loose volume) = 5.4 (Yield) x 0.76 (CAF) = 4.104 Cu. Ft. Coarse Aggregate Loose Volume.

Since the coarse aggregate solids per cu. ft. is 60.6%, we calculate the absolute volume in 4.104 cu. ft. coarse aggregate loose volume as follows:

$$4.104 \text{ (Cu. Ft. Loose Volume)} \times .606 \left(\frac{\% \text{ solids per cu. ft.}}{100}\right) = 2.487$$

Mortar (Absolute Volume) = 5.400 (Yield) - 2.487 (Abs. Vol. Coarse Aggregate) = 2.913 Cu. Ft.

$$\text{Water: } \frac{\text{Water Factor per Sack Cement (Gallons)}}{\text{Water per Cu. Ft. (Gallons)}} = \frac{6.5}{7.5} = 0.867$$

$$\text{Cement: } \frac{94 \text{ (Pounds per Cu. Ft. Loose)}}{3.10 \text{ (Sp. Gr.)} \times 62.5 \text{ (Pounds Water per Cu. Ft.)}} = 0.485$$

Paste = 0.867 (Abs. Vol. Water) + 0.485 (Abs. Vol. Cement) = 1.352 Cu. Ft.

Fine Aggregate = 2.913 (Mortar) - 1.352 (Paste) = 1.561

Yield = Total Concrete Produced per Sack Cement = Coarse Aggr. + Water + Cement + Fine Aggr. = 5.400

Fine Aggregate Factor =

$$\frac{1.561 \text{ (Cu. Ft. Abs. Vol. Fine Aggr.)}}{0.614 \left(\frac{\% \text{ F. A. Solids}}{100}\right) \times 2.913 \text{ (Cu. Ft. Abs. Vol. Mortar)}} = 87.3*$$

*An increase in the coarse aggregate factor, with the cement factor and the water factor remaining the same, will result in a decrease in the fine aggregate factor, which will result in an increase in the slump.

Step 3.

Since the job control of the various ingredients comprising the concrete is by weight, it will be necessary to convert Absolute Volume to pounds. This is done by the formula:

Wt. in lbs. = Abs. Vol. x (Wt. of one Cu. Ft. water x Specific Gravity)

Water	=	0.867 (62.5 x 1.0)	=	54.2 lbs.
Cement	=	0.485 (62.5 x 3.1)	=	94.0 lbs.
Fine Aggregate	=	1.561 (62.5 x 2.65)	=	258.5 lbs.
Coarse Aggregate	=	2.487 (62.5 x 2.61)	=	405.7 lbs.

Since we have the weights for a one-sack batch, we need to calculate the weights for the amount of concrete desired:

For example, we need to know the batch weights for a 5 cu. yd. Transit Truck Mixer; the rated capacity by the Truck Mixer Manufacturer's Bureau of the National Ready-Mix Association. Five cubic yards times 27 = 135 Cu. Ft., the size of the batch.

$$\frac{135 \text{ Cu. Ft.}}{5.4 \text{ Cu. Ft. (Yield)}} = 25.0 \text{ Sacks Cement per batch.}$$

The specifications will not permit the use of a fraction of a sack of cement unless bulk cement is used.

To calculate the weights for a 135 Cu. Ft. batch, we multiply the weights for a one-sack batch by 25.0

Water	54.2 x 25.0	=	1355 lbs.
Cement	94.0 x 25.0	=	2350 lbs.
Fine Aggregate	258.5 x 25.0	=	6463 lbs.
Coarse Aggregate	405.7 x 25.0	=	10143 lbs.

To convert pounds of water into gallons, divide by 8.33.

The above mineral aggregate weights were calculated on saturated surface dry materials. For actual bin weights, corrections are made on these weights to compensate for free water contained in the aggregates, or for absorption. See Test Methods Tex-403-A and Tex-409-A. It must be remembered that a corresponding correction must be made in the amount of mixing water used to compensate for the amount of free water in the aggregates, or for the amount of absorption in the aggregates.

EXAMPLE III

ABSOLUTE VOLUME METHOD
SPECIFIED CEMENT FACTOR
WITH
CEMENT DISPERSING ADMIXTURE

Example design of a one-sack batch follows:

Fine Aggregate	-- SSD specific gravity	2.65
Fine Aggregate	-- Wt. per Cu. Ft. saturated surface dry loose	101.8
Fine Aggregate	-- Per cent of solids	61.4
Coarse Aggregate	-- SSD specific gravity	2.61
Coarse Aggregate	-- Wt. per Cu. Ft. saturated surface dry loose	98.8
Coarse Aggregate	-- Per cent of solids	60.6
Cement Factor	-- Sacks per Cu. Yd. of Concrete	5.0*
Water Factor	-- Gals. per sack of cement	6.0*
Coarse Aggregate Factor (CAF, Optional)		0.78*
Fine Aggregate Factor (FAF, to be determined)		

*By way of explanation regarding the selection of the design factors, the water factor is assumed at the beginning in making the first small trial batch, Test Method C-11-1, and is usually the maximum allowed in the governing specification. It will be satisfactory to assume a lower value than the maximum if experience on previous projects so indicates. At this same time, the minimum cement factor required in the governing specification is selected. The exact water factor to use with the minimum cement factor will be determined in the first small trial batch. Once this relationship is established and the water-cement ratio - cement factor curve is drawn, based on data from all four small trial batches, it will be quite obvious what cement factor to use with any water-cement ratio, or vice versa. It must be remembered that the water factor must include the liquid of the cement dispersing admixture. See Part III of Small Trial Mixes for an example as to how this is done. The cement dispersing admixture must be used exactly in accordance with the manufacturer's recommendations, unless otherwise directed by the Materials and Tests Division.

The coarse aggregate factor is usually selected on the basis of what has proved to be satisfactory on previous projects. Once this selection is made and found to be satisfactory in the first small trial batch, it must remain constant throughout any series of preliminary tests.

Batch Design
Abs. Vol. in
Cu. Ft. per
Sack Cement

Step 1. Concrete Yield:

$$\text{Abs. Vol.} = \frac{27 \text{ (Cu. Ft. in 1.0 Cu. Yd.)}}{5 \text{ (Sacks cement per cu. yd.)}} \qquad = 5.400$$

Step 2. A coarse aggregate factor of 0.78 is used in this example, which means that each unit volume of concrete contains 78 per cent of coarse aggregate saturated surface dry loose volume.

Coarse aggregate (loose volume) = 5.4 (Yield) x 0.78 (CAF) = 4.212 Cu. Ft. Coarse Aggregate Loose Volume.

Since the coarse aggregate solids per cu. ft. is 60.6%, we calculate the absolute volume in 4.212 cu. ft. coarse aggregate loose volume as follows:

$$4.212 \text{ (Cu. Ft. Loose Volume)} \times .606 \left(\frac{\% \text{ solids per Cu. Ft.}}{100} \right) = 2.552$$

Mortar (Absolute Volume) = 5.400 (Yield) - 2.552 (Abs. Vol. Coarse Aggregate) = 2.848 Cu. Ft.

$$\text{Water: } \frac{\text{Water Factor per Sack Cement (Gallons)}}{\text{Water per Cu. Ft. (Gallons)}} = \frac{6.0}{7.5} \qquad = 0.800$$

$$\text{Cement: } \frac{94 \text{ (Pounds per Cu. Ft. Loose)}}{3.10 \text{ (Sp. Gr.)} \times 62.5 \text{ (Pounds Water per Cu. Ft.)}} \qquad = 0.485$$

Paste = 0.800 (Abs. Vol. Water) + 0.485 (Abs. Vol. Cement) = 1.285 Cu. Ft.

Fine Aggregate = 2.848 (Mortar) - 1.285 (Paste) = 1.563

Yield = Total Concrete Produced per Sack Cement = Coarse Aggr. + Water + Cement + Fine Aggr. = 5.400

Fine Aggregate Factor =

$$\frac{1.563 \text{ (Cu. Ft. Abs. Vol. Fine Aggr.)}}{0.614 \left(\frac{\% \text{ F. A. Solids}}{100} \right) \times 2.848 \text{ (Cu. Ft. Abs. Vol. Mortar)}} = 89.4^{*}$$

*An increase in the coarse aggregate factor, with the cement factor and the water factor remaining the same, will result in a decrease in the fine aggregate factor which in turn will result in an increase in the slump.

Step 3.

Since the job control of the various ingredients comprising the concrete is by weight, it will be necessary to convert Absolute Volume to pounds. This is done by the formula:

Wt. in lbs. = Abs. Vol. x (Wt. of one Cu. Ft. Water x Specific Gravity)

Water	= 0.800 (62.5 x 1.0)	=	50.0 lbs.
Cement	= 0.485 (62.5 x 3.1)	=	94.0 lbs.
Fine Aggregate	= 1.563 (62.5 x 2.65)	=	258.9 lbs.
Coarse Aggregate	= 2.552 (62.5 x 2.61)	=	416.3 lbs.

Since we have the weights for a one-sack batch, we need to calculate the weights for the amount of concrete desired:

For example, we need to know the batch weights for a 5 cu. yd. Transit Truck Mixer; the rated capacity by the Truck Mixer Manufacturer's Bureau of the National Ready-Mix Association. Five cubic yards times 27 = 135 Cu. Ft., the size of the batch.

$$\frac{135 \text{ Cu. Ft.}}{5.4 \text{ Cu. Ft. (Yield)}} = 25.0 \text{ Sacks Cement per Batch.}$$

The specifications will not permit the use of a fraction of a sack of cement, unless bulk cement is used.

To calculate the weights for a 135 Cu. Ft. batch, we multiply the weights for a one-sack batch by 25.0.

Water	50.0 x 25.0	=	1250 lbs.
Cement	94.0 x 25.0	=	2350 lbs.
Fine Aggregate	258.9 x 25.0	=	6473 lbs.
Coarse Aggregate	416.3 x 25.0	=	10408 lbs.

To convert pounds of water into gallons, divide by 8.33.

The above mineral aggregate weights were calculated on saturated surface dry materials. For actual bin weights, corrections are made on these weights to compensate for free water contained in the aggregates, or for absorption. See Test Methods Tex-403-A and Tex-409-A. It must be remembered that a corresponding correction must be made in the amount of mixing water used to compensate for the amount of free water in the aggregates, or for the amount of absorption in the aggregates.

EXAMPLE IV

ABSOLUTE VOLUME METHOD, SPECIFIED CEMENT FACTOR WITH AIR-ENTRAINING ADMIXTURE AND CEMENT DISPERSING ADMIXTURE

Example design of a one-sack batch follows:

Fine Aggregate	-- SSD specific gravity	2.65
Fine Aggregate	-- Wt. per Cu.Ft. saturated surface dry loose	101.8
Fine Aggregate	-- Per cent of solids	61.4
Coarse Aggregate	-- SSD specific gravity	2.61
Coarse Aggregate	-- Wt. per Cu.Ft. saturated surface dry loose	98.8
Coarse Aggregate	-- Per cent of solids	60.6
Cement Factor	-- Sacks per cu. yd. of concrete	5.0*
Water Factor	-- Gals. per sack of cement (from water-cement ratio - cement factor curve or assumed)	6.0*
Coarse Aggregate Factor (CAF, Optional)		.78*
Air Factor	-- (AF, Optional from 3% to 6%)	4.0*
Fine Aggregate Factor (FAF, to be determined)		

*By way of explanation, regarding the selection of the design factors, the water factor is assumed at the beginning in making the first small trial batch, Test Method C-11-1, and is usually the maximum allowed in the governing specification. It will be satisfactory to assume a lower value than the maximum if experience on previous projects so indicates. At this same time, the minimum cement factor required in the governing specification is selected. The exact water factor to use with the minimum cement factor will be <u>determined</u> in the <u>first</u> small trial batch. Once this relationship is established, and the water-cement ratio - cement factor curve is drawn, based on data from all four small trial batches, it will be quite obvious what cement factor to use with any water-cement ratio, or vice versa. It must be remembered that the water factor must include the liquid of the admixtures. See Part IV of Small Trial Mixes for an example as to how this is done. It is permissible to vary from the manufacturer's recommendations for air-entraining admixtures in order to obtain the desired amount of entrained air, but it is not permissible to vary from the manufacturer's recommendations for cement dispersing admixtures, unless otherwise directed by the Materials and Tests Division.

The coarse aggregate factor is usually selected on the basis of what has proved to be satisfactory on previous projects. Once this selection is made and found to be satisfactory in the first small trial batch, it must remain constant throughout any series of preliminary tests.

Batch Design
Abs. Vol. in
Cu. Ft. per
Sack Cement

Step 1. Concrete Yield:

$$\text{Abs. Vol.} = \frac{27 \text{ (Cu. Ft. in 1.0 Cu. Yd.)}}{5 \text{ (Sacks Cement per Cu. Yd.)}} = 5.400$$

Step 2. A coarse aggregate factor of 0.78 is used in this example, which means that each unit volume of concrete contains 78% of coarse aggregate saturated surface dry loose volume.

Coarse aggregate (loose volume) = 5.400 (Yield) x 0.78 (CAF) = 4.212 Cu. Ft. Coarse Aggregate Loose Volume.

Since the Coarse Aggregate Solids per Cu. Ft. is 60.6%, we calculate the absolute volume in 4.212 Cu. Ft. Coarse Aggregate Loose Volume thusly:

$$4.212 \text{ (Cu. Ft. Loose Volume)} \times .606 \left(\frac{\% \text{ solids per cu. ft.}}{100} \right) = 2.552$$

Mortar (Absolute Volume) = 5.400 (Yield) - 2.552 (Abs. Vol. Coarse Aggregate) = 2.848 Cu. Ft.

$$\text{Water: } \frac{\text{Water Factor per Sack of Cement (Gallons)}}{\text{Water per Cu. Ft. (Gallons)}} = \frac{6.0}{7.5} = 0.800$$

$$\text{Cement: } \frac{94 \text{ (Pounds per Cu. Ft. Loose)}}{3.10 \text{ (Sp. Gr.)} \times 62.5 \text{ (Pounds Water per Cu. Ft.)}} = 0.485$$

$$\text{Air (Abs. Vol.)} = 0.04 \left(\frac{4\%}{100} \right) \times 5.400 \text{ (Yield)} = 0.216$$

Paste: 0.800 (Abs. Vol. Water) + 0.485 (Abs. Vol. Cement) + 0.216 (Abs. Vol. Air) = 1.501 Cu. Ft.

Fine Aggregate: 2.848 (Mortar) - 1.501 (Paste) = 1.347

Yield = Total Concrete Produced per Sack Cement = Coarse Aggr. + Water + Cement + Fine Aggr. + Air = 5.400

Fine Aggregate Factor =

$$\frac{1.347 \text{ (Cu. Ft. Abs. Vol. Fine Aggr.)}}{0.614 \left(\frac{\% \text{ F. A. Solids}}{100} \right) \times 2.848 \text{ (Cu. Ft. Abs. Vol. Mortar)}} = 0.77$$

Step 3.

Since the job control of the various ingredients comprising the concrete is by weight, it will be necessary to convert Absolute Volume to pounds. This is done by the simple formula:

Wt. in lbs. = Abs. Vol. x (Wt. of one Cu. Ft. Water x Specific Gravity)

Water	=	0.800 (62.5 x 1.0)	=	50.0 lbs.
Cement	=	0.485 (62.5 x 3.1)	=	94.0 lbs.
Fine Aggregate	=	1.347 (62.5 x 2.65)	=	223.1 lbs.
Coarse Aggregate	=	2.552 (62.5 x 2.61)	=	416.3 lbs.
Air	=	0.216 (62.5 x 0)	=	0.0 lbs.*

*The specifications require that admixtures be dispensed in a liquid state and the amount of liquid which is required to produce the design per cent of air is included in the amount of mixing water.

Since we have the weights for a one-sack batch, we need to calculate the weights for the amount of concrete desired.

For example, we need to know the batch weights to be used for a 34-E Concrete Paver. The specifications allow a 20% overload; therefore, the size of the batch is 34.0 cu. ft. + 20% of 34.0 (6.8) which equals 40.8 cu. ft., the size of the batch. Then, $\left(\frac{40.8}{5.400\ (\text{Yield})}\right)$ = 7.556 sacks cement per batch.

The specifications will not permit the use of a fraction of a sack of cement unless bulk cement is used. In the following example, if sacked cement is used, you would calculate for a 7-sack batch.

To calculate the weights for a 40.8 cu. ft. batch, we multiply the weights for a one-sack batch by 7.556.

Water	=	50.0 lbs. x 7.556	=	378 lbs.*
Cement	=	94.0 lbs. x 7.556	=	710 lbs.
Fine Aggregate	=	223.1 lbs. x 7.556	=	1686 lbs.
Coarse Aggregate	=	416.3 lbs. x 7.556	=	3146 lbs.
Air	=	0.0 lbs. x 7.556	=	0 lbs.*

*The specifications require that admixtures be dispensed in a liquid state and the amount of liquid which is required to produce the design per cent of air is to be included in the amount of mixing water.

To convert pounds of water into gallons, divide by 8.33.

The above mineral aggregate weights were calculated on saturated surface dry materials. For actual bin weights, corrections are made on these weights to compensate for free water contained in the aggregates or for absorption. See Test Methods Tex-403-A and Tex-409-A. It must be remembered that a corresponding correction must be made in the amount of mixing water used to compensate for the amount of free water in the aggregates, or for the amount of absorption in the aggregates.

JOB CONTROL

(CONCRETE PAVEMENT)

ROUTINE TESTS ON MATERIALS

There are certain routine tests which must be made in order to adequately control the concrete mixture and to determine if the materials meet the specification requirements. The plant inspector should make sieve analyses on each 100 cubic yards of the coarse aggregate and each 100 cubic yards of sand or fine aggregate by Test Method Tex-401-A. These materials should be sampled for acceptance or rejection as delivery is being made. The loss by decantation of both the coarse aggregate and sand should be determined by Test Method Tex-406-A at least once, and more often if necessary. The presence of an undesirable amount of organic impurities in the sand should be determined by Test Method Tex-408-A, at least once, and more frequently if necessary, particularly if a local sand is being used. The use of materials not meeting the specification requirements for grading, decantation and organic impurities is prohibited.

TESTS FOR CONCRETE DESIGN CONTROL

While paving operations are in progress, the specific gravity of the coarse and fine aggregate is to be determined in accordance with Test Method Tex-403-A at least twice, and more frequently if necessary. The specific gravity of materials from any particular source does not vary but a very small amount, if any; however, this value is one of the factors governing yield and should be checked occasionally during paving operations. Determine the per cent of solids in both the coarse and fine aggregates by Test Method Tex-405-A as often as necessary to control workability. Any change in the per cent of solids of any aggregate does not affect the yield as long as the weights of these materials are not changed; however, it will affect the workability of the concrete mix. As long as the workability of a concrete mix remains the same, the per cent of solids in the aggregates is not changing. In order to properly control the amount of mixing water, determine the amount of free moisture in the coarse and fine aggregate in accordance with Test Method Tex-409-A approximately once each hour. The moisture content of the first few batches at the beginning of paving each day is critical, particularly if aggregates have been left in the bins over night and moisture has settled to the bottom parts of the bins. For this reason, materials should not be left in the bins over night. After each rain, special attention must be given to moisture uniformity of the stockpiled aggregates. Aggregates should be fed into the bins with as uniform moisture content as possible. Remember, material in the bottom layers of a stockpile usually has a higher free moisture content than material in the top layers of a stockpile. Determine, as often as necessary, the absorption in the coarse aggregate and the sand by Test Method Tex-403-A. Aggregates containing absorption are in a more uniform condition as compared to aggregates containing free moisture; therefore, it is not necessary to test aggregates for absorption as frequently. Coarse aggregate containing more than 0.5% free moisture and all fine aggregate shall be stockpiled for at least 24 hours prior to use.

BEGINNING PAVING OPERATIONS

From the pilot strength curve, select the water-cement ratio required to produce concrete of the specified strength, and from the cement factor curve, select the cement factor to correspond with the selected water-cement ratio. Should this selection result in a cement factor below the minimum required in the specifications, select the minimum cement factor provided in the specifications and the corresponding water-cement ratio. Assuming the specifications require a flexural strength of 575 pounds per square inch, our example pilot strength curve indicates that a water-cement ratio of 6.9 will produce this strength. However, this water-cement ratio is above the maximum of 6.8 allowed in the specifications, therefore it cannot be used. From the cement factor curve, the cement factor for a water-cement ratio of 6.8 is 4.25, however, this value is below the minimum 4.5 cement factor required in the specifications, so it too, cannot be used. In this case, it will be necessary to select the minimum required cement factor of 4.5 and the corresponding water-cement ratio of 6.4 for the design factors. Design a mix using these design factors and the same coarse aggregate factor used in making the pilot tests and begin paving operations on this design.

CONTROL OF WORKABILITY OF CONCRETE

The mixer inspector should at all times observe the concrete closely to see that it is workable in every respect. He should test the slump of the concrete by Test Method Tex-415-A each time a set of beams is made and more frequently if necessary to insure that the slump of the concrete complies with the specifications. Consecutive batches should have the same slump. If they do not, it probably indicates that material with variable free moisture content is being fed into the bins. It must be emphasized that no amount of testing can offset or compensate for charging the bins with material having a non-uniform free moisture content. Likewise, the frequency of tests must be governed by the uniformity of the materials.

Air content of concrete should be tested at least four times a day in accordance with Test Method Tex-416-A.

