

CONCRETE AND MORTAR
DESIGN AND CONTROL OF CONCRETE

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1. GENERAL

1.01 This section provides information intended to assist in obtaining the concrete mixture best suited to the needs of the particular underground conduit construction job in hand and to ensure uniformity of characteristics throughout the job. The information of this section will also be useful in other construction operations where concrete of similar characteristics is needed.

2. CLASSES OF CONCRETE

2.01 The use to be made of the concrete and the conditions under which it is employed in underground conduit construction impose varying requirements on the concrete provided. To meet these requirements, eight different mixes have been designed and are designated by class as listed below:

Class 1A For manholes where the concrete is to be compacted by hand tamping.

Class 1B For manholes where the concrete is to be compacted by mechanical vibration and also for replacing

concrete pavement. It may also be used for floors in manholes where compacting is to be done by hand tamping.

Class 1C For manholes where the concrete is to be compacted by hand tamping and where high early strength is required. Its use may also be indicated during low temperatures; see G45.170.1.

Class 1D For manholes where the concrete is to be compacted by mechanical vibration and where high early strength is required and also for concrete pavement replacement where high early strength is required. It may be used for floors in manholes where high early strength is required, and where compacting is to be done by hand tamping. For additional uses during low temperatures, see G45.170.1.

Class 2A For conduit base or top protection and for complete encasement of multiple tile conduit. It may also be used for plain (non-reinforced) concrete floors in manholes and as a substitute for Class 2C concrete.

Class 2B For conduit encasement, particularly where it is necessary to work the concrete between and around closely spaced units of various types of single conduit.

Class 2C For replacement of concrete base for asphalt, brick, granite block and wood block pavement.

Class 2D To be used as a substitute for Class 2C concrete where high early strength is required or during low temperatures, as outlined in G45.170.1.

2.02 Pavement replacement is usually covered by Municipal, County or State regulations. Where such regulations are in existence, the restoration shall be made to conform. Whenever possible, arrangements should be made to have permanent paving restored by recognized local paving contractors using materials approved by the governing authorities.

3. CEMENT

3.01 Normal cement as described in G45.110.1 shall be used for Classes 1A, 1B, 2A, 2B and 2C concrete.

3.02 High early strength cement as described in G45.110.1 shall be used for Classes 1C, 1D and 2D concrete.

4. WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH

4.01 All concrete of the Class 1 grades shall have a water-cement ratio of 6 gallons of mixing water for each sack of cement used. Such concrete shall have a minimum compressive strength of 3,600 pounds per square inch at 28 days when made with normal cement and at 7 days when made with high early strength cement.

4.02 All concrete of the Class 2 grades shall have a water-cement ratio of 7-1/2 gallons of mixing water for each sack of cement used. Such concrete shall have a minimum compressive strength of 2,500 pounds per square inch at 28 days when made with normal cement and at 7 days when made with high early strength cement.

4.03 The water contained in the aggregates shall be considered as a part of the mixing water. Therefore, the quantity of water added at the mixer shall