At the beginning of paving operations, the mixer inspector should observe the mix and determine if the coarse aggregate factor is the proper one to use. From this observation he may decide that this factor should be reduced because the mix is harsh and difficult to finish with the usual finishing operations, or, he may decide this factor could be increased without making the mix harsh and hard to finish. In either case, he should advise the plant inspector to make those changes in the mix design his observations indicate should be made.

The mixer inspector is directly responsible for the workability of the mix. He should at all times adjust the quantity of mixing water in order to maintain the proper consistency and slump of the mix, but should this amount vary by more than two gallons from the amount shown on Form 356, a new mix design or a new moisture test should be requested immediately.

The plant inspector should make all changes in the mix design requested by the mixer inspector, and should make all changes in the batch weights occasioned by variations in moisture content and specific gravity. If there is an actual change in the specific gravity, which will seldom occur, it will be necessary for the plant inspector to redesign the mix. The specific gravities used at the start of paving operations should be the average of several tests, and the variations noted. Only one test should not form the basis for making a change. As previously stated, any change in the per cent of solids of the aggregates, and the batch weights remaining the same, does not change the yield or absolute volume of the aggregates, but does change the workability of the mix. Should the per cent solids change to the extent that it is apparent that the workability of the mix has changed, then redesign the mix using the new values for the per cent of solids.

Should free water appear on the slab behind the finishing operations, appropriate changes in the mix design or aggregates must be made. This condition is usually encountered when the humidity is high and the rate of evaporation is low.

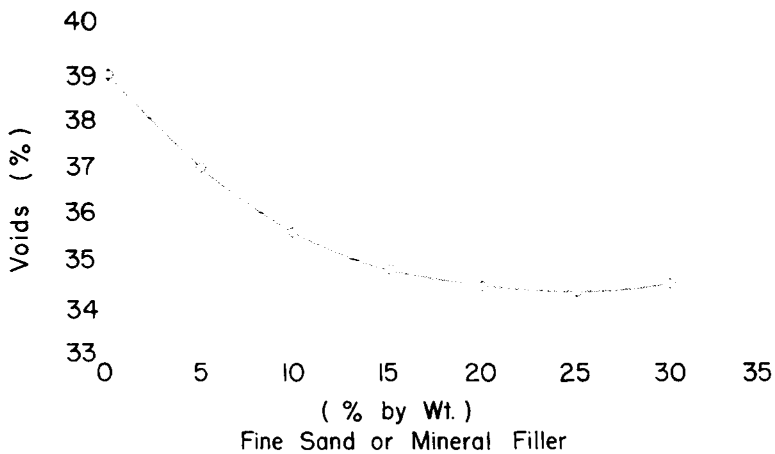
BLEEDING AND ITS CONTROL

All concrete, sooner or later, will lose some of the moisture used as mixing water. When this rate of loss exceeds the rate of evaporation from the pavement surface, we call this bleeding. This bleeding is more likely to occur when using a fine aggregate having a relatively high percentage of voids. Bleeding is objectionable for several reasons. It will leave a thin film or laitance on the pavement surface which will readily wear or scale off under traffic. This produces an unsightly surface as well as an open, weak surface which will deteriorate much faster than a tight, strong, low voidage surface. In addition, bleeding will unduly delay finishing operations, and cause the finishing of joints to become quite difficult.

There are several methods by which bleeding can be prevented or materially reduced. The addition of entrained air or more entrained air generally will allow a reduction in the amount of mixing water required to maintain the same slump, thus reducing the amount of water available for bleeding.

The addition of fine sand or mineral filler up to a certain amount will usually result in a decrease in the per cent voids in the fine aggregate, (See figure "Reduction of Voids in Fine Aggregate").

REDUCTION OF VOIDS IN FINE AGGREGATE



This reduction in voids usually will allow a reduction in the amount of mixing water required to maintain the same slump, and, here again, the amount of water available for bleeding is reduced. At the same time, the addition of fine sand or mineral filler will increase the surface area of the fine aggregate which will tend to hold the moisture within the concrete for a longer period of time, thereby decreasing the rate of moisture loss. In some instances, additional fines can be incorporated within the fine aggregate by altering the method of processing this material by the producer. It is the responsibility of the contractor to furnish aggregates which, when combined into a concrete mix, do not bleed. If the contractor fails to do this, it will then be necessary to use additional cement for this purpose.

HAIR CRACKING AND ITS CONTROL

Hair cracking is just the opposite of bleeding. This condition is due to the rate of evaporation being much greater than the rate of moisture loss from the concrete surface. An increase in the percentage of voids in the fine aggregate will give some relief. Thoroughly wetting the subgrade will afford additional relief; however, the primary remedial action consists of accelerated curing operations. There are some chemicals on the market which are supposed to correct this condition; however, the specifications do not provide for their use.

CONTROL OF STRENGTH OF CONCRETE

Two test beams for a flexural strength value shall be taken from the concrete for each 500 square yards of pavement placed, or in accordance with the specification requirements. The mixer inspector should make these two beams from the same batch of concrete according to Test Method Tex-420-A. Each pair of beams should be numbered consecutively, beginning with "1" and continuing throughout the paving operations. Each beam should be plainly marked with the proper number, followed by "A" on one beam and "B" on the other. The mixer inspector should record the number of the beams and the station number at which they were made on Form 311. He also should make a slump test by Test Method Tex-415-A from the same batch from which the beams were made and record this on Form 311. The curing and handling of test beams shall be in accordance with Test Method Tex-420-A.

Seven days after the beams are made, the plant inspector should test the beams in accordance with Test Method Tex-420-A, in each case recording the flexural strength of beams "A" and "B" and the average of these two values on Form 312. The average strength of each pair of beams constitutes one 'flexural strength value.'

The plant inspector should keep a tabulation of all flexural strength values. Where more than one strength is specified, separate tabulations for each strength must be kept. After each day's testing, the last ten consecutive flexural strength values obtained from concrete having the same water-cement ratio, are averaged. Discard any value which varies by more than 10% from the average obtained. Calculate and record a new average, called the 'adjusted average,' from the remaining values. If this adjusted average varies from the strength required by the specifications by more than 4%, the batch must be redesigned employing the water-cement ratio, as determined from the pilot strength curve, to produce the required strength, provided the maximum water-cement ratio is not exceeded and the minimum cement factor is met.

The following example, in conjunction with the sample curves shown under 'Preliminary Tests,' illustrates the procedure. In the column headed: 'W/C Job Running On,' the values shown indicate the water-cement ratio being used at the time the beams were tested.

FLEXURAL STRENGTH DATA

Beam No.	Beams Made on W/C	C.F.	Date	Date Beams Tested	Flexural Strength Values	Adj. Avg.	W/C Job Running On
1 A & B	6.4	4.5	5-14-63	5-21-63	573		6.4
2 "	"	"	"	"	604		"
3 "	"	"	"	"	520 x		"
4 "	"	"	"	"	610		"
5 "	"	"	5-15-63	5-22-63	593		"
6 "	"	"	"	"	625		"
7 "	"	"	"	"	640		"
8 "	"	"	"	"	615		"
9 "	"	"	"	"	595		"
10 "	"	"	"	"	680 x		"
11 "	"	"	"	"	630		"
12 "	"	"	"	"	600	614	"
13 "	"	"	5-16-63	5-23-63	635		"
14 "	"	"	"	"	595		"
15 "	"	"	"	"	620	624	"

Since only four flexural values were obtained on 5-21-63, it is impossible to calculate the average of the last ten values. The first adjusted average value of 614 pounds was obtained by averaging the values 3 through 12 and calculating the adjusted average after discarding value numbers 3 and 10, both of which varied more than 10% from the initial average.

Assume the specifications require a flexural strength of 575 pounds per square inch, a minimum cement factor of 4.5 and a maximum water-cement ratio of 6.8. Even though the strength exceeds the required strength by more than 4%, and the water-cement ratio is less than the maximum allowed, it isn't possible to redesign the mix because the minimum cement factor required is already being used.

It may be of interest to note that the adjusted value of 624 pounds was obtained from values 6 through 15; however, Value No. 10 was not discarded this time since its value did not vary from the initial value by as much as 10%. This adjusted average strength exceeds the required strength even more than in the first adjusted average; however, it still isn't possible to redesign the mix with a lower cement factor because the minimum is still being used.

HOW TO CORRECT FOR FREE MOISTURE

Let us now make certain of the proper way in which to apply free moisture determination test data.

Stockpiled aggregates usually contain free moisture, or moisture over and above a saturated surface dry condition. The relation of weight to absolute volume depends upon the specific gravity, and specific gravities are determined on aggregates in a saturated, surface dry condition. Therefore, it is important that we be able to compensate our stockpile aggregate weights for the discrepancy between the saturated, surface dry condition and the free moisture content of the aggregates.

The per cent of free moisture in a wet sample is the weight of the free moisture divided by the weight of the wet sample. Thus it is clear that the free moisture is expressed as a percentage of the wet sample weight and not as a percentage of the saturated surface dry weight.

The first type of problem presents no difficulties. Let us assume 1000 pounds of wet sand which contains 10 per cent free moisture. We wish to know the weight of saturated, surface dry sand in this 1000 pounds of wet sand.

Since the free moisture equals 10 per cent of the total wet weight, then the saturated, surface dry sand equals 90 per cent of the total wet weight = 1000 x 0.9 = 900 pounds.

The second type of problem is by far the more common. These problems arise continuously.

Let us assume that we wish to procure 1000 pounds of saturated, surface dry sand. The sand at our disposal contains 10 per cent of free moisture. How much of this wet sand should we weigh out in order to secure 1000 pounds of saturated, surface dry sand?

The free moisture is expressed as a percentage of the total wet weight. Therefore, the wet sand weight must contain 10 per cent of free moisture and 90 per cent of saturated surface dry sand. Therefore, the saturated surface dry weight which is required (1000 pounds) is considered as a partial percentage of the total weight of wet sand to be weighed out. Thus, 1000 ÷ 0.9 = 1111.1 pounds, which is the correct answer. As a check, 90 per cent of 1111.1 pounds = 1111.1 x 0.9 = 1000.0 pounds.

This is very simple, but many careless operators make the mistake of increasing the given saturated, surface dry weight by the per cent of free moisture in order to arrive at the total wet weight. Using the above example: 1000 x 1.10 = 1100 pounds. Now 90 per cent of 1100 pounds is 990 pounds, and not 1000 pounds, so that this method is obviously wrong.

Therefore we may calculate the amount of wet aggregate which will be required to yield a given amount of saturated, surface dry aggregate according to the following formula:

$$\text{Wet aggregate required} = \frac{\text{Given Ssd. Wt.}}{1.000 - \frac{\%\ \text{Free M.}}{100}}$$

While on the subject, let us go a step further and see what becomes of the excess free moisture when wet aggregate is being used in concrete.

Assume that our design, in this case, calls for 1200 pounds of saturated, surface dry sand and 304 pounds of mixing water. The sand in our stockpile contains 2.3 per cent free moisture.

We would weigh out $\frac{1200}{1.000-0.023} = \frac{1200}{0.977} = 1228$ pounds of wet sand.

In this 1228 pounds of wet sand, however, is 1228 - 1200 = 28, or 1228 x 0.023 = 28, pounds of water. The mix design calls for 304 pounds of mixing water. Therefore, we must subtract the weight of free water in the sand from the weight of the designed mixing water.

Water to be added at the mixer = 304 - 28 = 276 pounds.

When a bin weight (the weight to be sent to the mixer) is corrected for free moisture content of the aggregate, the designed saturated, surface dry weight is divided by 1.0 - % Free Moisture ÷ 100.

As multiplication is easier, and more rapid than division, the following table of reciprocals is provided:

FACTORS FOR CALCULATION OF BIN WEIGHTS CORRECTED FOR FREE MOISTURE

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.0000	1.0010	1.0020	1.0030	1.0040	1.0050	1.0060	1.0070	1.0081	1.0091
1	1.0101	1.0111	1.0121	1.0132	1.0142	1.0152	1.0163	1.0173	1.0183	1.0194
2	1.0204	1.0215	1.0225	1.0235	1.0246	1.0256	1.0267	1.0277	1.0288	1.0299
3	1.0309	1.0320	1.0331	1.0341	1.0352	1.0363	1.0373	1.0384	1.0395	1.0406
4	1.0417	1.0428	1.0438	1.0449	1.0460	1.0471	1.0482	1.0493	1.0504	1.0515
5	1.0526	1.0537	1.0549	1.0560	1.0571	1.0582	1.0593	1.0604	1.0616	1.0627
6	1.0638	1.0650	1.0661	1.0672	1.0684	1.0695	1.0707	1.0718	1.0730	1.0741

Example in use of free moisture correction factors:

Assume the designed, saturated, surface dry weight to be 1200 pounds, and the stockpile sand to contain 2.3 per cent free moisture (as in preceding example). In place of dividing 1200 by 1.000 - 0.023, or 0.977, let us go to the moisture table. Opposite "2" and under ".3" is the factor "1.0235." This factor is the reciprocal of 0.977, or (1.0 ÷ 0.977).

Therefore, $1200 \times 1.0235 = \frac{1200}{0.977} = 1228$ pounds

HOW TO CORRECT FOR ABSORPTION

It is important that we know how to compensate our stockpile aggregate weights properly for the discrepancy between the saturated, surface dry condition and the absorptive condition of the aggregate.

The per cent of absorption in a dry sample is the weight of water which is absorbed divided by the weight of the dry sample. Thus it is evident that the absorption is expressed as a percentage of the dry sample weight, and not as a percentage of the saturated, surface dry sample weight.

One type of problem presents no difficulties. Let us assume 1000 pounds of crushed stone which has an absorption of 10 per cent. We wish to know how much this stone would weigh were it saturated and surface dry. As the dry stone will absorb 10 per cent of its own weight, we increase the dry weight by 10 per cent.

Saturated, surface dry weight = 1000 x 1.1 = 1100 pounds.

Another type of problem is more common. Assume that we wish to procure 1000 pounds of saturated, surface dry stone. The stone at our disposal has 10 per cent absorption. How much of this stone should we weigh out in order that we may have 1000 pounds of saturated, surface dry stone after absorption has taken place?

Since the absorption is expressed as a percentage of the dry weight, then the saturated surface dry weight (1000 pounds) must equal the dry weight (100 per cent) increased by the per cent absorption (10 per cent).

Therefore, Dry weight desired $= \frac{1000}{1.1} = 909.1$ pounds.

The dry weight increased by 10 per cent should equal the saturated, surface dry weight, and 909.1 x 1.1 = 1000 pounds, thus showing our method to be correct.

This is quite simple, but many operators will carelessly decrease the given saturated, surface dry weight by the per cent of absorption in order to obtain the dry weight desired. Using the above example:

Dry Weight desired = 1000 x 0.9 = 900 pounds

This is obviously incorrect, as the dry weight increased by the per cent of absorption does not equal the saturated, surface dry weight desired. (900 x 1.1 = 990 pounds).

Let us now see what allowance is made for the mixing water which will be absorbed by dry aggregates.

Assume that our design calls for 2400 pounds of saturated, surface dry coarse aggregate and 304 pounds of mixing water. The coarse aggregate in our stockpile has absorption of 1.7 per cent.

We would weigh out $\frac{2400}{1.000 + 0.017}$ = 2360 pounds of the dry stone.

This 2360 pounds of dry stone will absorb 2400 - 2360 = 40, or 2360 x 0.017 = 40 pounds of our 304 pounds of mixing water. Therefore, we must add this amount of water to the designed amount of mixing water.

Water to be added at the mixer = 304 + 40 = 344 pounds.

The following table of reciprocals is provided for convenience in correcting bin weights. This table is similar to the table of reciprocals provided for free moisture corrections, and may be used in the same manner.

Factors for Calculation of Bin Weights Corrected for Absorption

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.0000	.9990	.9980	.9970	.9960	.9950	.9940	.9930	.9921	.9911
1	.9901	.9891	.9881	.9872	.9862	.9852	.9843	.9833	.9823	.9814
2	.9804	.9794	.9785	.9775	.9766	.9756	.9747	.9737	.9728	.9718

CONCRETE FOR STRUCTURES
NATURAL AGGREGATES
SECTION

CONCRETE FOR STRUCTURES
(NATURAL AGGREGATES)

SMALL TRIAL MIXES (Concrete for Structures, Natural Aggregates)

The specifications require that trial designs be made and tested in accordance with this Bulletin prior to use in the field only when an approved admixture is used in the concrete. Under certain conditions, admixtures are required to be used by the governing specifications, which see.

The primary purpose in making these small trial batches is to determine the water-cement ratio to use with the specified cement factor that will produce concrete meeting the requirements for consistency, workability and slump, and to determine the amount of air-entraining admixture required to entrain a specified amount of entrained air. This data is needed for the design of the larger batch or batches used to make pilot tests for strength, and for the design of the mix to be used on the project.

Let us assume that we need to design a mix in which both an air-entraining admixture and a cement dispersing admixture are required. The following discussion and example gives the procedure for doing this.

1. Design a mix by the Absolute Volume Method (Specified Cement Factor) using a cement factor of 5.0, a water factor of 6.0, a coarse aggregate factor of 0.78, an entrained air content of 4%, and a cement dispersing admixture according to the manufacturer's recommendations - unless otherwise advised by the Materials and Tests Division. See Mix Design, Example IV, for an example of the method for doing this. By way of explanation, the water factor value was selected on basis of past experience, and, naturally, should be as close to the determined value as possible. The coarse aggregate factor was selected in much the same manner. The cement factor is specified in the specifications, the minimum and maximum being the same value in the standard specifications adopted in 1962.

   The aggregates used in the small trial batches must be the same as the aggregates used in the pilot test batches and in the work. Should the furnished aggregates, when using the specified cement factor, the maximum amount of water and entrained air allowed and the cement dispersing admixture, fail to produce concrete meeting the requirements for workability, slump and consistency, it will be necessary to re-design the mix, requiring the contractor to furnish additional or other aggregates until the mix does meet these requirements. Should this same concrete, even though meeting the requirements for workability, etc., fail to meet the strength requirements, it will be necessary for the contractor to furnish better materials until the strength requirements are met. In certain instances, the specifications allow the use of additional cement to improve the strength and workability, which see.

From the above design, calculate a trial mix batch of 0.50 cubic foot (size is optional) by use of a factor derived as follows:

$$\text{Factor} = \frac{0.50}{\text{Yield}}$$

The weights for a one-sack batch multiplied by this factor will give the weights for a 0.50 cubic foot batch. For an example of this procedure, see Test Method C-11-1 'Small Concrete Trial Mixes,' Part IV.

2. Make this mix in accordance with Test Method C-11-1 Part IV. Enough water should have been used to produce a slump of approximately 1-1/2 inches. If the manufacturer's recommendations for using the air-entraining admixture did not produce the design per cent of entrained air within one per cent, plus or minus, vary the amount of admixture until it does. Do not vary the manufacturer's recommendations for using cement dispersing admixtures at any time, unless so advised by the Materials and Tests Division.

3. Under those specifications which specify only one cement factor, it will not be necessary to make more than one small trial mix. We will assume that the small trial batch resulted in a satisfactory mix having a slump of 1-1/2 inches, a water factor of 5.9 for the cement factor of 5.0 and 3.4% entrained air. This mix did not appear to be oversanded, nor did it appear to be harsh, which indicates that the coarse aggregate factor selected is satisfactory. If the mix had been oversanded, it would have been necessary to redesign, using a higher coarse aggregate factor, in which case, another small trial batch would have been required. If the mix had been harsh or undersanded, it would have been necessary to redesign, using a lower coarse aggregate factor, in which case, another small trial batch would have been required.

4. It may be well to emphasize that under this procedure of making small trial batches, the water-cement ratios determined are the correct values to use with the corresponding cement factor which, when using an air-entraining admixture will produce 4% entrained air. There will not be any corrections made in these water-cement ratio values due to any reduction in water occasioned by the use of an air-entraining admixture and/or a cement dispersing admixture since this procedure automatically does this.

PILOT TESTS FOR STRENGTH (Concrete for Structures, Natural Aggregates)

The specifications do not require the contractor to furnish a mixer for mixing these batches. Almost all of the concrete for structures is produced by facilities of ready-mix plants. This involves the use of very large mixers which makes it impractical and uneconomical to mix a corresponding size batch for the purpose of making test specimens that would only use a small percentage of the concrete. It would be just as impractical to mix a small concrete batch of adequate size for making the test specimens in one of these large mixers. For these reasons, the pilot test batches are to be mixed in facilities provided by the Department, unless other arrangements are made which are satisfactory to both the engineer and contractor. The mixing cycle of the pilot test batches should duplicate the job mixing cycle in so far as it is possible and practical.

The following procedure is submitted for guidance and as an example:

1. Design a mix using the design factors determined in the small trial batch and in accordance with the applicable example in Mix Designs.

2. Thoroughly clean and properly oil the beam and/or cylinder forms.

3. Immediately prior to making the pilot batch, determine the free moisture or absorption of the aggregates and calculate the proper weights and the gallons of mixing water to be used for the size of batch selected.

4. Weigh out a batch and run this batch through the mixing facility for a length of time sufficient to coat its inside parts, but do not use this batch for making test specimens. Check the slump, workability and per cent of entrained air of this batch immediately. Redesign the mix if the slump and workability are not satisfactory. The slump should be approximately one-half inch greater than the slump of the corresponding small trial batch. Change the amount of air-entraining admixture if the per cent of entrained air varies more than 1%, plus or minus, from the design per cent.

5. Weigh out and mix a batch as designed. Immediately check the workability and made a slump test in accordance with Test Method Tex-415-A. Determine the per cent of entrained air by Test Method Tex-416-A. If the concrete does not comply with the requirements for workability, consistency and per cent of entrained air, discard the concrete and redesign, making the proper changes until it does meet the requirements. Providing the concrete meets the requirements for consistency, workability and per cent of entrained air, make ten beams in accordance with Test Method Tex-420-A where flexural strength governs, or make 15 cylinders in accordance with Test Method Tex-418-A where compressive strength governs. It is suggested that ten beams be made, in addition to the 15 cylinders, where compressive strength governs.

   The beams are tested at 7 days of age where flexural strength control is used. This requires that the test beams be made at least 7 days prior to using the concrete on the job.

   The cylinders are tested at 28 days of age where compressive strength control is used. This requires that the test cylinders be made at least 28 days prior to using the concrete on the job. In case the ten beams have been made, in addition to the 15 cylinders, they may be tested at 7 days for informational purposes. This will allow the engineer to know the quality of the concrete within 7 days, instead of 28 days.

6. Cover all test beams and/or cylinders with saturated burlap or cotton mats as soon as possible without unduly marring the surface of the concrete. Keep the burlap or cotton mats saturated until the test specimens are removed from the forms.

7. From 24 to 30 hours after making, remove the test specimens from the forms, being careful not to damage them, and immerse them in the curing tank. Keep them completely immersed and cured in accordance with Test Method Tex-418-A or Tex-420-A until they are tested. Curing facilities for curing pilot test specimens shall be furnished by the Department unless other suitable facilities are available which are satisfactory to both the engineer and contractor. The contractor shall furnish and operate adequate curing facilities for curing test specimens made to test concrete placed on the project. These curing facilities are to be equipped with heating and/or cooling devices which will maintain the temperature of the curing water at 70° to 90°F. at all times.

8. For flexural strength control, test the 10 beams in accordance with Test Method Tex-420-A seven days after they were made and calculate the average flexural strength in pounds per square inch (Modulus of Rupture). This average flexural strength must be equal to or greater than the strength required in the governing specifications. If it is not, it will be necessary for the contractor to furnish additional or other aggregates, which when combined to produce workable concrete, will meet the strength requirements.

   For compressive strength control, submit the 15 cylinders to the Austin Laboratory or to an approved commercial laboratory in time so they will be tested 28 days after they were made. Calculate the average compressive strength in pounds per square inch of these 15 cylinders. This average compressive strength must be equal to or greater than the strength required by the governing specifications. If it is not, it will be necessary for the contractor to furnish additional or other aggregates, which when combined to produce workable concrete, will meet the strength requirements. In case beams also were made, test them in the same manner as stated above; however, use this average value as a reference. Providing the cylinders met the strength requirements, then job beam strengths equal to or greater than the pilot beam strengths will indicate to the engineer within 7 days whether or not the concrete will likely meet the compressive strength requirements at 28 days.

   There are special conditions whereby the governing specifications allow the use of additional cement in order for the concrete to meet the strength requirements. If it is anticipated this condition may occur, it is recommended that an additional set of pilot tests for strength be made, and in this mix design, decrease the water-cement ratio one-half gallon and calculate the corresponding cement factor as outlined under Small Trial Batches, Concrete Pavement. If this condition should occur, and no preliminary tests were made for it, allow 8 pounds per square inch increase in flexural strength or 75 pounds per square inch increase in compressive strength for each 0.1 gallon decrease in the water-cement ratio. These values are realistic, and on the basis of these values and the actual strength being obtained, calculate the water-cement ratio that will produce the required strength, then calculate the corresponding cement factor as outlined under Small Trial Batches, Concrete Pavement. For example, on a flexural strength control project, let us assume that the flexural strengths are 468 psi instead of the required 500 psi; the water-cement ratio is 6.5 gallons and the cement factor is 5.0. It will be necessary to reduce the water-cement ratio 0.4 gallon $\left(\frac{500-468}{8}\right)$ which results in a revised water-cement ratio of 6.1 gallons (6.5 - 0.4). The total amount of water being used per cubic yard of concrete is 32.5 gallons (6.5 x 5.0). Since the total amount of water per cubic yard of concrete is constant for any water-cement ratio, the revised cement factor is 5.3 (32.5 ÷ 6.1). The probability of ever having to use this procedure is remote.

JOB CONTROL
(CONCRETE FOR STRUCTURES)
(NATURAL AGGREGATES)

ROUTINE TESTS ON MATERIALS

The sampling and testing of materials may be logically divided into two parts. Under Part I, the materials are to be sampled and tested to determine whether the materials meet the governing specifications. Under Part II, the materials are to be sampled and tested to control the concrete mixture and design.

PART I

The plant inspector should make sieve analyses on each 100 cubic yards of coarse aggregate and on each 100 cubic yards of fine aggregate received or used by Test Method Tex-401-A. The loss by decantation of both the coarse aggregate and fine aggregate should be determined by Test Method Tex-406-A at least once, and more often if necessary. The presence of an undesirable amount of organic impurities in the fine aggregate should be determined by Test Method Tex-408-A at least once and more frequently if necessary.

PART II

The specific gravity of the coarse and fine aggregate is to be determined in accordance with Test Method Tex-403-A at least once and more often if necessary. Determine the per cent of solids in both the coarse and fine aggregate by Test Method Tex-405-A as often as necessary to control workability. In order to control the amount of mixing water, determine the amount of free moisture in the coarse and fine aggregate in accordance with Test Method Tex-409-A as often as necessary, or determine the absorption in the coarse aggregate and the absorption in the fine aggregate by Test Method Tex-403-A.

The specifications require that test specimens for strength be made at certain intervals of time or quantity of concrete placed. Test cylinders shall be made in accordance with Test Method Tex-418-A and test beams shall be made in accordance with Test Method Tex-420-A. Determine the slump of the concrete in accordance with Test Method Tex-415-A each time test specimens for strength are made and more frequently if necessary in order to control the workability of the concrete. Where an air-entraining admixture is used, determine the per cent of entrained air in accordance with Test Method Tex-416-A each time a set of test specimens for strength is made and more frequently if necessary to control the per cent of entrained air. Test cylinders shall be tested for strength in accordance with Test Method Tex-418-A and test beams shall be tested for strength in accordance with Test Method Tex-420-A.

Most of the concrete for structures is produced in ready-mix plants. This type of operation introduces a time element which makes it very difficult to control the slump of the concrete at the structure site. Loss of slump in the concrete is dependent upon the elapsed time between batching operations and placing operations. For this reason, it is desirable to duplicate job mixing cycles and conditions when making the small trial batches and the pilot test batches. Unless this is done, the design water-cement ratio probably will not be adequate to meet the demand of the mix for proper slump at the point of placing the concrete. While it is important to have enough slump, it is just as important not to have too much slump. It is essential that a high degree of accuracy be maintained in determining the amount of mixing water to use in each batch. Even though the engineer has the authority to grant permission to add water to the concrete after the initial mixing water, the better practice is to add the proper amount of water in the beginning that will produce concrete having the desired consistency at the time of placing. The maximum water-cement ratio required by the specifications cannot be exceeded under any circumstances. There may be times when a water reducing admixture may be required so that the specified maximum water-cement ratio will not be exceeded.

All admixtures must be measured and dispensed in a liquid state. If powdered admixtures are used they must be mixed with water in the proper amounts prior to use, and it is very important to see that this mixture is uniform. Periodic additional mixing or agitating may be necessary to maintain uniformity.

Where ready-mix plants are used, the contractor must provide and use a ticket system for recording the transportation of batches from the proportioning plant to the site of work. This ticket system must be used in accordance with the governing specifications, which see.

CONCRETE FOR STRUCTURES
LIGHTWEIGHT CONCRETE
SECTION

CONCRETE FOR STRUCTURES
(LIGHTWEIGHT CONCRETE)

INTRODUCTION

There are certain characteristics peculiar to lightweight aggregates and lightweight concrete which precludes their being handled in the conventional manner. In order to produce satisfactory lightweight concrete, special consideration must be given to the following characteristics:

1. Lightweight aggregates have a high and variable rate of absorption which makes it impractical to use specific gravity values in the design computations, and creates a problem in the control of the mix.

2. Coarse Aggregate is lighter than the mortar of the concrete, causing it to float to the surface if the concrete is not properly worked or the concrete is too wet.

3. A properly proportioned batch of lightweight concrete usually will have the general appearance of being slightly oversanded when compared to a batch of natural aggregate concrete.

4. With lubrication partially provided by the use of an air-entraining admixture and a cement dispersing admixture, concrete having the desired workability can usually be obtained.

PRELIMINARY TESTS

As soon as possible the inspector should submit a representative sample of the lightweight coarse aggregate, the natural fine aggregate, cement and water to the Austin Laboratory for testing. These materials should be submitted in sufficient quantities for testing each material.

PRELIMINARY TESTS ON MATERIALS

The following tests are to be made by the plant or laboratory inspector:

1. Make sieve analysis on the lightweight coarse aggregate and on the natural fine aggregate in accordance with Test Method Tex-401-A except that both of these materials shall be moisture free when making these tests.

2. The natural fine aggregate will be tested for loss by decantation in accordance with Test Method Tex-406-A and for organic impurities by Test Method Tex-408-A.

3. Determine the absorption of the lightweight coarse aggregate and the natural fine aggregate in accordance with Test Method Tex-403-A. The aggregates shall begin from an oven dry (moisture free) constant weight condition.

4. Determine the unit weight of the moisture free lightweight coarse aggregate and the unit weight of the moisture free natural fine aggregate in accordance with Test Method Tex-404-A. The value used for each aggregate should be the average of not less than three tests on each particular aggregate.

5. Determine the per cent of solids in the lightweight coarse aggregate in accordance with Test Method Tex-429-A. The value used should be the average of not less than three tests.

6. Determine the bulk specific gravity of the natural fine aggregate in accordance with Test Method Tex-403-A.

7. Determine the per cent of solids in the natural fine aggregate using the values obtained in above steps Nos. 4 and 6 and by the following formula:

$$\% \text{ Solids Natural Fine Aggregate} = \frac{\text{Moisture Free Unit Weight}}{\text{Bulk Sp. Gr.} \times 62.5}$$

PRELIMINARY TESTS ON CONCRETE

The governing specification requires that the following condition be met: "Prior to mixing any concrete which will be used in the structure, the contractor shall prepare trial batches, proportioned and tested in accordance with Texas Highway Department Bulletin C-11." This means that the contractor must furnish and operate mixing and curing facilities for these preliminary batches and test specimens made therefrom, or make other arrangements with the engineer which are satisfactory.

In making these trial batches, they should be large enough for making all of the required tests, including test cylinders. At the same time, they should be small enough to be consistent with economy. Since most of the concrete will be mixed in large transit-truck mixers, it appears that their use for mixing these trial batches might be impractical.

Test cylinders are not to be made from a trial batch until the concrete meets the requirements for slump, entrained air, workability, consistency, wet unit weight and yield. Test cylinders should be made from such a trial batch using the minimum cement factor and another set of test cylinders should be made from a satisfactory trial batch using a cement factor of one sack more than the minimum. Should the concrete with the minimum cement factor fail to meet the strength requirements and should the concrete with the higher cement factor exceed the strength requirements, the contractor would be allowed to start placing concrete without further delay using the appropriate cement factor.

In making these trial batches, it is essential that job mixing cycles and conditions be duplicated as closely as possible. If the concrete on the job is to be mixed and agitated for a period of 15 minutes, then the trial batch concrete should be mixed and agitated for the same period of time.

The following procedure is submitted as an example and for guidance:

1. Design a mix as illustrated under Mix Design for Lightweight Concrete.

2. Calculate the moisture free weights and/or volume for the size of the trial batch as illustrated under Design Weights for One-Sack Batch.

3. Immediately prior to making the trial batch, determine the moisture in the aggregates (based on oven dry weights) and calculate the batch weights and amount of mixing water to be used based on these determinations and as illustrated under Trial Batches.

4. Weigh out the batch and mix this batch in the mixer for the required mixing time but do not use this batch for making test cylinders. Check the slump, workability, per cent of entrained air and the wet weight of this concrete immediately after discharge from the mixer. From the wet weight, calculate the yield. If the concrete does not meet the requirements for slump, workability, per cent of entrained air, wet weight and yield, redesign the mix until it does.

MIX DESIGNS
(LIGHTWEIGHT CONCRETE)

Due to the difficulties involved in the determination of accurate values for specific gravity and absorption of lightweight aggregate, the conventional method of design by absolute volume is not practical. However, two methods of design are presented in this Bulletin and Design Method No. 1 is a modification of the conventional absolute volume method of design. Design Method No. 2 is based on the trial-and-error principle which requires the designer to estimate the quantity of aggregates and water to use with a specified cement factor and a specified amount of entrained air to produce one cubic yard of concrete. It will be satisfactory to use either method of design.

For either design method used, in the actual mixing of the concrete, enough water will be used, regardless of the design quantity, to produce concrete having the desired slump.

When using Design Method No. 1 (Modified Absolute Volume), past experience indicates that a coarse aggregate factor between 70 and 76 and a water-cement ratio between 5.0 and 6.0 will usually produce satisfactory concrete. Due to the absorption of the lightweight aggregate being more or less indeterminate, the exact water-cement ratio cannot be determined, and it need not be determined since the specifications do not establish any values for this design factor. A water-cement ratio value must be assumed for design purposes and should be adjusted if the need is indicated from the concrete. In calculating the design wet unit weight of the lightweight concrete, it will be necessary to estimate the amount of water absorbed by the aggregates. The lightweight coarse aggregate will usually absorb from 5 to 20 per cent by weight based on the oven dry weight. In some instances this total absorption does not occur in the concrete prior to the pouring and finishing operations. This is the reason the per cent of absorption to use in the design calculations is difficult to establish and is to be determined on a trial-and-error basis. The absorption of the natural fine aggregate is quite small and fast so it will be satisfactory to use the total absorption value in the design calculations for this material.

When using Design Method No. 2 (Trial-and-Error), past experience indicates that from 30 to 35 cubic feet (loose volume) of moisture free aggregates and a total of 40 to 50 gallons of water when used with a specified cement factor and a specified air factor will produce one cubic yard of concrete. The amount of coarse aggregate will usually vary from 55 to 60 per cent of the total aggregate (loose volume).

All lightweight concrete must meet the requirements of the governing specifications. An air-entraining admixture and a cement dispersing admixture must be used in all lightweight concrete. These admixtures must be approved by the Materials and Tests Division (D-9) prior to use.

Preliminary tests on the materials proposed for use gave the following results:

1. All materials met the specification requirements.

2. Per cent solids of the lightweight coarse aggregate: 52.4

3. Moisture free unit weight of lightweight coarse aggregate: 37.3 pounds per cubic foot.

4. Per cent solids of the natural fine aggregate: 61.8

5. Moisture free unit weight of natural fine aggregate: 102.8 pounds per cubic foot.

6. Bulk specific gravity of natural fine aggregate: 2.661

DESIGN METHOD NO. 1 (Modified Absolute Volume)

The basic unit of design is one cubic yard of concrete. Even though this procedure is based on absolute volume, there may be a certain amount of trial-and-error involved in this method due to the difficulty in determining or estimating the amount of water to allow for the absorption of the lightweight coarse aggregate. Also, if an error is made in determining the per cent of solids in the lightweight coarse aggregate, this will be reflected slightly in the yield, but the reflection will be more pronounced in the wet unit weight of the concrete.

From the above information of the preliminary tests, the design factors can be established which it is estimated will produce one cubic yard of concrete. In actual job practice, the first design should use the minimum cement factor required in the specifications, and we will assume this to be 5.0. This design procedure may logically be divided into 6 steps:

Step 1. Establish the Design Factors for one cubic yard of concrete.

Step 2. Determine the absolute volume in cubic feet of all the ingredients for one cubic yard of concrete. The quantities of the admixtures are considered to be a part of the amount of mixing water as shown under Design Factors.

Step 3. Convert the absolute volume in cubic feet of the aggregate into cubic feet (loose volume).

Step 4. Calculate the weights of all the ingredients for one cubic yard of concrete. Beginning with this step, Design Method No. 1 (Modified Absolute Volume) is identical with Design Method No. 2 (Trial-and-Error).

These four steps will produce the required values for one cubic yard of concrete which is the basic unit of the design. Any size batch can now be calculated by using the above values with the correct factor.

Step 5. Calculate the design weights for a batch of concrete to be mixed in the trial batches.

DESIGN FACTORS FOR ONE CUBIC YARD OF CONCRETE

Cement Factor	5.0 Sacks
Water-Cement Ratio - 5.8 gals. =	
(5.8) (5.0 Sacks) =	29.0 Gallons
Coarse Aggregate Factor	72
Air Factor	7.0 Per Cent
Cement Dispersing Admixture	*1.250 Gallons
Air-Entraining Admixture	**3.000 Fluid Ounces
Absorption Lightweight Coarse Aggregate	18.0 Per cent dry wt.
Absorption Natural Fine Aggregate	0.5 Per cent dry wt.

ABSOLUTE VOLUMES FOR ONE CUBIC YARD OF CONCRETE

Abs. Vol. in Cubic Feet

Lightweight Coarse Aggregate:

$$27 \text{ (cubic feet per yard)} \times 0.72 \text{ (CAF)} \times 0.524 \left(\frac{\%\ \text{Solids}}{100} \right) = 10.187$$

$$\text{Water: } \frac{5.0 \text{ (sks. Cement)} \times 5.8 \text{ (Gals. per Sk. Cement)}}{7.5 \text{ (Gallons per cu. ft.)}} = 3.867$$

$$\text{Cement: } 5.0 \text{ (Sacks Cement)} \times 0.485 \text{ (Cu. Ft. per sk.)} = 2.425$$

$$\text{Air: } 27 \times 0.07 \left(\frac{\text{Per Cent Entrained Air}}{100} \right) = 1.890$$

Cement Dispersing Admixture:

$$\frac{0.25 \text{ (Gal. per sk. Cement)} \times 5.0 \text{ (Sks. Cement)}}{7.5 \text{ (Gallons per Cu. Ft.)}} = 0.167$$

Air-Entraining Admixture:

$$\frac{0.6 \text{ (Fl. Oz. per Sk. Cement)} \times 5.0 \text{ (Sks. Cement)}}{32 \text{(Fl. Ozs. per Qt.)} \times 4 \text{(Qts. per Gal.)} \times 7.5 \text{(Gals. per Cu. Ft.)}} = 0.003$$

*Based on Manufacturer's recommendation of one quart per sack of cement.

**Based on Manufacturer's recommendation of 0.60 fluid ounce per sack of cement.

	Abs. Vol. in Cubic Feet
Natural Fine Aggregate: 27 - (10.187 + 3.867 + 2.425 + 1.890 + 0.167 + 0.003) =	8.461

CALCULATE CUBIC FEET OF AGGREGATES (LOOSE VOLUME)

	Cubic Feet (Loose Vol.)
Lightweight Coarse Aggregate: $10.187 \div 0.524 \left(\frac{\text{Per cent solids}}{100}\right)$ =	19.44
Natural Fine Aggregate: $8.461 \div 0.618 \left(\frac{\text{Per cent solids}}{100}\right)$ =	13.69

DESIGN WEIGHTS FOR ONE CUBIC YARD OF CONCRETE

	Moisture Free Wts.
Lightweight Crs. Aggr.: 19.44 (Cu. Ft.) x 37.3 (Lbs. per Cu. Ft.)	= 725.1 lbs.
Cement: 5.0 (Sacks) x 94.0 (Lbs. per Sack)	= 470.0 lbs.
Water: 5.8 (Gals. per Sk. Cement) x 5.0 (Sks. Cement) x 8.33 (Lbs. per gallon)	= 241.6 lbs.
Natural Fine Aggregate: 13.69 (Cu. Ft.) x 102.8 (Lbs. per Cu. Ft.)	=1407.3 lbs.
Cement Dispersing Admixture: 1.25 (Gals.) x *8.33 (Lbs. per Gal.)	= 10.4 lbs.
Air-Entraining Admixture: $3.00 \text{ Fl. Ozs.} \times \left(\frac{1}{15.3 \text{ (Fl. Ozs. per Lb.)}}\right)$	= 0.2 lb.

Before the design wet unit weight of the concrete can be calculated, the per cent of absorption of the lightweight coarse aggregate in the concrete must be estimated. If the lightweight coarse aggregate becomes saturated in the concrete before the concrete is finished in the structure, then the per cent of absorption as determined by Test Method Tex-403-A may be used, otherwise a smaller value must be used. We will assume a value of 16% for the absorption of the lightweight coarse aggregate. In addition, the absorption of the natural fine aggregate was determined to be 0.5 per cent and it is satisfactory to use this value.

*Based on the assumption that this material has a specific gravity of 1.00.

Water Absorbed by Lightweight Crs. Aggr: 725.1 x 0.16	=	116.0 lbs.
Water Absorbed by Natural Fine Aggr: 1407.3 x 0.005	=	7.0 lbs.
Total Calculated weight for one Cubic Yard Concrete	=	2977.6 lbs.

Calculated wet wt. for one Cu. Ft. Conc. = $\frac{2977.6}{27}$ = 110.3 lbs.

The specifications do not allow a maximum dry unit weight of the concrete in excess of 110 pounds per cubic foot. The difference between the wet unit weight and the dry unit weight will vary with different aggregates and depends to a large extent on the per cent of absorption of the lightweight coarse aggregate. Concrete made with a lightweight coarse aggregate having a relatively high per cent of absorption can be expected to show a greater loss from wet weight to dry weight than concrete made with a lightweight coarse aggregate having a relatively low per cent of absorption.

The above design appears to be satisfactory since the design wet unit weight of the concrete is 110.3 pounds per cubic foot which no doubt will result in a dry unit weight somewhat less than 110 pounds per cubic foot. The next step is to calculate the weights for a trial batch of concrete to be mixed and of adequate size to make the necessary tests, including test cylinders. A one-sack batch is proposed since it will be large enough to make all of the required tests. To calculate the weights of the various ingredients for a one-sack batch, divide the weights for one cubic yard of concrete by 5.0 (sacks cement per Cu. Yd.) or multiply these weights by the batch factor of 0.200 (1/5).

DESIGN WEIGHTS FOR ONE-SACK TRIAL BATCH

			Moisture Free Wt.
Lightweight Coarse Aggregate:	725.1 x 0.200	=	145.0 lbs.
Cement:	470.0 x 0.200	=	94.0 lbs.
Water:(241.6 + 116.0 + 7.0)	x 0.200	=	72.9 lbs.
Natural Fine Aggregate:	1407.3 x 0.200	=	281.5 lbs.
Cement Dispersing Admixture:	10.4 x 0.200	=	2.08 lbs.
Air-Entraining Admixture:	0.20 x 0.200	=	*0.04 lb.

*Since this material is used in such small quantities, it is recommended that the metric system of measurement be used. One fluid ounce equals 29.57 cubic centimeters. 29.57cc x 3.00 fl. oz. x 0.200 = 17.7 cubic centimeters to be used in the above batch instead of 0.04 pounds.

DESIGN METHOD NO. 2 (Trial-and-Error)

The trial-and-error method of mix design employs the principle of determining the total loose volume of moisture free aggregates and the amount of water, which when used with a predetermined amount of cement and entrained air will produce one cubic yard of concrete meeting all of the specification requirements. When designing lightweight concrete by the trial-and-error method, the designer must estimate the quantity of each aggregate and water to use with a specified cement factor and entrained air, then calculate the design wet weight per cubic foot of the concrete. If the calculated wet weight per cubic foot appears satisfactory, then trial batches based on the design will be made and the actual unit weight of the concrete from these trial batches will be made and the yield determined. In the actual mixing of the concrete, an amount of water will be used, regardless of the design quantity, to produce concrete having the desired slump.

As previously stated, approximately 30 to 35 cubic feet (loose volume) of moisture free aggregates and a total of from 40 to 50 gallons of water will usually produce one cubic yard of satisfactory concrete. The amount of coarse aggregate will usually vary from 55 to 60 per cent of the total amount of aggregate, loose volume.

From this information the design factors can be estimated which it is anticipated will produce one cubic yard of concrete, the basic unit of design. In actual job practice, the first design should use the minimum cement factor required in the specifications, and we will assume this to be 5.0.

DESIGN FACTORS FOR ONE CUBIC YARD OF CONCRETE

Cement Factor	5.0 Sacks
Total Aggregates (Moisture Free)	33.13 Cu.Ft.
Water	43.77 Gals.
Air Factor	7.0 Per Cent
Cement Dispersing Admixture (5.0 x 0.25 Gal.)	*1.25 Gals.
Air-Entraining Admixture (5.0 x 0.60 Fl. oz.)	**3.00 Fl. Ozs.
Lightweight Coarse Aggregate	58.68% of Total Aggr.
Natural Fine Aggregate	41.32% of Total Aggr.

*Based on manufacturer's recommendation of one quart per sack of cement.

**Based on manufacturer's recommendation of 0.60 fluid ounce per sack of cement.

From the above design factors and pertinent values obtained in preliminary tests, the next step is to calculate the weights of the various materials in order to determine the design weight of one cubic yard of concrete and the design wet unit weight of one cubic foot of concrete.

DESIGN WEIGHTS FOR ONE CUBIC YARD OF CONCRETE

	Moisture Free Wt.
Lightweight Coarse Aggregate: $0.5868 \left(\frac{\%\ \text{Tot. Aggr.}}{100}\right) \times 33.13 \left(\begin{matrix}\text{Cu. Ft.}\\ \text{Loose Vol.}\end{matrix}\right) \times 37.3 \left(\begin{matrix}\text{Lb. per}\\ \text{Cu. Ft.}\end{matrix}\right)$	= 725.1 lbs.
Cement: 5.0 sacks x 94.0 lbs. per sack	= 470.0 lbs.
Water: 43.77 gallons x 8.33 lbs. per gallon	= 364.6 lbs.
Natural Fine Aggregate $0.4132 \left(\frac{\%\ \text{Tot. Aggr.}}{100}\right) \times 33.13 \left(\begin{matrix}\text{Cu. Ft.}\\ \text{Loose Vol.}\end{matrix}\right) \times 102.8 \left(\begin{matrix}\text{Lb. per}\\ \text{Cu. Ft.}\end{matrix}\right)$	= 1407.3 lbs.
Cement Dispersing Admixture: 1.25 gals. x *8.33 lbs. per gal.	= 10.4 lbs.
Air-Entraining Admixture: $3.0\ \text{Fl. Oz.} \times \left(\frac{1}{15.3\ \text{Fl. Oz. per lb.}}\right)$	= 0.2 lb.
Total Calculated Weight for One Cu. Yd. Concrete	= 2977.6 lbs.
Calculated wet weight for one Cu. Ft. Concrete $= \frac{2977.6}{27}$	= 110.3 lbs.

*Based on the assumption this material has a specific gravity of 1.00.

The specifications do not allow a maximum dry unit weight of the concrete in excess of 110 pounds per cubic foot. The difference between the wet unit weight and the dry unit weight will vary with different aggregates and depends to a large extent on the per cent of absorption of the lightweight coarse aggregate. Concrete made with a lightweight coarse aggregate having a relatively high per cent of absorption can be expected to show a greater loss from wet weight to dry weight than concrete made with a lightweight coarse aggregate having a relatively low per cent of absorption.

The above design appears to be satisfactory since the design wet unit weight of the concrete is 110.3 pounds per cubic foot, which no doubt will result in a dry unit weight of the concrete somewhat less than 110 pounds per cubic foot. The next step is to calculate the weights for a trial batch of concrete to be mixed and of adequate size to make the necessary tests, including test cylinders. A one-sack batch is proposed since it will be large enough to make all of the required tests. To calculate the weights of the various ingredients for a one-sack batch, divide the weights for one cubic yard of concrete by 5.0 (sacks cement per Cu. Yd.) or multiply these weights by the batch factor of 0.200 (1/5).

DESIGN WEIGHTS FOR ONE-SACK TRIAL BATCH

			Moisture Free Wt.
Lightweight Coarse Aggregate:	725.1 x 0.200	=	145.0 lbs.
Cement:	470.0 x 0.200	=	94.0 lbs.
Water:	364.6 x 0.200	=	72.9 lbs.
Natural Fine Aggregate:	1407.3 x 0.200	=	281.5 lbs.
Cement Dispersing Admixture:	10.4 x 0.200	=	2.08 lbs.
Air-Entraining Admixture:	0.20 x 0.200	=	*0.04 lb.

*Since this material is used in such small quantities, it is recommended that the metric system of measurement be used. One fluid ounce equals 29.57 cubic centimeters. 29.57cc x 3.00 fluid ounces x 0.200 = 17.7 cubic centimeters to be used in the above batch instead of 0.04 pound.

TRIAL MIXES (Applies to Design Methods No. 1 or No. 2)

The next step is to correct the design weights for moisture. Since the moisture of the aggregates is expressed as a percentage of the moisture free (oven dry) weight, determine the wet weight required by the following formula:

$$\text{Wet Wt. of Aggr.} = \text{Dry Wt.} \times \left(1.000 + \frac{\%\ \text{Moisture}}{100}\right)$$

The moisture of the lightweight coarse aggregate was found to be 16% and the moisture of the natural fine aggregate was found to be 4% in accordance with Test Method Tex-403-A. Correct the weights as follows:

		Moisture Free Weight (Pounds)		Correction Factor $1 + \frac{\%\ \text{Moisture}}{100}$		Batch Weights
Lightweight Coarse Aggr.	=	145.0	x	1.16	=	168.2 lbs.
Natural Fine Aggr.	=	281.5	x	1.04	=	292.8 lbs.
Mixing Water	= 72.9-(168.2-145.0)-(292.8-281.5)				=	38.4 lbs.
Cement - No Correction					=	94.0 lbs.
Cement Dispersing Admix.	- No correction				=	2.08 lbs.
Air-Entraining Admixture	- No correction				=	0.04 lb.
				Total Batch Weight	=	595.5 lbs.

1. Weigh out 80% of the mixing water (any amount which will be less than the final amount used is satisfactory) and add the cement dispersing admixture and the air-entraining admixture to this amount of water and thoroughly mix.

2. Place approximately one-half of this liquid mixture in the mixer, then add the aggregates and cement and start mixing. Add the other one-half of the liquid mixture to the mix and continue mixing. Then

add enough water to the mix to produce a slump of approximately 2-1/2 inches after mixing and agitating for a period of time which will correspond to the actual job mixing and agitating time. It is essential that a record be kept of the exact amount of water, with the admixtures, which is used to produce concrete having the desired slump. It is immaterial whether this exact amount is more or less than the amount of mixing water previously calculated.

3. Discharge the concrete from the mixer and immediately check the slump, Test Method Tex-415-A; determine the per cent of entrained air, Test Method Tex-416-A; determine the wet unit weight of the concrete, Test Method Tex-417-A and calculate the yield. By visual inspection, determine if the concrete is workable and if the proportions of the lightweight coarse aggregate and the natural fine aggregate are satisfactory. Do not use this batch for making test cylinders, but on the basis of the tests and observation, make any necessary changes in the mix design before making the batch to be used for making test cylinders.

4. Weigh out the same or adjusted batch and repeat steps one, two and three except make the test cylinders from this batch provided the concrete meets all of the requirements. Check the slump in accordance with Test Method Tex-415-A; determine the per cent of entrained air by Test Method Tex-416-A; determine the wet unit weight of the concrete in accordance with Test Method Tex-417-A; make 15 test cylinders in accordance with Test Method Tex-418-A and calculate the yield in accordance with the following formula:

$$\text{Yield} = \frac{\text{Actual Batch Weight Lbs.}}{\text{Actual Wet Unit Weight Lb/Cu. Ft.}} \div \text{Batch Factor}$$

5. Six test cylinders are to be cured in accordance with Test Method Tex-418-A and tested at 7 days for job control. These six test cylinders may be tested on a hand operated compression machine furnished by the contractor. If the compressive strength of the 7 day test cylinders meets the specification requirements for 28 day compressive strength, and this will frequently happen, it will be satisfactory to start placing concrete on the basis of these tests, provided it is anticipated that the concrete will meet the specification requirement for dry unit weight at 28 days. Six other test cylinders are to be cured in accordance with Test Method Tex-418-A and tested at 28 days. These six test cylinders may be tested by the Austin Laboratory or an approved commercial laboratory. The remaining three cylinders are to be tested for air-dried unit weight in accordance with Test Method Tex-417-A.

6. In the above batch, 42.4 pounds of mixing water was actually used instead of the calculated quantity of 38.4 pounds. The total batch weight actually used would be the total calculated batch weight (595.5 pounds) + (42.4 - 38.4) which equals 599.5 pounds. The actual wet unit weight was found to be 112.6 pounds per cubic foot.

$$\text{Yield} = \frac{599.5}{112.6} \div 0.200 = 26.62 \text{ Cu. Ft.} = 0.99 \text{ Cu. Yd.}$$

The other results of this batch are as follows:

Consistency and Workability	Good
Entrained Air	7.6%
Slump	2-1/2 inches
7 Day Compressive Strength	2260 psi
28 Day Compressive Strength	2850 psi
28 Day Air-Dried Unit Weight	109.7 pounds

7. Repeat all of the above procedures, however design this mix using a cement factor 1.0 greater than the minimum, which in this instance results in a new cement factor of 6.0. If using Design Method No. 1 (Modified Absolute Volume), calculate the new water-cement ratio by the following formula:

$$\text{New WCR} = \frac{\text{Previous Cement Factor x Previous Water-Cement Ratio}}{\text{New Cement Factor}}$$

In this particular instance we would have

$$\text{New WCR} = \frac{5.0 \times 5.8}{6.0} = 4.83 \text{ Gals. per Sack Cement}$$

All of the other design factors should remain the same. If using Design Method No. 2 (Trial-and-Error) decrease the amount of natural fine aggregate by approximately 0.8 Cu.Ft.(loose) to offset the increase of the cement by 1 sack (1 Cu.Ft.loose). For either design method, the total amount of water required for this batch should be very nearly the same as for the previous batch. This batch having a 6.0 cement factor produced the following results:

Actual Wet Unit Weight	112.0 pounds
Yield	1.01 Cu.Yd.
Consistency and Workability	Good
Entrained Air	8.1%
Slump	2-3/4 inches
7 Day Compressive Strength	2910 psi
28 Day Compressive Strength	3600 psi
28 Day Air-Dried Unit Weight	109.0 pounds

8. It will be noted that the 5.0 cement factor batch met all of the specification requirements except for strength and the 6.0 cement factor batch met all of the specification requirements, and exceeded the strength requirement. On the basis of the above tests, a cement factor of 5.2 should produce concrete having the required 28 day strength of 3000 psi. This value was derived as follows:

$$\text{Cement Factor} = 5.0 + \left(\frac{x}{150} = \frac{1.0}{750}\right) = 5.0 + 0.2 = 5.2$$

JOB CONTROL
(CONCRETE FOR STRUCTURES)
(LIGHTWEIGHT CONCRETE)

ROUTINE TESTS ON MATERIALS

As aggregates are delivered to the project, the plant inspector should make sieve analyses on each 100 cubic yards of lightweight coarse aggregate and each 100 cubic yards of natural fine aggregate in accordance with Test Method Tex-401-A. The loss by decantation of the natural fine aggregate should be determined by Test Method Tex-406-A at least once, and more often if necessary to insure delivery of quality aggregate. The presence of an undesirable amount of organic impurities in the natural fine aggregate should be determined by Test Method Tex-408-A at least once and more frequently if necessary. Moisture free unit weight of the lightweight coarse aggregate should be determined by Test Method Tex-404-A for each shipment of material. For this test, it is essential that a representative sample of the aggregate be tested. The per cent of absorption for each shipment of lightweight coarse aggregate should be determined in accordance with Test Method Tex-403-A. Here again, it is essential to secure a representative sample.

ROUTINE TESTS ON CONCRETE

Moisture determinations should be made as often as necessary to insure that the required volumes of aggregates are weighed into each batch and to indicate the amount of water to use with each batch. The moisture determinations should be made by oven drying the various aggregates to constant weight. The percentage of moisture in a wet sample is the loss in weight (weight of water) divided by the oven dry weight and this result multiplied by 100. Calculate the amount of wet aggregate which will be required to produce the desired amount of dry aggregate by the following formula:

$$\text{Wt. of Wet Aggr. Required} = \text{Dry Wt. desired} \times \left(1.000 + \frac{\%\ \text{Moisture}}{100}\right)$$

Do not become confused regarding this formula. It is correct because the per cent of moisture is based upon the oven dry weight of the aggregate.

In addition to the test cylinders which are required by the specifications, periodic tests for slump, per cent of entrained air and wet unit weight of the concrete should be made for proper control of lightweight concrete. With regards to the slump of the concrete, it is preferable that loss in slump of the concrete due to additional absorption of the aggregate, be held to a minimum after placing the concrete in the structure. Good engineering judgment must be exercised in determining the point of sampling for the slump test.

Slump of the concrete should be maintained as uniform as possible. To do this will require a uniform moisture content of the aggregates in the stockpile and a minimum of segregation of the lightweight coarse aggregate in the stockpile. The amount of water added in the mixer should be adjusted if necessary to maintain the desired slump. Lightweight concrete may be properly placed with an apparent lower slump than normal concrete.

Air content will vary due to certain amount of inherent error in the test itself and due to actual variations in the amount of entrained air. No attempt should be made to correct for a variation less than 1.0 per cent. However, if the average air content is higher or lower than desired, then the amount of air-entraining admixture should be changed. The strength of the air-entraining admixture solution must be uniform. Agitators may and should be used if necessary.

When a wet unit weight of the concrete is determined, the volume or yield of the concrete batch should be calculated by dividing the total weight of the materials used for one batch by the wet unit weight per cubic foot. The actual volume should be compared to the design volume and when a variation greater than 3 per cent is found, the batch weights should be corrected so the actual volume of the concrete will correspond with the design volume.

For example, consider a 5 cu. yd. or 135 cubic foot size batch. We will assume that the total weight of materials for this size batch is 14,989.0 pounds, and the wet unit weight of the concrete was determined to be 109.8 pounds per cubic foot.

The yield or total volume of concrete produced would be $\frac{14,989.0}{109.8}$ = 136.5 cubic feet. The per cent of variation would be $100\left(\frac{136.5-135.0}{135}\right)$ = 1.1%. This variation is well within the allowable of 3 per cent (plus or minus) therefore no correction in the batch weights or design is necessary.

DEFINITIONS
TEST PROCEDURES
FORMS FOR REPORTS
EQUIPMENT

DEFINITION OF TERMS

The following definitions and explanations are included in order to clarify the meaning of certain terms used in this bulletin. It is impossible to define all of the terms which may not be familiar to an operator inexperienced in the design and control of concrete mixtures, but the following have been selected either because they appear to be most liable to misunderstanding or because they require detailed explanation.

CONCRETE is an intimate mixture of cement, water, mineral aggregates and air when an air-entraining admixture is used. The water causes the cement to hydrate and bind the aggregate particles together. Concrete is designed to fill a definite space, or to produce a definite volume.

MORTAR is an intimate mixture of cement, water, fine aggregate, and air when using an air-entraining admixture. With a given coarse aggregate the quality of the mortar controls both the strength and workability of the concrete.

EXCESS MORTAR is the absolute volume of mortar in excess of the amount required to fill the voids in the coarse aggregate. If 0.80 cubic foot of coarse aggregate in a loose condition is used to produce 1.00 cubic foot of concrete, then the excess mortar = 1.00 - 0.80 = 0.20 cubic foot, or 20%. Hence, the excess mortar is always the complement of the coarse aggregate factor when both are expressed as percentages.

PASTE is an intimate mixture of cement, water, and air when using an air-entraining admixture. With given aggregates the proportion of water and cement determines the strength of the concrete, and, as paste is the lubricant of the mortar, the consistency of the paste determines the consistency or workability, of the mortar.

EXCESS PASTE is the absolute volume of paste in excess of the amount required to fill the voids in the fine aggregate. If 0.80 cubic foot of fine aggregate in a loose condition is used to produce 1.0 cubic foot of mortar, then the excess paste = 1.00 - 0.80 = 0.20 cubic foot, or 20%. Hence, the excess paste is always the complement of the fine aggregate factor when both are expressed in percentages.

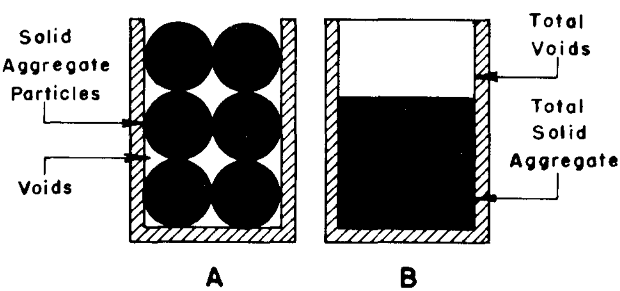
COARSE AGGREGATE is that portion of the mineral aggregate which is retained on the No. 4 sieve. This is an arbitrary distinction. It usually consists of gravel, crushed gravel, crushed stone, or a mixture of two or more of these materials. The small portion of the coarse aggregate passing the No. 4 sieve shall be considered as coarse aggregate in all designs and proportions.

FINE AGGREGATE is that portion of the mineral aggregate which passes the No. 4 sieve. This is an arbitrary distinction. It consists of sand or a combination of sands, or a combination of sand and mineral filler. The small portion of fine aggregate retained on the No. 4 sieve shall be considered as fine aggregate in all designs and proportions.

MINERAL FILLER is a very fine material and may be clean stone dust, crushed sand, crushed shell or other approved inert material. It is used to improve the workability of concrete mixes where the condition of the aggregate is such that the mix is not plastic and cohesive. It is effective in reducing bleeding of the mix where a low cement factor is used and the fine aggregate is deficient in sizes finer than the 100-mesh sieve. Mineral filler is considered a part of the fine aggregate when making voidage determinations, but is not to be included in samples of sand to be tested for loss by decantation, sieve analysis, or organic impurities. The introduction of an approved mineral filler into the mix after the job has begun does not require an additional set of pilot beams prior to use.

ABSOLUTE VOLUME The terms 'absolute volume' and 'solid volume' are synonymous and are used interchangeably. The absolute volume of a given amount of a material is the total volume of the solid portions of the material. The word 'solid' as here used does not necessarily imply 'rigid.' It merely signifies the absence of air spaces or voids. Water contains no voids; therefore, the volume of a given amount of water is the solid volume of the water. In order to visualize more clearly the solid volume of a material which contains voids, assume a measure of given volume which is filled with loose aggregate (A). Part of the total volume of the measure is occupied by solid aggregate particles and the remainder of the total volume is occupied by air spaces, or voids. Now, assume the aggregate to be converted into a liquid state. The particles will flow together and form a solid mass as in "B," the volume of which is equal to the total volume of all the solid aggregate particles in "A." When the aggregate particles in "A" are in a saturated, surface dry condition, as they are in concrete, the absolute volume of aggregate in "B" is the total absolute volume of the impermeable portion of all aggregate particles plus the **volume of the absorbed water.**

LOOSE VOLUME AND ABSOLUTE VOLUME



DESIGN FACTORS The water-cement ratio, the coarse aggregate factor, the fine aggregate factor, the air factor and the cement factor are known as 'design factors.' The fine aggregate factor is not used in the actual design but is always calculated.

CEMENT FACTOR is the number of sacks of cement used to produce one cubic yard of concrete. The symbol "CF" is used to signify the cement factor. The cement factor is equal to 27/yield or 27/absolute volume of concrete produced by one sack of cement.

WATER-CEMENT RATIO is the number of gallons of mixing water used with one sack of cement. It is frequently referred to as 'gallons of water per sack of cement' and might also be termed the 'water factor.' The symbol "W/C" is used to signify the water-cement ratio.

Explanation: The water-cement ratio determines the proportion by weight of water and cement and, as water has a constant specific gravity of 1.0 and as cement has a constant specific gravity of 3.1, it also determines the proportion by absolute volume of water and cement.

As concrete is designed to produce a given absolute volume and as this volume is expressed in cubic feet, the cubic foot becomes our standard unit of measurement. Therefore, while the water-cement ratio is spoken of in terms of gallons of water per sack of cement, it must also be considered in terms of cubic feet of water per cubic foot of cement.

A gallon of water weighs 8.33 pounds and a cubic foot of water weighs 62.5 pounds; hence, a cubic foot of water contains 62.5/8.33, or 7.5 gallons. Therefore, gallons of water divided by 7.5 (gallons per cubic foot) equals cubic feet of water. Hence, a water-cement ratio of 6.5 gallons of water per sack of cement = 6.5/7.5 = 0.867 cubic foot of water per sack of cement.

The specific gravity of cement is 3.1 and the weight of a cubic foot of water is 62.5 pounds. Therefore, a solid cubic foot of cement (containing no voids) would weigh 62.5 x 3.1, or 193.75 pounds. A sack of cement is equal to 1.0 cubic foot of cement in a loose condition, and weighs 94 pounds. Therefore, the absolute volume of one sack (1 cubic foot) of cement = 94/(62.5 x 3.1) = 94/193.75 = 0.485 cubic foot.

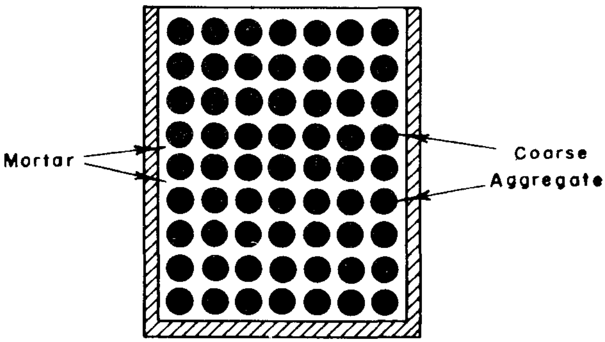
As the water-cement ratio determines the proportion of water and cement it also establishes the absolute volume of the paste when considering a one-sack batch of concrete.

Effect Upon Mix: The water-cement ratio exerts a more profound effect upon the mix than any other factor, or feature of mix design. With a given set of aggregates and a given cement the water-cement ratio governs the strength of the concrete, the higher the ratio the lower the strength and vice versa, provided good workability be maintained. As high cement factors produce high strength concrete and as low cement factors produce low strength concrete, it may be thought that the cement factor governs strength, but a closer analysis shows that a change of any magnitude in the cement factor is accompanied by a change in the water-cement ratio, and that a constant water-cement ratio produces constant strengths irrespective of the cement factor, provided good workability be maintained. This is true not only for small variations in cement content but for extreme variations.

As water is the chief lubricating agent for the concrete, it is evident that the total amount of mixing water, which is a function of the water-cement ratio in conjunction with the cement factor, is the greatest single factor in controlling the consistency and workability of the mix.

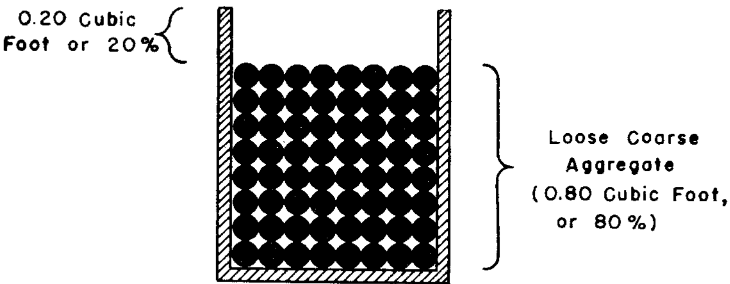
COARSE AGGREGATE FACTOR is the loose volume of coarse aggregate in a unit volume of concrete. Expressed in another way the coarse aggregate factor is the per cent of any given volume of concrete which is occupied by the loose volume of the coarse aggregate. The symbol "CAF" is used to signify the coarse aggregate factor.

COARSE AGGREGATE FACTOR OF 0.80



1.0 Cubic Foot
of Concrete

COARSE AGGREGATE FACTOR OF 0.80



1.0 Cubic Foot

Explanation: Assume that we are making 1.0 cubic foot of concrete with a coarse aggregate factor of 0.80. Without the sand, cement, and water the coarse aggregate, including the voids, would occupy 0.8 cubic foot, or 80% of the total volume of concrete, leaving 0.2 cubic foot, or 20% of the volume as unoccupied space. Concrete is composed of coarse aggregate and mortar. Assume a mortar sufficiently fluid so that, when poured into the measure (as illustrated in the accompanying figure), it will completely fill all the voids in the coarse aggregate. When the measure is completely filled with this mortar, the voids in the coarse aggregate will be completely filled and there will be 0.2 cubic foot additional mortar. This additional mortar is called 'Excess Mortar,' meaning mortar in excess of the amount required to fill the coarse aggregate voids. In this case we have 20% excess mortar when the value is expressed as a percentage of the total volume of concrete.

Ordinary concrete mortar is not sufficiently fluid to flow into all the coarse aggregate voids, so let us take the coarse aggregate in the preceding figure and mix it in a normal manner with the same amount of ordinary concrete mortar. The accompanying figure represents the concrete which is obtained. This concrete, as in the preceding figure, has a coarse aggregate factor of 0.80 or 80%, and excess mortar of 0.20, or 20%. The excess mortar is now distributed throughout the entire volume of concrete, but is, nevertheless, still an excess over and above enough to fill the voids in the loose coarse aggregate.

It is now apparent that the coarse aggregate factor determines the loose volume of coarse aggregate in any given volume of concrete, but this is not all the information available. If we know the per cent solids (or per cent voids) in the coarse aggregate, we can immediately determine the absolute volume of coarse aggregate to be used in any given volume of concrete designed with any given coarse aggregate factor. The absolute volume of concrete multiplied by the coarse aggregate factor equals the loose volume of the coarse aggregate. The loose volume of the coarse aggregate multiplied by the per cent solids in the loose aggregate equals the absolute volume of the coarse aggregate.

From the foregoing explanation it may be seen that the proportion of coarse aggregate to mortar may be varied by varying the coarse aggregate factor. By increasing the coarse aggregate factor the absolute volume of coarse aggregate is increased and the absolute volume of mortar is decreased proportionately, and vice versa.

Effect Upon Mix: As the mortar not only fills the voids in the coarse aggregate but separates the coarse aggregate particles, it is obvious that some excess mortar is always required in order to produce workable concrete. Experience has shown that a minimum of 15% excess mortar (coarse aggregate factor of 0.85) is required to produce paving concrete which is workable and will not produce honeycomb, but ordinarily the best results are obtained with a coarse aggregate factor of from 0.80 to 0.83. Specifications limit the coarse aggregate factor to a maximum of 0.85 but do not require a minimum.

Concrete without sufficient excess mortar to make it workable is said to be 'undersanded.' Such a mix is harsh and difficult to place and finish properly without producing undesirable honeycomb. The opposite extreme of an undersanded mix is an 'oversanded' mix. An oversanded mix has too low a coarse aggregate factor, or more than sufficient excess mortar. It requires much more paste to lubricate a given amount of sand than to lubricate the same amount of coarse aggregate. Thus, if the coarse aggregate factor be lowered excessively, one of two unfortunate conditions will result: (1) if the net amount of paste with a constant water-cement ratio is kept constant, the mix will be dried up and become unworkable; (2) if the water-cement ratio is kept constant and the net amount of mixing water is increased to provide workability, the cement factor is increased and the cost of the concrete increased.

In studying the effect of the coarse aggregate factor upon the workability of the mix it is also necessary to consider the effect of the voidage content of the coarse aggregate. It has been seen that the absolute volume of coarse aggregate per unit volume of concrete is a function of both the coarse aggregate factor and the per cent solids (or voids) in the coarse aggregate. As the maximum coarse aggregate factor which may be successfully employed is practically constant with a given coarse aggregate irrespective of the voidage content, it is obvious that low voids (high per cent solids) are desirable.

The coarse aggregate factor or the voidage content of the coarse aggregate does not affect the strength of the concrete provided the water-cement ratio remains constant and good workability be maintained.

FINE AGGREGATE FACTOR is the loose volume of fine aggregate (sand) in a unit volume of mortar. Expressed in another way, it is the per cent of any given volume of mortar which is occupied by the loose volume of the fine aggregate. The symbol "FAF" is used to signify the fine aggregate factor.

Explanation: The fine aggregate factor bears precisely the same relation to mortar as does the coarse aggregate factor to concrete. (See 'Coarse Aggregate Factor.') Thus, it becomes unnecessary to enter into a detailed explanation of the functioning of the fine aggregate factor except to define an additional term which is used frequently. As the paste not only fills the voids in the sand but separates the sand particles, it is obvious that some additional paste is required. This additional paste is called 'excess paste,' meaning paste in excess of the amount required to fill the sand voids.

Effect Upon Mix: Mortar without sufficient excess paste (too high a fine aggregate factor) is dry and the concrete produced with such a mortar is difficult to place and finish properly without producing undesirable honeycomb. Mortar with too low a fine aggregate factor is too wet and may not be sufficiently plastic and cohesive to secure the desired consistency of concrete. In a mix which is too wet the constituent ingredients may segregate when placed on the grade and the excessive amount of water may cause undesirable bleeding subsequent to finishing operations. Specifications do not limit the fine aggregate factor.

It is generally true that a mortar with a constant fine aggregate factor produces constant workability irrespective of the voids in the fine aggregate. Thus, it becomes apparent that it is desirable to reduce the voids in the fine aggregate as low as possible provided such practice is economical.

SPECIFIC GRAVITY is the ratio of the weight of a given absolute volume of a material to the weight of an equal volume of water. (See 'Saturated, surface dry Specific Gravity.') Thus, water has a specific gravity of 1.0. As an example of specific gravity consider 1.0 cubic foot of water, which weighs 62.5 pounds, in comparison with a solid cubic foot of stone weighing 125.0 pounds. The volume of the stone is the same as the volume of water, but the weight of the stone is twice that of the water. Therefore, the specific gravity of the stone = 125.0/62.5 =2.0.

Therefore, it becomes apparent that specific gravity determines the exact relation of weight to volume and vice versa. This is the most fundamental relation in absolute volume design of concrete. Knowing the specific gravity, the weight may be determined when the volume is known, or the volume determined when the weight is known, as follows:

$$\text{Weight (gm.)} = \text{Volume (ml.)} \times \text{specific gravity}$$

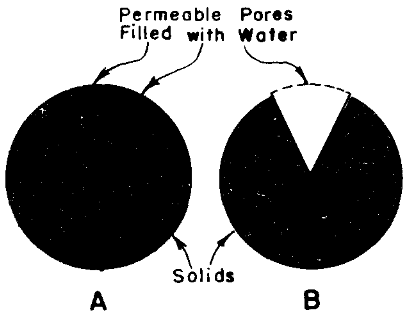
$$\text{or, Weight (lb.)} = \text{Volume (cu. ft.)} \times 62.5 \times \text{specific gravity}$$

$$\text{Volume (ml.)} = \frac{\text{Weight (gm.)}}{\text{Specific Gravity}}$$

$$\text{or, Volume (cu. ft.)} = \frac{\text{Weight (lb.)}}{62.5 \times \text{specific gravity}}$$

SATURATED, SURFACE DRY CONDITION An aggregate particle is said to be in a 'saturated, surface dry condition' when its interior permeable pores are completely saturated with water and its surface is dry. In the accompanying figure, "A" represents an aggregate particle, the total volume of which is composed of a solid impermeable portion, and of permeable, capillary pores. In "B" the total volume of the impermeable portion is shown as one mass, and the total volume of the permeable pores is shown as one mass. When this particle is immersed for a sufficient length of time, the permeable pores become filled with water. The aggregate particle will be in this condition when it is a part of a mass of concrete. If the particle had free (surface) moisture at the time the concrete was mixed, the mortar would take this moisture from the surface of the particle. If the particle had absorption (was not completely saturated) at the time the concrete was mixed, the capillary action of the permeable pores would take water from the mortar. Thus, the total absolute volume of the aggregate particle when it is part of a mass of concrete is the solid volume of the impermeable portion of the particle plus the volume of the water required to fill the permeable pores. Therefore, for the purpose of concrete design, specific gravities are determined on aggregate in a saturated, surface dry condition, and absolute volumes are calculated on the saturated surface dry basis.

AGGREGATE PARTICLE IN SATURATED SURFACE-DRY CONDITION



SATURATED, SURFACE DRY SPECIFIC GRAVITY The 'saturated, surface dry specific gravity' of a material is the ratio of the weight of a given absolute volume of the material in a saturated, surface dry condition to the weight of an equal volume of water. (See 'Specific Gravity.') Saturated, surface dry specific gravity is the only type of specific gravity (except for cement) used in concrete design. Therefore, for convenience, the words 'saturated, surface dry' are frequently omitted in this bulletin with the understanding that the terms 'specific gravity' and 'saturated, surface dry specific gravity' are synonymous.

BULK SPECIFIC GRAVITY is the ratio of the weight of a given absolute volume of material in an oven dry condition to the weight of an equal volume of water.

UNIT WEIGHT of a material is the weight (pounds) of 1.0 cubic foot of the material in a saturated, surface dry, and loose condition. The unit weight of an aggregate is not to be confused with the weight of a cubic foot of that aggregate containing free moisture or absorption. When the aggregate is not saturated and surface dry, the proper correction must be applied before the true unit weight is obtained. See Test Tex-404-A.

VOIDS (PER CENT) The air spaces between loose particles of aggregate or cement are known as 'voids.' The volume of voids signifies that portion of the total volume of loose aggregate which is occupied by the air spaces between the solid aggregate particles. When this volume is expressed as a percentage of the total volume of loose aggregate, it is known as 'per cent voids.' The 'per cent voids' is always the complement of the 'per cent solids.' (See 'Solids.')

SOLIDS (PER CENT) Concrete is designed on the basis of absolute, or solid volume. Aggregates and cement, however, are not solid masses but are composed of separate particles. Thus, while aggregates and cement are proportioned on the basis of solid volumes, they are actually handled in a loose condition. A given volume of cement or aggregate in a loose condition is composed of two separate and distinct volumes, 'solids' and 'voids.' The term 'solids' signifies that portion of the total volume which is occupied by solid particles in a saturated, surface dry condition. When the volume of solids is expressed as a percentage of the total volume of loose cement or aggregate, it is known as 'per cent solids.' It is obtained by dividing the unit weight of the material by 62.5 (weight of 1.0 cubic foot of water) times the specific gravity of the material, and multiplying the quotient by 100. The 'per cent solids' is always the complement of the 'per cent voids.' (See 'Voids.')

SOLID VOLUME See 'Absolute Volume.'

ABSORPTION Stockpiled aggregates are seldom, if ever, completely dry, but even though an aggregate contains some absorbed moisture, it may be drier than saturated, surface dry. Where this is the case, it has the capacity to absorb water. The weight of water which will be absorbed by an aggregate in reaching a saturated, surface dry condition, when expressed as a percentage of the weight of the dry aggregate (stockpile condition) is known as the 'per cent absorption' of that aggregate.

FREE MOISTURE Stockpiled aggregates usually contain surface moisture, or moisture in excess of a saturated, surface dry condition. This excess moisture is known as 'free moisture' and, when expressed as a percentage of the weight of the wet aggregate (stockpile condition) is known as the 'per cent free moisture.'

OVEN DRY AGGREGATE is an aggregate that has been dried in an oven at a designated temperature to a constant weight.

MOISTURE FREE AGGREGATE The terms 'oven dry aggregate' and 'moisture free aggregate' are synonymous and are used interchangeably.

WORKABILITY OF CONCRETE A concrete mix is said to be 'workable' or to have good 'workability' when it is of the proper consistency (see 'Consistency of Concrete'), is plastic, cohesive, easy to place and finish, and when it will slump onto the subgrade or into the forms properly without forming honeycomb. A mix is said to be 'unworkable,' or to have poor workability when the concrete is stiff, or harsh, or sloppy, when the materials tend to segregate, when the concrete will not slump onto the subgrade or into the forms properly, when the concrete forms honeycomb, or when the mix is difficult to place and finish. The terms 'workable' and 'workability' are further defined in Standard Specifications as follows:

"Workable concrete is defined as concrete which can be placed without honeycomb and without voids in the surface of the pavement after the specified finishing machine has been over a given area twice. Workability shall be obtained without producing a condition such that free water appears on the surface of the slab when being finished as specified."

Strength and workability are the two chief factors which determine the quality of the concrete. Provided specified strengths are maintained, workable concrete is acceptable, while unworkable concrete is unacceptable.

CONSISTENCY OF CONCRETE The word 'consistency' as applied to concrete is used in connection with 'workability' of concrete. It signifies the degree of viscosity of the mass, or the resistence to movement, or separation of the constituent particles. Hence, concrete of improper consistency might be either too wet, too dry, or for other reasons harsh or unworkable. Concrete of proper consistency has the correct degree of fluidity and plasticity, being neither too wet nor too dry.

SLUMP of freshly mixed concrete is the amount (distance in inches) of settlement of the fresh concrete when tested according to Test No. Tex-415-A. Slump is not a complete measure of the consistency and workability of concrete, but it is imperative to have some method of expressing workability in units, and slump, when coupled with other requirements, is very satisfactory. (See 'Consistency of Concrete' and 'Workability of Concrete.')

ENTRAINED AIR is the deliberate introduction of air spaces or voids within the volume of concrete by adding a material to the concrete called 'Air-entraining Admixture.' These voids are in the form of minute bubbles, and it is estimated there are many billions of them in a cubic foot of concrete containing between 4 to 5 per cent air. The specifications require the use of entrained air in continuously reinforced concrete pavement, lightweight concrete for structures and in concrete for structures, using natural aggregates, under certain conditions and places. The use of entrained air produces a more workable concrete and concrete which is more resistant to severe frost action and to effects of applications of salts for snow and ice removal. Entrained air is considered an integral part of the paste, its use increases the volume of paste notwithstanding the ability to reduce the water-cement ratio due to the increased workability of the mix. To offset this increase in the volume of paste, the volume of the fine aggregate must be reduced accordingly. This is shown in the sample design under Example I, 'Mix Design.'

AIR-ENTRAINING ADMIXTURE is defined in the standard specifications as a "material which, when added to a concrete mix in the quantity as recommended by the manufacturer, will entrain uniformly dispersed microscopic air." The Materials and Tests Division issues a list of approved Air-Entraining Admixtures, periodically, in the form of Administrative Circulars.

AIR-ENTRAINING AGENT The terms 'Air-Entraining Agent' and 'Air-Entraining Admixture' are synonymous and are used interchangeably.

AIR-ENTRAINING ADDITIVE The terms 'Air-Entraining Additive' and 'Air-Entraining Admixture' are synonymous are are used interchangeably.

CEMENT DISPERSING ADMIXTURE is defined in the standard specifications as "a material which, when added to a concrete mix in the quantity as recommended by the manufacturer, will change the physical characteristics and properties of the concrete as prescribed under Specification Item 437.3," which see. The primary use of this material is in placing structural concrete (natural aggregates) in hot weather (see Section 420.13 of the Standard Specifications) and in lightweight concrete for structures. When placing lightweight concrete in cool weather, it may be desirable, or even necessary, to eliminate that part of the admixture which retards the initial set of the concrete.

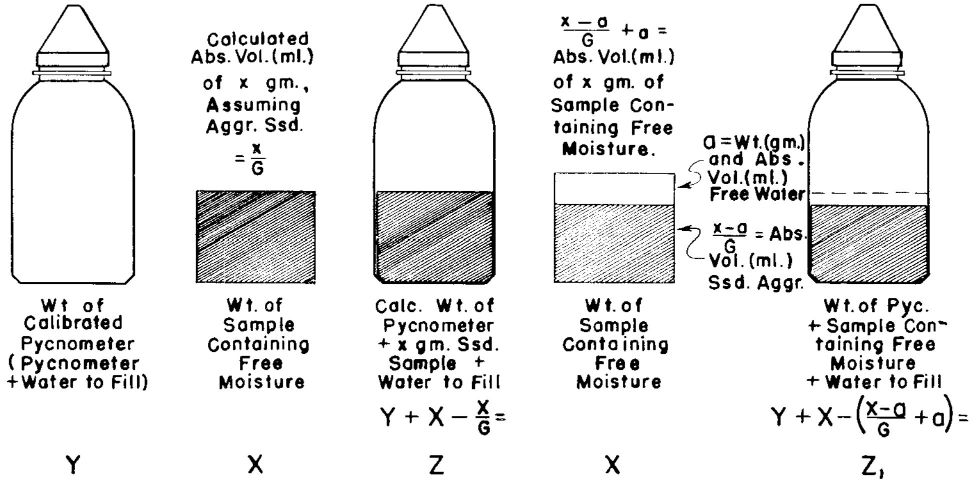
CEMENT DISPERSING AGENT and 'Cement Dispersing Admixture' are synonymous terms and are used interchangeably.

RETARDING AGENT This term is probably used interchangeably with the term 'Cement Dispersing Admixture,' and may refer to that part of the admixture which retards the initial set of the concrete.

FINENESS MODULUS of the fine aggregate is determined by adding the accumulative percentages by weight retained on the following sieves: Nos. 4, 8, 16, 30, 50 and 100 and dividing this sum by 100.

RETEMPERED CONCRETE is concrete to which water has been added after it has taken its initial set in order to reproduce concrete meeting the requirements for consistency and workability.

DERIVATION OF FREE MOISTURE FORMULA

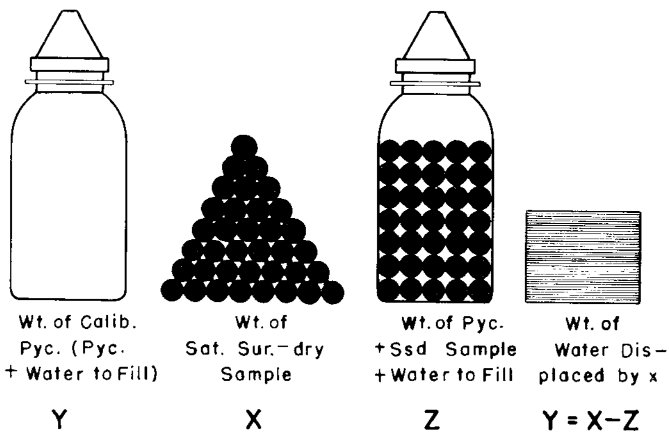


$$Z - Z_1 = \left(Y + X - \frac{X}{G}\right) - \left[Y + X - \left(\frac{X-a}{G} + a\right)\right] = \frac{a\,(G-1)}{G}$$

$$a = \frac{G\,(Z - Z_1)}{G - 1} = \text{Wt. Free Water in Wet Sample}$$

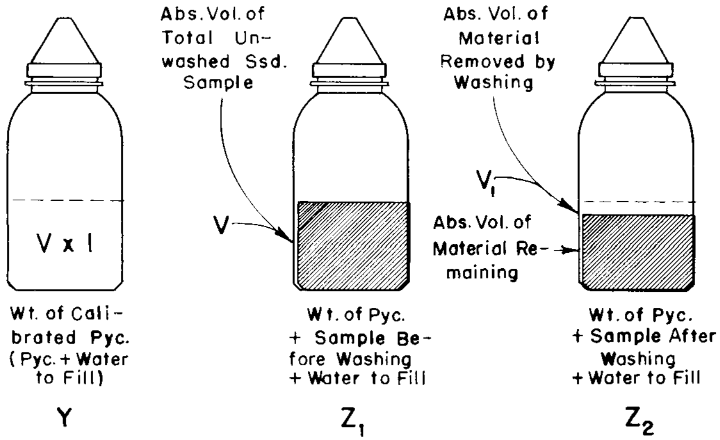
$$\%\ \text{Free Moisture} = \frac{100\,a}{X} = \frac{100\,G\,(Z - Z_1)}{X\,(G-1)}$$

DERIVATION OF SATURATED SURFACE–DRY SPECIFIC GRAVITY FORMULA



$$\text{Vol. } X = \text{Vol. } Y + X - Z;\quad \text{Sat. Sur.-Dry Sp. Gr.} = \frac{X}{Y + X - Z}$$

DERIVATION OF LOSS BY DECANTATION FORMULA



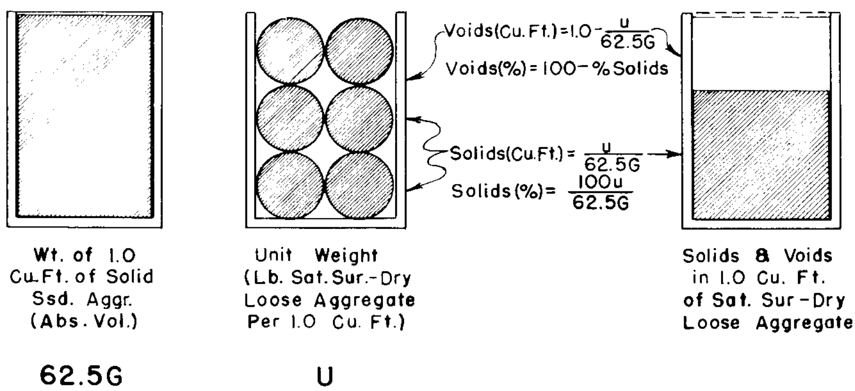
G = Sat. Sur.–Dry Sp. Gr. of Sample (G is unknown and is of no importance except to clarify the derivation)

$$Z_1 - Y = VG - (V \times 1); \quad \text{Therefore} \quad V = \frac{Z_1 - Y}{G - 1}$$

$$Z_1 - Z_2 = V_1 G - (V_1 \times 1); \quad \text{Therefore} \quad V_1 = \frac{Z_1 - Z_2}{G - 1}$$

$$\text{Loss (\% by Abs. Vol.)} = 100 \frac{V_1}{V} = 100 \frac{Z_1 - Z_2}{Z_1 - Y}$$

DERIVATION OF % SOLIDS AND % VOIDS FORMULA



SAMPLING

All samples must be as representative as possible in all respects of the total quantity of material. Particular attention is called to the fact that in sampling coarse aggregate for moisture tests care should be exercised to secure representative grading, as particle size has a large influence on moisture content.

Samples submitted to the Austin Laboratory should be addressed, 'Materials and Tests Laboratory, Camp Hubbard, Austin, Texas'.

COARSE AGGREGATE When sampling coarse aggregate from a stockpile, the final sample should be composed of several small samples taken at different locations on the pile. These small samples should be obtained by shovelling away not less than 6 inches of surface material at each location and then taking one shovelful of the material. Samples should not be taken from an area which obviously contains segregated material. If the sample so obtained is larger than that required, the size of the sample should be reduced by quartering.

When sampling coarse aggregate from cars, the samples should be obtained in the foregoing manner, and from at least three locations in the car, one from near each end and one from the center.

A 30-pound sample of coarse aggregate from each source must be submitted to the Austin Laboratory for screen analysis and Los Angeles Rattler wear tests. If additional tests are desired the sample submitted should contain 75 pounds of the material.

SAND is sampled in the same manner as is coarse aggregate. A 20-pound sample of sand from each source must be submitted to the Austin Laboratory for sieve analysis and mortar tensile strength tests.

CEMENT When sampling cement in sacks, a composite sample should be obtained from approximately 60 sacks. Select the sacks at random, taking one sampling tubeful from each sack. When sampling bulk cement, a composite sample should be obtained by taking a small sample from each of approximately 40 batches. Ordinarily this is done at the cement scales. One sample (one gallon friction-top bucketful) from each shipment shall be submitted to the Austin Laboratory.

MINERAL FILLER should be sampled in the same manner as cement. One sample (one gallon friction-top bucketful) from each shipment shall be submitted to the Austin Laboratory.

WATER Where there is any doubt regarding the quality of water, one quart of water from each source should be submitted to the Austin Laboratory in a sealed and carefully packed glass container.

STANDARD METHODS OF TEST PROCEDURES

TEST NUMBER C-11-1

SMALL CONCRETE TRIAL MIXES

Equipment: Galvanized metal mixing pan with smooth bottom and sides, 80-pound aggregate scales, torsion balance, tared weighing bucket, two 3-quart water containers and blunt-nosed trowel.

Foreword: The small trial mix is one of the most useful tools at the disposal of the operator in controlling a concrete paving job. The mix is so small that a high degree of accuracy must be employed in all steps in order to achieve proper results. If the test is improperly performed, results may be very misleading. The primary purpose of this test is to determine the water-cement ratio to use with a specified cement factor which will produce concrete meeting all of the requirements for consistency and workability.

Procedure:

1. Determine the average grading of the coarse aggregate to be used by a sufficient number of sieve analyses made according to Test Method Tex-401-A. Use the 2", 1-1/2", 1-1/4", 1", 3/4", and 1/2" sieves, and record the individual rather than the cumulative percentages.

Example:

Average Sieve Analysis of Stock Pile

Passing	Retained	Per Cent
	2"	8.0
2"	1-1/2"	10.3
1-1/2"	1-1/4"	10.5
1-1/4"	1"	18.0
1"	3/4"	17.3
3/4"	1/2"	20.1
1/2"		15.8
	Total	100.0

2. Secure representative samples of sufficient size of all materials to be used in the trial mixes. Pass the coarse aggregate through a 2-1/2-inch sieve, discarding that which is retained.

3. Air-dry the coarse aggregate and the sand, or sands, to a constant room-dry or sun-dry condition. This is done so that a stable moisture content may be maintained. Small amounts of aggregate containing free moisture, or of saturated, surface dry aggregate, lose water so rapidly by evaporation that this variable must be controlled.

4. Determine the water absorption of the dried aggregates by method Tex-403-A.

5. Select two sieves which will most nearly separate the coarse aggregate into three cuts of equal weight. Separate the coarse aggregate into these three sizes. This is done so that, by recombination of the sizes, the grading of the aggregate in the trial mixes will be constant, and representative of the grading of the stock pile.

Example:

Assuming a grading as in the above example, the 1-1/4" and 3/4" sieves would be selected and proportions of the three cuts would be as follows:

Passing	Retained	Per Cent by Wt.
	1-1/4"	28.8
1-1/4"	3/4"	35.3
3/4"		35.9

These proportions would be maintained in all trial mixes.

6. Select the design factors desired (water-cement ratio, coarse aggregate factor, cement factor, per cent of entrained air) and other essential design features which it is desired to investigate, such as the proportion by weight of fine sand, mineral filler, etc. Design a 0.50 cubic foot mix according to Example I of 'Mix Design' when using an air-entraining admixture, according to Example II of 'Mix Design' when not using any admixtures, according to Example III of 'Mix Design' when using a cement dispersing admixture and according to Example IV of 'Mix Design' when using an air-entraining admixture and a cement dispersing admixture.

PART I

Example with Air-Entraining Admixture:

Assume the following:

Water-cement ratio	= 6.8
Coarse aggregate factor	= 0.82
Cement factor	= 4.5
Per cent entrained air	= 4.0
Per cent by weight of fine sand in total fine aggregate	= 10.0
Yield	= 6.000 Cu.Ft.

The aggregates are found to have the following characteristics:

Coarse Aggregate	Specific gravity		= 2.61
	Voids		= 39.4 %
	Absorption		= 0.4 %
	Grading	Retained 1-1/4"	= 28.8 %
		1-1/4" to 3/4"	= 35.3 %
		Pass 3/4"	= 35.9 %
Fine Aggregate	Average specific gravity		= 2.65
	Voids		= 38.6 %
	Absorption (coarse sand)		= 0.2 %
	Absorption (fine sand)		= 0.1 %

Calculations should be carried sufficiently far to insure that proportions in the small trial mix are as accurate as in a large mix.

		1-Sack Batch Weight SSD (Pounds)		Factor for 0.50 Cu.Ft. Mix $\frac{0.50}{6.000}$		SSD Wt. (Pounds)
Coarse Aggregate	=	486.4	x	0.08333	=	40.53
Fine Aggregate	=	229.6	x	0.08333	=	19.13
Cement	=	94.0	x	0.08333	=	7.83
Water	=	56.7	x	0.08333	=	4.72
Air-Entraining Admixture	=	**0.4 Fl. Ozs.				
	=	*11.83cc	x	0.08333	=	0.99cc

Fine Aggregate =	Coarse sand	= 19.13 x 0.90	= 17.22
	Fine sand	= 19.13 x 0.10	= 1.91

*Since the amount of air-entraining admixture used in any mix design will be small, the metric system of measurement will be used. One fluid ounce equals 29.57 cubic centimeters.

**The manufacturer recommends that 0.4 fluid ounces be used per sack of cement to produce 4% entrained air in the concrete.

Correct for absorption as follows, or according to the Table on Page 35.

		SSD Wt. (Pounds)		Correction $1 + \frac{\% \text{ Abs.}}{100}$		Batch Wt. (Pounds)
Coarse Aggregate	=	40.53	÷	1.004	=	40.37
Coarse sand	=	17.22	÷	1.002	=	17.19
Fine sand	=	1.91	÷	1.001	=	1.91

Mixing Water = 4.72 + (40.53 - 40.37)
+ (17.22 - 17.19) = 4.91 lbs.
4.91 (lbs.) x 453.6 (gms/lb.) = 2227.2 gms.

The three sizes of coarse aggregate would be proportioned according to the average screen analysis as follows:

Size		Total Dry Coarse Aggregate (lb.)		$\frac{\% \text{ by Wt.}}{100}$		Batch Wt. (Pounds)
Retained 1-1/4"	=	40.37	x	0.288	=	11.63
1-1/4" to 3/4"	=	40.37	x	0.353	=	14.25
Pass 3/4"	=	40.37	x	0.359	=	14.49

1. Secure the tare weight of a large weighing bucket and weigh out to the nearest 0.01 pound on the 80-pound aggregate scales the proper amount of each ingredient in the following order: the largest size of coarse aggregate, the middle size of coarse aggregate, the smallest size of coarse aggregate, the coarse sand, the fine sand, the mineral filler, if any, and the cement. The dry sand should be kept thoroughly mixed to prevent undue segregation. To insure greater accuracy, all weights should be cumulative provided the scales have enough capacity.

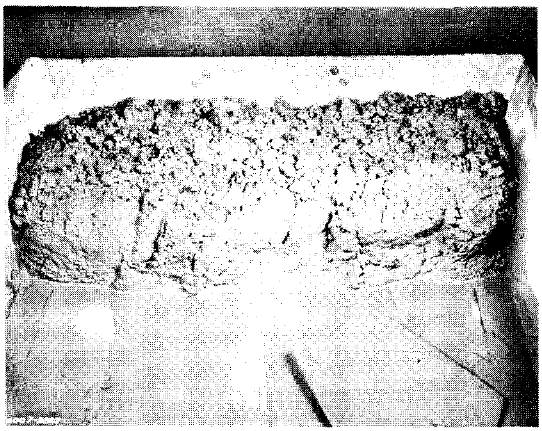
Example:

		Individual Wt. (Lb.)	Cumulative Wt. (Lb.)
Weighing bucket		12.64	12.64
Coarse Aggr.	Retained 1-1/4"	11.63	24.27
	1-1/4" to 3/4"	14.25	38.52
	Pass 3/4"	14.49	53.01
Coarse sand		17.19	70.20
Fine sand		1.91	72.11
Cement		7.83	79.94

2. Secure the tare weight of a 3-quart container (Container No. 1) as follows: fill Container No. 1 with water, pour out and waste the water, then weigh Container No. 1 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance. Let us assume the tare weight to be 312.5 grams. Set the designed weight of water (2227.2 grams in example mix) plus tare weight of Container No. 1, (312.5 grams), plus an additional weight of water equal to 10% of the designed weight of water (222.7 grams) for a total weight of 2762.4 grams. Remove Container No. 1 from the torsion balance. Tare another container (Container No. 2) as follows: fill Container No. 2 with water, pour out and waste the water, then weigh Container No. 2 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance; say 216.0 grams. Transfer 70% of the designed weight of water (.70 x 2227.2 = 1559 grams) from Container No. 1 to Container No. 2. Add one cubic centimeter (1 gram, assuming the specific gravity of the admixture to be 1.000) of the air-entraining admixture to the water in Container No. 2 and thoroughly mix.

3. Dampen the bottom and sides of the mixing pan with a moist cloth, but do not leave any apparent free water in the pan. Place the dry ingredients in the pan and thoroughly mix them with a blunt-nosed trowel. Add the water and admixture from Container No. 2 and thoroughly mix this liquid with the dry ingredients. The mix should be dry; so add enough water from Container No. 1, always mixing, to produce concrete having an estimated slump slightly more than one inch. In order to maintain homogeneity in the mix, scrape all of the concrete into a uniform cake at one end of the pan. Weigh Container No. 1 with the remaining water and record, say 662.0 grams.

A Completed Small Concrete Trial Mix



4. Place the concrete in the slump cone, beginning at one end of the fresh concrete cake and cleaning the pan thoroughly with the trowel as the cake becomes progressively smaller. Make the slump specimen and secure the slump in accordance with Test Method Tex-415-A. Let us assume the slump measured 1-1/4 inches, which is satisfactory, since the slump obtained from a small trial mix is, on the average, approximately one-half inch less than the slump which will be obtained from a large batch of identical concrete made in a big mixer. Also, the mix did not appear to be too harsh nor oversanded, indicating the coarse aggregate factor which was selected is satisfactory.

5. From the remaining cake of concrete, place the concrete in the air meter, removing the concrete from the pan in much the same manner as when making the slump, and determine the air content in accordance with Test Method Tex-416-A. Let us assume the air tested to be 3.4%, which is satisfactory since a variation not exceeding one per cent (plus or minus) is considered satisfactory.

6. We will now calculate the amount of water used and determine the water-cement ratio to use with a cement factor of 4.5.

Wt. of Container No. 1 at beginning	= 2762.4 grams
Wt. of Container No. 1 at end	= - 662.0 gms.
Amount of Water Used	= 2100.4 gms.
Less water used for absorption = 4.91 lbs. - 4.72 lbs. = 0.19 lbs. = 0.19 lbs. x 453.6 (grams per pound)	= - 86.2 gms.
Plus 1 gram air-entraining admixture	= + 1.0 gm.
Total amount of liquid used for saturated surface dry aggregates	= 2015.2 gms.
To convert grams back to pounds, divide by 453.6 = $\frac{2015.2}{453.6}$	= 4.44 lbs.
To calculate pounds of water for a one-sack batch, divide by the factor used for a 0.50 cu. ft. batch, $\frac{4.44}{0.08333}$	= 53.3 lbs.
To convert pounds to gallons, divide by 8.33 = $\frac{53.3}{8.33}$	= 6.4 gals.

7. 6.4 gallons is the water-cement ratio to use with a 4.5 cement factor as illustrated in this example. The original design used a water-cement ratio of 6.8 as compared to a determined water-cement ratio of 6.4. The error in the amount of fine aggregate used is so small it will be considered to have had no influence on the result, so the mix does not need to be redesigned, nor does the trial batch need to be remade.

PART II

Example without Concrete Admixtures:

Assume the following:

Water-cement ratio	=	6.5
Coarse Aggregate factor	=	0.76
Cement factor	=	5.0
Per cent by weight of fine sand in total fine aggregate	=	10.0
Yield	=	5.400 Cu.Ft.

The aggregates are found to have the following characteristics:

Coarse Aggregate	Specific gravity		=	2.61
	Voids		=	39.4 %
	Absorption		=	0.4 %
	Grading	Retained 1-1/4"	=	28.8 %
		1-1/4" to 3/4"	=	35.3 %
		Pass 3/4"	=	35.9 %
Fine Aggregate	Average specific gravity		=	2.65
	Voids		=	38.6 %
	Absorption (coarse sand)		=	0.2 %
	Absorption (fine sand)		=	0.1 %

Calculations should be carried sufficiently far to insure that proportions in the small trial mix are as accurate as in a large mix.

		1-Sack Batch Weight SSD (Pounds)		Factor for 0.50 Cu.Ft. Mix $\frac{0.50}{5.400}$		SSD Wt. (Pounds)
Coarse Aggregate	=	405.7	x	0.09259	=	37.56
Fine Aggregate	=	258.5	x	0.09259	=	23.93
Cement	=	94.0	x	0.09259	=	8.70
Water	=	54.2	x	0.09259	=	5.02

Fine Aggregate	=	Coarse sand = 23.93 x 0.90	=	21.54
		Fine sand = 23.93 x 0.10	=	2.39

Correct for absorption as follows, or according to the Table on Page 35.

		SSD Wt. (Pounds)		Correction $1 + \frac{\% \text{ Abs.}}{100}$		Batch Wt. (Pounds)
Coarse Aggregate	=	37.56	÷	1.004	=	37.41
Coarse sand	=	21.54	÷	1.002	=	21.50
Fine sand	=	2.39	÷	1.001	=	2.39

Mixing water = 5.02 + (37.56 - 37.41)
+ (21.54 - 21.50) = 5.21 lbs.
5.21 (lbs.) x 453.6 (gms/lb.) = 2363.3 gms.

The three sizes of coarse aggregate would be proportioned according to the average sieve analysis as follows:

Size		Total Dry Coarse Aggregate (lb.)		% by Wt. / 100		Batch Wt. (Pounds)
Retained 1-1/4"	=	37.41	x	0.288	=	10.77
1-1/4" to 3/4"	=	37.41	x	0.353	=	13.21
Pass 3/4"	=	37.41	x	0.359	=	13.43

1. Secure the tare weight of a large weighing bucket and weigh out to the nearest 0.01 pound, on the 80-pound aggregate scales, the proper amount of each ingredient in the following order: the largest size of coarse aggregate, the middle size of coarse aggregate, the smallest size of coarse aggregate, the coarse sand, the fine sand, the mineral filler, if any, and the cement. The dry sand should be kept thoroughly mixed to prevent undue segregation. To insure greater accuracy all weights should be cumulative provided the scales have enough capacity.

Example:

		Individual Wt. (Lb.)	Cumulative Wt. (Lb.)
Weighing bucket		9.89	9.89
Coarse Aggr.	Retained 1-1/4"	10.77	20.66
	1-1/4" to 3/4"	13.21	33.87
	Pass 3/4"	13.43	47.30
Coarse sand		21.50	68.80
Fine sand		2.39	71.19
Cement		8.70	79.89

2. Secure the tare weight of a 3-quart container (Container No. 1) as follows: fill Container No. 1 with water, pour out and waste the water, then weigh Container No. 1 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance. Let us assume the tare weight to be 312.5 grams. Set the designed weight of water (2363.3 grams in example mix) plus tare weight of Container No. 1 (312.5 grams), plus an additional weight of water equal to 10% of the designed weight of water (236.3 grams) for a total weight of 2912.1 grams. Remove Container No. 1 from the torsion balance. Tare another container (Container No. 2) as follows: fill Container No. 2 with water, pour out and waste the water, then weigh Container No. 2 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance; say 216.0 grams. Transfer 70% of the designed weight of water (.70 x 2363.3 = 1654.3 grams) from Container No. 1 to Container No. 2.

3. Dampen the bottom and sides of the mixing pan with a moist cloth, but do not leave any apparent free water in the pan. Place the dry ingredients in the pan and thoroughly mix them with a blunt-nosed trowel. Add the water from Container No. 2 and thoroughly mix this liquid with the dry ingredients. The mix should be dry, so add enough water from Container No. 1, always mixing, to produce concrete having an estimated slump slightly more than one inch. In order to maintain homogeneity in the mix, scrape all of the concrete into a uniform cake at one end of the pan. Weigh Container No. 1 with the remaining water and record, say 617.0 grams.

4. Place the concrete in the slump cone, beginning at one end of the fresh concrete cake and cleaning the pan thoroughly with the trowel as the cake becomes progressively smaller. Make the slump specimen and secure the slump in accordance with Test Method Tex-415-A. Let us assume the slump measured 1-1/2 inches, which is satisfactory, since the slump obtained from a small trial mix is, on the average, approximately one-half inch less than the slump which will be obtained from a large batch of identical concrete made in a big mixer. Also, the concrete did not appear to be too harsh nor oversanded, indicating the coarse aggregate factor which was selected is satisfactory.

5. We will now calculate the amount of water used and determine the water-cement ratio to use with a cement factor of 5.0.

Wt. of Container No. 1 at beginning	= 2912.1 grams
Wt. of Container No. 1 at end	= - 617.0 gms.
Amount of Water Used	= 2295.1 gms.

Less water used for absorption
= 5.21 lbs. - 5.02 lbs. = 0.19 lbs.
= 0.19 lbs. x 453.6 (grams per pound) = - 86.2 gms.

Total amount of water used for saturated surface dry aggregates = 2208.9 gms.

To convert grams back to pounds, divide by 453.6 = $\frac{2208.9}{453.6}$ = 4.87 lbs.

To calculate pounds of water for a one-sack batch, divide by the factor used for a 0.50 cu. ft. batch, $\frac{4.87}{0.09259}$ = 52.6 lbs.

To convert pounds to gallons, divide by 8.33 = $\frac{52.6}{8.33}$ = 6.3 gals.

6. 6.3 gallons is the water-cement ratio to use with a 5.0 cement factor as illustrated in this example. The original design used a water-cement ratio of 6.5 as compared to a determined water-cement ratio of 6.3. The error in the amount of fine aggregate used is so small it will be considered to have had no influence on the result, so the mix does not need to be redesigned, nor does the trial batch need to be remade.

PART III

<u>Example with Cement Dispersing Admixture:</u>

Assume the following:

Water-cement ratio	=	6.0
Coarse aggregate factor	=	0.78
Cement factor	=	5.0
Per cent by weight of fine sand in total fine aggregate	=	10.0
Yield	=	5.400 Cu. Ft.

The aggregates are found to have the following characteristics:

Coarse Aggregate	Specific Gravity		=	2.61
	Voids		=	39.4 %
	Absorption		=	0.4 %
	Grading	Retained 1-1/4"	=	28.8 %
		1-1/4" to 3/4"	=	35.3 %
		Pass 3/4"	=	35.9 %
Fine Aggregate	Average specific gravity		=	2.65
	Voids		=	38.6 %
	Absorption (coarse sand)		=	0.2 %
	Absorption (fine sand)		=	0.1 %

Calculations should be carried sufficiently far to insure that proportions in the small trial mix are as accurate as in a large mix.

		1-Sack Batch Weight SSD (Pounds)		Factor for 0.50 Cu. Ft. Mix $\frac{0.50}{5.400}$		SSD Wt. (Pounds)
Coarse Aggregate	=	416.3	x	0.09259	=	38.55
Fine Aggregate	=	258.9	x	0.09259	=	23.97
Cement	=	94.0	x	0.09259	=	8.70
Water	=	50.0	x	0.09259	=	4.63
Cement Dispersing Admixture	=**1 quart					
	= *946.24cc		x	0.09259	=	87.6cc

Fine Aggregate	= Coarse sand = 23.97 x 0.90	=	21.57
	Fine sand = 23.97 x 0.10	=	2.40

*Since the amount of cement dispersing admixture used in any mix design will be small, the metric system of measurement will be used. One fluid ounce equals 29.57 cubic centimeters.

**The manufacturer recommends that one quart be used per sack of cement.

Correct for absorption as follows, or according to the Table on Page 35.

		SSD Wt. (Pounds)		Correction $1 + \frac{\% \text{ Abs.}}{100}$		Batch Wt. (Pounds)
Coarse aggregate	=	38.55	÷	1.004	=	38.40
Coarse sand	=	21.57	÷	1.002	=	21.53
Fine sand	=	2.40	÷	1.001	=	2.40

Mixing water = 4.63 + (38.55 - 38.40) + (21.57 - 21.53) = 4.82 lbs.

4.82 (lbs.) x 453.6 (gms/lb.) = 2186.4 gms.

The three sizes of coarse aggregate would be proportioned according to the average sieve analysis as follows:

Size		Total dry Coarse Aggregate (lb.)		% by Wt. / 100		Batch Wt. (Pounds)
Retained 1-1/4"	=	38.40	x	0.288	=	11.06
1-1/4" to 3/4"	=	38.40	x	0.353	=	13.56
Pass 3/4"	=	38.40	x	0.359	=	13.78

1. Secure the tare weight of a large weighing bucket and weigh out to the nearest 0.01 pound, on the 80-pound aggregate scales, the proper amount of each ingredient in the following order: the largest size of coarse aggregate, the middle size of coarse aggregate, the smallest size of coarse aggregate, the coarse sand, the fine sand, the mineral filler, if any, and the cement. The dry sand should be kept thoroughly mixed to prevent undue segregation. To insure greater accuracy, all weights should be cumulative provided the scales have enough capacity.

Example:

		Individual Wt. (Lb.)	Cumulative Wt. (Lb.)
Weighing bucket		8.89	8.89
Coarse Aggr.	Retained 1-1/4"	11.06	19.95
	1-1/4" to 3/4"	13.56	33.51
	Pass 3/4"	13.78	47.29
Coarse sand		21.53	68.82
Fine sand		2.40	71.22
Cement		8.70	79.92

2. Secure the tare weight of a 3-quart container (Container No.1) as follows: fill Container No. 1 with water, pour out and waste the water, then weigh Container No. 1 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance. Let us assume the tare weight to be 312.5 grams. Set the designed weight of water (2186.4 grams in example mix) plus tare weight of Container No. 1 (312.5 grams), plus an additional weight of water equal to 10% of the designed weight of water (218.6 grams) for a total weight of 2717.5 grams. Remove Container No. 1 from the torsion balance. Tare another container (Container No. 2) as follows: fill Container No. 2 with water, pour out and waste the water, then weigh Container No. 2 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance, say 216.0 grams. Transfer 70% of the designed weight of water (.70 x 2186.4 = 1530.5 grams) from Container No. 1 to Container No. 2. Add 87.6 cubic centimeters (87.6 grams, assuming the specific gravity of the admixture to be 1.00) of the cement dispersing admixture to the water in Container No. 2 and thoroughly mix.

3. Dampen the bottom and sides of the mixing pan with a moist cloth, but do not leave any apparent free water in the pan. Place the dry ingredients in the pan and thoroughly mix them with a blunt-nosed trowel. Add the water and admixture from Container No. 2 and thoroughly mix this liquid with the dry ingredients. The mix should be dry, so add enough water from Container No. 1, always mixing, to produce concrete having an estimated slump slightly more than one inch. In order to maintain homogeneity in the mix, scrape all of the concrete into a uniform cake at one end of the pan. Weigh Container No. 1 with the remaining water and record; say 568.4 grams.

4. Place the concrete in the slump cone, beginning at one end of the fresh concrete cake and cleaning the pan thoroughly with the trowel as the cake becomes progressively smaller. Make the slump

specimen and secure the slump in accordance with Test Method Tex-415-A. Let us assume the slump measured 1-1/2 inches, which is satisfactory since the slump obtained from a small trial mix is, on the average, approximately one-half inch less than the slump which will be obtained from a large batch of identical concrete made in a big mixer. Also, the concrete did not appear to be too harsh, nor oversanded, indicating the coarse aggregate factor which was selected is satisfactory.

5. We will now calculate the amount of water used and determine the water-cement ratio to use with a cement factor of 5.0.

Wt. of Container No. 1 at beginning	= 2717.5 grams
Wt. of Container No. 1 at end	= - 568.4 gms.
Amount of Water Used	= 2149.1 gms.
Less water used for absorption = 4.82 lbs. - 4.63 lbs. = 0.19 lbs. = 0.19 lbs. x 453.6 (grams per pound)	= - 86.2 gms.
Plus 87.6cc cement dispersing admixture	= + 87.6 gms.
Total amount of liquid used for saturated surface dry aggregates	= 2150.5 gms.
To convert grams back to pounds divide by 453.6 = $\frac{2150.5}{453.6}$	= 4.74 lbs.
To calculate pounds of water for a one-sack batch, divide by the factor used for a 0.50 cu.ft. batch, $\frac{4.74}{0.09259}$	= 51.2 lbs.
To convert pounds to gallons, divide by 8.33 = $\frac{51.2}{8.33}$	= 6.1 gals.

6. 6.1 gallons is the water-cement ratio to use with a 5.0 cement factor as illustrated in this example. The original design used a water-cement ratio of 6.0 as compared to a determined water-cement ratio of 6.1. The error in the amount of fine aggregate used is so small it will be considered to have had no influence on the result, so the mix does not need to be redesigned, nor does the trial batch need to be remade.

PART IV

Example with Air-Entraining Admixture and Cement Dispersing Admixture:

Assume the following:

Water-cement ratio	=	6.0
Coarse aggregate factor	=	0.78
Cement factor	=	5.0
Per cent entrained air	=	4.0
Per cent by weight of fine sand in total fine aggregate	=	10.0
Yield	=	5.400 Cu. Ft.

The aggregates are found to have the following characteristics:

Coarse Aggregate	Specific gravity		=	2.61
	Voids		=	39.4%
	Absorption		=	0.4%
	Grading	Retained 1-1/4"	=	28.8%
		1-1/4" to 3/4"	=	35.3%
		Pass 3/4"	=	35.9%
Fine Aggregate	Average specific gravity		=	2.65
	Voids		=	38.6%
	Absorption (coarse sand)		=	0.2%
	Absorption (fine sand)		=	0.1%

Calculations should be carried sufficiently far to insure that proportions in the small trial mix are as accurate as in a large mix.

		1-Sack Batch Weight SSD (Pounds)		Factor for 0.50 Cu. Ft. Mix $\frac{0.50}{5.400}$		SSD Wt. (Pounds)
Coarse Aggregate	=	416.3	x	0.09259	=	38.55
Fine Aggregate	=	223.1	x	0.09259	=	20.66
Cement	=	94.0	x	0.09259	=	8.70
Water	=	50.0	x	0.09259	=	4.63
Air-Entraining Admixture	=	**0.4 Fl. Ozs.				
	=	*11.83cc	x	0.09259	=	1.10cc
Cement Dispersing Admixture	=	**1 quart				
	=	*946.24cc	x	0.09259	=	87.61cc

Fine Aggregate = Coarse sand = 20.66 x 0.90 = 18.59
Fine sand = 20.66 x 0.10 = 2.07

*Since the amount of air-entraining and cement dsipersing admixture used in any mix design will be small, the metric system of measurement will be used. One fluid ounce equals 29.57 cubic centimeters.

**The manufacturer recommends that 4 fl. ozs. of air-entraining admixture be used per sack of cement to produce 4% entrained air and that one quart of cement dispersing admixture be used per sack of cement.

Correct for absorption as follows, or according to the Table on Page 35.

		SSD Wt. (Pounds)		Correction $1 + \frac{\%Abs.}{100}$		Batch Wt. (Pounds)
Coarse aggregate	=	38.55	÷	1.004	=	38.40
Coarse sand	=	18.59	÷	1.002	=	18.55
Fine sand	=	2.07	÷	1.001	=	2.07

Mixing Water = 4.63 + (38.55 - 38.40)
+ (18.59 - 18.55) = 4.82 lbs.
4.82 (lbs.) x 453.6 (gms/lb.) = 2186.4 gms.

The three sizes of coarse aggregate would be proportioned according to the average sieve analysis as follows:

Size		Total Dry Coarse Aggregate (lbs.)		% by Wt. / 100		Batch Wt. (Pounds)
Retained 1-1/4"	=	38.40	x	0.288	=	11.06
1-1/4" to 3/4"	=	38.40	x	0.353	=	13.56
Pass 3/4"	=	38.40	x	0.359	=	13.78

1. Secure the tare weight of a large weighing bucket and weigh out to the nearest 0.01 pound, on the 80-pound aggregate scales, the proper amount of each ingredient in the following order: the largest size of coarse aggregate, the middle size of coarse aggregate, the smallest size of coarse aggregate, the coarse sand, the fine sand, the mineral filler, if any, and the cement. The dry sand should be kept thoroughly mixed to prevent undue segregation. To insure greater accuracy, all weights should be cumulative provided the scales have enough capacity.

Example:

		Individual Wt. (Lbs.)	Cumulative Wt. (Lbs.)
Weighing bucket		12.30	12.30
Coarse Aggr.	Retained 1-1/4"	11.06	23.36
	1-1/4" to 3/4"	13.56	36.92
	Pass 3/4"	13.78	50.70
Coarse sand		18.55	69.25
Fine sand		2.07	71.32
Cement		8.70	80.02

2. Secure the tare weight of a 3-quart container (Container No. 1) as follows: fill Container No. 1 with water, pour out and waste the water, then weigh Container No. 1 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance. Let us assume the tare weight to be 312.5 grams. Set the designed weight of water (2186.4 grams in example mix) plus tare weight of Container No. 1 (312.5 grams) plus an additional weight of water equal to 10% of the designed weight of water (218.6 grams) for a total weight of 2717.5 grams. Remove Container No. 1 from the torsion balance. Tare another container (Container No. 2) as follows: fill Container No. 2 with water, pour out and waste the water, then weigh Container No. 2 with the water which adheres to the inside surface to the nearest 0.5 gram on the torsion balance, say 216.0 grams. Transfer 70% of the designed weight of water (.70 x 2186.4 = 1530.5 grams) from Container No. 1 to Container No. 2. Add one cubic centimeter (1 gram, assuming the specific gravity of the admixture to be 1.00) of the air-entraining admixture and 87.6 cubic centimeters (87.6 grams, assuming the specific gravity of the admixture to be 1.00) of the cement dispersing admixture to the water in Container No. 2 and thoroughly mix.

3. Dampen the bottom and sides of the mixing pan with a moist cloth, but do not leave any apparent free water in the pan. Place the dry ingredients in the pan and thoroughly mix them with a blunt-nosed trowel. Add the water and admixture from Container No. 2 and thoroughly mix this liquid with the dry ingredients. The mix should be dry, so add enough water from Container No. 1, always mixing, to produce concrete having an estimated slump slightly more than one inch. In order to maintain homogeneity in the mix, scrape all of the concrete into a uniform cake at one end of the pan. Weigh Container No. 1 with the remaining water and record, say 671.0 grams.

4. Place the concrete in the slump cone, beginning at one end of the fresh concrete cake and cleaning the pan thoroughly with the trowel as the cake becomes progressively smaller. Make the slump specimen and secure the slump in accordance with Test Method Tex-415-A. Let us assume the slump measured 1-1/2 inches, which is satisfactory since the slump obtained from a small trial mix is, on the average, approximately one-half inch less than the slump which will be obtained from a large batch of identical concrete made in a big mixer. Also, the concrete did not appear to be too harsh nor oversanded, indicating the coarse aggregate factor which was selected is satisfactory.

5. From the remaining cake of concrete, place the concrete in the air meter, removing the concrete from the pan in much the same manner as when making the slump, and determine the air content in accordance with Test Method Tex-416-A. Let us assume the air tested to be 3.4%, which is satisfactory since a variation not exceeding one per cent (plus or minus) is considered permissible.

6. We will now calculate the amount of water used and determine the water-cement ratio to use with a cement factor of 5.0.

Wt. of Container No. 1 at beginning	= 2717.5 grams
Wt. of Container No. 1 at end	= - 671.0 gms.
Amount of Water Used	= 2046.5 gms.

Less water used for absorption
= 4.82 lbs. - 4.63 lbs. = 0.19 lbs.
= 0.19 lbs. x 453.6 (grams per pound) = - 86.2 gms.

Plus 1 gram air-entraining admixture = + 1.0 gm.

Plus 87.6 grams cement dispersing admixture = + 87.6 gms.

Total amount of liquid used for saturated surface dry aggregates = 2048.9 gms.

To convert grams back to pounds, divide by 453.6 = $\frac{2048.9}{453.6}$ = 4.52 lbs.

To calculate pounds of water for one-sack batch, divide by the factor used for a 0.50 cu. ft. batch, $\left(\frac{4.52}{0.09259}\right)$ = 48.8 lbs.

To convert pounds to gallons, divide by 8.33 = $\frac{48.8}{8.33}$ = 5.9 gals.

7. 5.9 gallons is the water-cement ratio to use with a 5.0 cement factor as illustrated in this example. The original design used a water-cement ratio of 6.0, as compared to a determined water-cement ratio of 5.9. The error in the amount of fine aggregate used is so small it will be considered to have had no influence on the result, so the mix does not need to be redesigned, nor does the trial batch need to be remade.

TEST NUMBER C-11-2

REDUCTION OF VOIDS IN SAND DEFICIENT IN FINES

Equipment: Sand sleeve, calibrated and tared 0.1-cubic foot measure, large milk pan, small hand-scoop, straightedge, and 80-pound aggregate scales.

Foreword: When a concrete sand is deficient in fines it may be desirable to add fine sand to remedy this condition. In such cases, it is desirable to study the voids reduction occasioned by the addition of varying amounts of the fine sand.

Procedure:

1. Secure representative samples of both sands. The sample of coarse sand should be sufficient (when dry) to fill the measure to overflowing. Dry both sands as in Test Method Tex-403-A until they are obviously drier than surface dry.

2. Weigh the sample of coarse sand to the nearest 0.01-pound on the 80-pound aggregate scales. Determine the unit weight of the coarse sand by Test Method Tex-404-A, taking care to lose none of the sample.

3. Add the fine sand to the sample of coarse sand in such increments that the resulting mixtures will contain 5%, 10%, 15%, etc., by weight of fine sand, and determine the unit weight of each combination. Continue to add the fine sand until the unit weights no longer increase, but tend to decrease.

Example for calculating additions of fine sand:

Original sample of coarse sand = 11.00 pounds

1st addition (5%) = $\frac{11.00}{0.95} - 11.00 = 11.58 - 11.00 = 0.58$ lbs.

2nd addition (10%) = $\frac{11.00}{0.90} - 11.58 = 12.22 - 11.58 = 0.64$ lbs.

3rd addition (15%) = $\frac{11.00}{0.85} - 12.22 = 12.94 - 12.22 = 0.72$ lbs.

4. Calculate the per cent of voids in each combination as in Test Method Tex-405-A and show the test data graphically. See the illustration of "reduction of voids in fine aggregate" under "Job Control."

TEST NUMBER C-11-3

DEPTH TESTS

Equipment: Depth test plates, rule, and depth test tool, or suitable metal pin.

Procedure:

1. Place at least three depth test plates firmly upon the subgrade on a line perpendicular to the center line of the pavement. These plates should be spaced at known intervals, and the location marked on each form in order that they may be readily located after the concrete is placed.

2. After the plates have been placed, and just prior to the placing of concrete over them, place a shovelful of fresh concrete on each plate.

3. After the pavement has been finished and before the concrete attains its initial set, work the pin through the concrete until it touches the metal plate. Care should be taken that the pin is perpendicular to the surface of the pavement.

4. Place a 12" straightedge (a straight 1 by 2" stake is acceptable) against the pin and with the edge on the surface of the pavement. Holding the straightedge and the pin firmly together, withdraw the pin from the concrete and measure the length projecting below the stake. At least two measurements should be taken at plate for a check.

5. Record the depth of the concrete over each of the three plates.

ASSEMBLY OF EQUIPMENT

TORSION BALANCE The torsion balance when received on the job will be partially disassembled and with the lower beam fastened rigidly to the base.

Assemble the balance as follows:

1. Remove the small plate from the underside of the base and take out the two large screws which project through the base and into the lower beams. Retain these screws, plate, etc. so that the balance may be properly prepared when it is shipped again.

2. Attach the graduated beam, the pan-holders (the right-hand pan-holder is identified by the letter "R"), and place the pans on the holders.

3. Check the level of the torsion balance table by means of a spirit level. Adjust the table until it is satisfactorily level in all directions. Place the balance on the table.

4. Place the sliding poise on the graduated beam at zero and move the adjustable tare weights to the extreme left. Release the beam arrest and adjust leveling screws at the base of the balance until the pointer oscillates equally on both sides of the index center.

5. Keep the balance clean and in adjustment at all times. Adjust the balance at zero load by means of the leveling screws before each series of weights are taken when testing.

BEAM FORMS Each beam form shall be 20 inches long, 6 inches wide, and 6 inches deep, inside measurements. They may be constructed singly or in gangs only for pilot test beams if more convenient or economical. It is required that beam forms for use after paving has begun be constructed singly. Steel beam forms may be obtained from the Equipment and Procurement Division (D-4).

If lumber is used for constructing forms, it shall be of a good quality, free from knots, seasoned properly, and dressed smooth. It shall be a minimum of 1 inch thick. Construction shall be of such type that the sides of the form do not deflect to an appreciable extent when the concrete is rodded into place. The sides of the form shall be hinged to the bottom of the form in such a manner that the sides overlap the bottom edge rather than the bottom extending under the edge of the sides. This is done in order that the green concrete will not be pinched when the sides of the forms are stripped.

The inside of the forms should be thoroughly oiled at least 24 hours before they are used for the first time and oiled each time immediately prior to using. Wipe all excess oil from the inside of the form before concrete is placed in it.

A minimum of 80 beam forms is required for the pilot test beams as 4 batches of 20 beams each are to be made at the same time. In case the contractor desires additional pilot tests more beam forms may be required or the additional tests may be run on some other day. The number of forms required for making job beams will be governed by the maximum amount of concrete placed in any one day. In estimating the number of forms bear in mind the specification requirements to the effect that two beams shall be made to represent a certain area of concrete placed.

MISCELLANEOUS The trial mix pan should be made of galvanized metal and should have smooth bottom and sides. It is desirable that the sides slope slightly inward toward the bottom. Recommended dimensions are 20 by 24 by 6 inches, although these may be varied considerably provided the overall volume is sufficient. Ordinarily it is necessary to have this pan manufactured at some local metal workers.

The 80-pound aggregate scale should be placed on a level and rigid support. The hanging rod should swing free either through a hole in the table top or over the edge of the table.

The sand sleeve should be of strong, pliable cloth of sufficiently tight weave to insure that dust will not pass through the mesh. It should be approximately 2 feet long and should be exactly 8-1/2 inches wide, not counting any overhanging seam, when laid flat.

FORMS FOR REPORTS

The following instructions cover the use of the forms for the design of concrete mixtures in laboratory or for recording the daily paving operations in the field.

For convenient reference, the headings on the forms are listed on the left-hand side of the page and are followed by the instructions as to how the data are to be recorded.

FORM 309 - CONCRETE DESIGN WORK SHEET (NATURAL AGGREGATES)

This form may be used for the design of concrete mixtures by following the examples given under "Mix Designs."

Texas Highway Department
Construction Form 309

County:
Project:
Date:

Design No:

CONCRETE DESIGN WORK SHEET
(NATURAL AGGREGATES)

AGGREGATE CHARACTERISTICS:

	SP. GR	SSD Unit Wt. Lbs./Cu. Ft.	% SOLIDS
Fine Aggregate (FA)			
Coarse Aggregate (CA)			
Water			
Cement			

DESIGN FACTORS:

Cement Factor (CF), sacks per cubic yard of concrete
Coarse Aggregate Factor (CAF),
Water Factor (WF), gal. per sack of cement
Air Factor (AF), %

BATCH FACTOR:

$\frac{\text{Size of Batch (Full Size)}}{\text{Yield for 1-Sk. Batch}}$

BATCH DESIGN (ONE SACK)	VOLUMES: 1-SK. BATCH (CU. FT.)		VOL. TO WT. (LB.) VOL. X 62.5 X SP. GR	1-SK. BATCH WTS.	FULL SIZE BATCH FACTOR	WTS.
1. Concrete Yield = $\frac{\text{Cu. Ft. per Cu. Yd.}}{\text{CF}}$	27 / =					
2. Volume CA = Yield X CAF X Solids	X X		X 62.5 X =			*
3. Volume Mortar = Yield — Vol. CA						
4. Volume Water = $\frac{\text{WF}}{\text{Gal. Water per Cu. Ft.}}$	/ 7.5		X 62.5 X 1.00 =			*
5. Volume One Sk. Cement		0.485	X 62.5 X 3.10 =	94.0		
6. Volume Entrained Air = Yield X AF	X					
7. Volume Paste = Vol. Cem. + Water + Air	0.485 +					
8. Volume FA = Vol. Mortar — Paste	—		X 62.5 X			*

9. Yield (Summation of 2, 4, 5, 6 & 8 to Check No. 1 Above)

10. Fine Aggregate Factor = $\frac{\text{Vol. FA}}{\text{FA Solids X Vol. Mortar}}$ = X

* Correct For Free Moisture or Absorption.

REMARKS: Volumes in Above Are Absolute Unless Otherwise Noted.
Water Added at Mixer Must Include the Liquid of the Admixtures.

FORM 310
FIELD LABORATORY AGGREGATE SIEVE ANALYSIS REPORT

This form is used for recording the results obtained from Sieve Analysis of Aggregates performed in the field laboratory. Space is also provided for recording the results of Decantation Test, Organic Impurities Test and Fineness Modulus Test.

AGGREGATE SIEVE ANALYSIS REPORT

County: ____ Project No: ____ Hwy: ____ Contractor: ____

Material Sources: Coarse Aggr.: ____ Fine Aggr.: ____

Date	PERCENT RETAINED ON SIEVE:																Loss by Decant.		Organic Impurities	Fineness Modulus	Remarks
	3"	2½"	1¾"	1½"	1"	¾"	½"	⅜"	¼"	#4	#8	#16	#20	#30	#50	#100	CA	FA			

FORM 311 REV.
DAILY ROAD REPORT - CONCRETE PAVEMENT

This is the daily report prepared by the mixer inspector to be used in recording the data to be used by the plant inspector in preparing Form Number 312. Form 311 should be prepared in duplicate, the mixer inspector **retaining a copy.**

Texas Highway De[redacted]
Construction Form 311 Rev

DAILY ROAD REPORT — CONCRETE PAVEMENT

COUNTY	PROJ. No.	DATE
BATCH METER	**PROGRESS**	**TIME**
START	STA.	HRS. RUN
STOP	STA.	HRS. LOST
BATCHES	LIN. FT.	CAUSE
CK. BATCHES	YIELD/BATCH	
	MATERIALS	
CEM. USED	CEM. OVER	STEEL: Bars
CEM. REQ.	CEM. UNDER	Wire Mesh

TEST SPECIMENS

STATION	BEAM No.	SLUMP	% AIR	STATION	BEAM No.	SLUMP	% AIR

PAVEMENT REPORT

Sta. to Sta.	Time to Time	Batches	Wt. Sand	Wt. Grav.	G. Wat.	Depth

INSPECTOR: ______________

Batch Meter

Start	Batch meter reading at beginning of day.
Stop	Batch meter reading at end of day.
Batches	Difference between start and stop reading.
Ck. Batches	As a check on the batch meter, the plant inspector secures from the batch bin operator the actual number of batches weighed during the day and enters this on his copy of this form.

Progress

Sta.	Station at start of day's work.
Sta.	Station at end of day's work.
Lin. Ft.	Difference Between stations.
Yield/Batch	Lin. Ft. Divided by the number of batches.

Time

Hrs. Run	Total time less hours lost.
Hrs. Lost	Total time lost in periods in excess of fifteen minutes.
Cause	Reasons for lost time in excess of fifteen minutes.

Materials

Cem. Used.	Actual Number of sacks used during day.
Cem. Req.	Theoretical number of sacks required.
Cem. Over	Number of sacks used in excess of number required.
Cem. Under	Number of sacks used under the number required.
Steel Bars or Wire Mesh	Pounds of steel used in excess of plan quantity.

Test Specimens

Station	Station from which concrete for beam was secured.
Beam No.	Identifying number of beam. The specifications require two beams at certain intervals and the average strength of these two will represent the strength for this section.
Slump	Result of Slump Test recorded to the nearest 1/8 inch.
% Air	Result of Air Content Test

Pavement Report

Sta. to Sta.	The beginning Station, Station number at which the moisture results were received, and the ending station for a day's run.
Time to Time	The beginning and ending of the time in which concrete is placed within the section "Sta. to Sta."
Batches	The number of batches placed within the section "Sta. to Sta."
Wt. Sand	The surface dry, loose weight of fine aggregate from Form Number 356.
Wt. Gravel	The surface dry, loose weight of coarse aggregate from Form Number 356.
G. Wat.	Gallons of water added at mixer from Form Number 356.
Depth	Three depth measurements are made for approximately each 200 feet of pavement and recorded to the nearest 1/8 inch. See Form 312 for example.
Inspector	The signature of mixer inspector.

FORM 312 REV.
FIELD LABORATORY REPORT FOR CONCRETE

This form is for recording the design, control, construction progress, and other pertinent data in the placing of concrete pavement during a day or part of a day. It must show the reasons for all mixer shut-downs in brief, but definite notes. Reasons for delays must be given. For example, lack of material, break in machinery, etc.

Texas Highway Department
Construction Form 312 Rev.

FIELD LABORATORY REPORT FOR CONCRETE

County ______ Project No. ______ Hwy. ______ Contractor ______ Date ______

I-SX. DESIGN	DESIGN NO ______				DESIGN NO ______				DESIGN NO. ______				DESIGN NO. ______			
Material	Sp. Gr	D.L.Wt. Cu.Ft.	% Solids	A.V. Per Sx.Cem.	Sp. Gr.	D.L.Wt. Cu.Ft.	% Solids	A.V. Per Sx.Cem.	Sp. Gr	D.L.Wt. Cu.Ft.	% Solids	A.V. Per Sx.Cem.	Sp. Gr.	D.L.Wt. Cu.Ft.	% Solids	A.V. Per Sx.Cem.
Water																
Cement																
Fine Agg.																
Coarse Agg.																
Air																
Yield																

DESIGN FOR ______ SACK BATCH- ______ CU. FT.

Time Sent	Des. No.	Cement Lbs.	FINE AGGREGATE Wt. D.L.	FINE AGGREGATE Moist Lbs.	FINE AGGREGATE FAF	COARSE AGGREGATE Wt. D.L.	COARSE AGGREGATE Moist Lbs.	COARSE AGGREGATE CAF

PAVEMENT REPORT

Time Rec'd	Sta to Sta.	Length Ft.	Batch-es	Water Added Gals.	Total Moist. Gals	Total Water Gals.	Cem. Factor	Water Per Sack	Depth fractions in ⅛ in.

BEAMS MADE				BEAMS BROKEN	
Station	Beam No.	Slump	% Air	Beam No.	7 Day
				Avg	
				Adj. Avg.	

CEMENT ______ FROM ______

Time	°F Cem	°F Air	Car or Trailer No.	Seal No.	No. Bbls. Sacks

MATERIAL & SOURCE:
Crs. Agg.: ______ Fine Agg.: ______
Water ______ Admix AEA ______ Ozs.
CDA ______ Lbs. Ozs.

LENGTH: ______ L.F. ______ SY/CY % In Place ______
CEMENT Used ______ Bulk Sacks Req'd ______ Over Under ______
STEEL: Bars ______ Lbs.; Wire Mesh ______ Lbs.
MIXING TIME ______ Sec HOURS ______ Run ______ Lost ______
TIME. Last Batch ______ Slab Finished ______

REMARKS ______ Superintendent ______
______ Inspector ______
Report No. ______

One Sack Design

Column 1	This lists the materials used. Space is provided for additional material.
Design No.	Space is provided for four different designs each numbered for identification. Under each design columns are provided for recording the specific gravity, dry loose weight, per cent solids, and absolute volume of each material. The total of the absolute volumes in each design must equal the theoretical yield per sack of cement for that design.
Design For	The size of the batch going into the mixer is given as, say, 6.800 sack batch, 40.8 cubic feet.
Time Sent	First Column: Time moisture test left the plant, Form 356.
Design No.	The identifying number of the design being used.
Cement, Lbs.	The number of pounds of cement in the batch.
Fine Aggregate	
Wt. D. L.	The surface dry, loose weight in the batch.
Moist. Lbs.	The pounds of free or absorbed moisture in the aggregate.
FAF	The fine aggregate factor.
Coarse Aggregate	
Wt. D. L.	The surface dry, loose weight in the batch.
Moist. Lbs.	The pounds of free or absorbed moisture in the aggregate.
CAF	The coarse aggregate factor.

Pavement Report

Time Rec'd.	Time the mixer inspector received moisture test, Form 356.
Sta. to Sta.	Stations numbers from Form 311.
Length Ft.	Difference between 'Sta. to Sta.'.
Batches	The number of batches placed between Sta. to Sta., Form 311.
Water Added Gals.	Gallons of water added at mixer, Forms 356 and 311.
Total Moist. Gals.	Total free moisture in combined aggregates, Form 356.
Total Water Gals.	The sum of 'water added at mixer' and 'Total Moist.'.
Cement Factor	The number of sacks of cement per cubic yard of concrete.
Water per Sack	Gallons of water per sack of cement.
Depth	See Form Number 311.

Beams Made	Data for the first four columns under this heading will be obtained from Form 311, 'Test Specimens'.
Beams Broken	Two columns are provided under this heading. The first is for the beam number and the second is for the results of a Seven Day Flexural Test.

Cement		Spaces are provided for brand and source.
	Time	Time car or trailer was delivered.
	°F. Cem.	Temperature of cement.
	°F. Air	Air Temperature
	Cem. Car or Trailer No.	Number and initial of car or trailer containing cement and seal numbers.
	No. Bbls. or Sacks	Number of barrels or sacks of cement in the shipment.

FORM 356 REV.
CONCRETE DESIGN REPORT

This form is used by the plant inspector for submitting design data to the mixer inspector and for comments on the design by the mixer inspector.

Texas Highway Department
Construction Form 356 Rev.

CONCRETE DESIGN REPORT

Water, Design Total = G.W. ____ × Bags/Batch ______ = _____ Gals. Gals. × 8.33 ______ = _____ Lbs.		Date:
________ Agg. ______ %	Free (−) or Absorbed (+) Water	
D. L. Wt. ______ × ______ = ______ Lbs.	______ Lbs.	Time ____
________ Agg. ______ %		C.A.F. =
D. L. Wt. ______ × ______ = ______ Lbs.	______ Lbs.	Cem. F. =
________ Agg. ______ %		Water F. =
D. L. Wt. ______ × ______ = ______ Lbs.	______ Lbs.	Air F. =
________ Agg. ______ %		
D. L. Wt. ______ × ______ = ______ Lbs.	______ Lbs.	
Total Free or Absorbed Water ______ Lbs.		
Add at Mixer ____________ Lbs. ______ Lbs. × .12 = ______ Gals.		Sig.
Received Sta. ______________ by Mixer Insp.		Time ____
Mixer Using: ______ Over ______ Gal.; Under ______ Gal.		
Admix: AEA ______ Ozs.; CDA ______ Qts. Lbs.		
Slump ______ in.; Air Temp. ______ °F; Water ______ °F		
Wind ____________________		
Weather ____________________		Sig.
Note: Mixer Inspector will not change water on basis of this report, but will report conditions at mixer and return immediately to plant Inspector with recommendations on mix design under remarks.		

Remarks:

Report No. ______

Water, Design Total	
G. W.	The gallons of water per sack of cement.
Bags/Batch	The number of sacks in the batch. The product of these two is the total gallons of water for the batch, without correction for moisture. This is converted to pounds by multiplying by 8.33.
Aggr. %	Space is provided for the free or absorbed water in four aggregates. The first space is for the type of aggregate, the second is for the per cent of free moisture or absorption. Free moisture is designated by (-) sign and absorption by (+) sign. The second line is for the saturated surface dry weight of aggregate in the batch times the correction factor for either free moisture or absorption (See Pages 33 and 35) to give the bin weights. Free (-) or Absorbed (+) Water is the difference in the saturated surface dry weight and the bin weight.
Add at Mixer	The pounds of water from 'Water, Design Total' less the pounds of water from 'Total Free Water' or plus the pounds of 'Total Absorbed Water' gives the pounds of water added at mixer. This multiplied by 0.12 gives gallons added at mixer.
Date	Date of report.
Time	Time of moisture test.
CAF	Coarse aggregate factor used in the design.
Cem. F.	The cement factor for the design.
Water F.	The water factor or gallons per sack of cement use the design.
Air F.	The design air factor in per cent.
Sig.	The signature of the plant inspector Initials are sufficient.

The above data are prepared and entered on the form by the plant inspector. The data shown below the double line are supplied by the mixer inspector.

Received Sta.	The station number at which concrete was being placed when the report was received.
Mixer Using	At the time this report is received, the 'Add at Mixer' water being used is that from a previous report and the difference between this and the 'Add at Mixer' water on this report is recorded as over or under, as the case may be.
Admix: AEA	Air-Entraining Admixture and amount used in ounces per batch.
CDA	Cement Dispersing Admixture and amount used in quarts or pounds per batch.

Slump	The slump in inches for the new design. Check tests should be made from time to time.
Air Temp. °F.	Temperature of air at mixer.
Water Temp. °F.	Temperature of water as it is introduced into mixer.
Wind	The direction and whether light, strong, hot, etc.
Weather	Type, clear and hot, or cool or cold, cloudy and cool, etc.
Time	The time the report is received.
Sig.	The signature or initials of the mixer inspector.
Remarks	The mixer inspector will take such information as necessary from this form and record it on his Form 311. He will return this form to the plant inspector with his comments as to whether the design is satisfactory or whether a redesign is necessary to meet specifications or obtain better workability. If a new design is necessary, another copy of the form containing the revised data is attached to the old report found at fault and returned to the mixer inspector with the new batch. The mixer inspector again indicates if satisfactory and returns both reports to the plant inspector for his files.
Report No.	The plant inspector shall number these reports consecutively beginning with number one each morning.

EQUIPMENT

The laboratory equipment necessary for the proper design and control of a Portland Cement concrete mixture is listed below. The equipment and supplies fall into three categories:

1. Material that is to be secured locally.
2. Equipment that is to be obtained from the Equipment and Procurement Divison by requisition. In requisitioning material from the Equipment Division, please itemize each item in a manner similar to that shown below. This will greatly facilitate the handling of your requisition.
3. Equipment furnished by contractor.

Material to be Secured Locally

4 - 1/2-gal. Mason Fruit Jars
1 - Sand Sleeve
1 - 6-ft. rule
1 - 50-ft. Steel Tape
3 - 13-oz. Prescription Bottles
1 - qt. 3 per cent solution Sodium Hydroxide
* Beam Molds, 6" x 6" x 20" of wood or metal
1 - Siphon Bulb (ear syringe)
1 - Trial Mix Pan, 20" x 24" x 6"
Supply of Depth Test Plates
1 - 11" x 11" Glass Plate

Equipment to be Obtained from Equipment and Procurement Division

1 - Beam Breaking Machine
1 - Slump Cone
1 - Torsion Balance
1 - Set of Metric Weights
1 - 80-lb. Aggregate Scale
1 - 30-lb. Spring Milk Scale
2 - Pycnometer Tops
1 - 1/2 Cu.Ft. Measure
1 - 1/10 Cu.Ft. Measure
3 - Round Aggregate Pans
1 - Depth Test Tool
1 - Square
1 - Small Shovel
1 - Trowel
* Steel Beam Molds

*The number of molds necessary should be determined by the Engineer.

1 - Tamping Rod
1 - Cement Sampling Tube
1 - Complete Set of Sieves
1 - Armored Thermometer, 0-220°F.
1 - Maximum-Minimum Thermometer
1 - 2-ft. Spirit Level
1 - 50cc Burette (graduated at 0.1cc intervals)
2 - 3-qt. water containers

Equipment furnished by Contractor

Curing tank of ample size with cooling and heating devices
Beam Forms for Pilot Tests for Strength
Burlap or Cotton Mats for Curing Test Specimens
Hand Operated Compression Machine may be required for testing job control cylinders on lightweight concrete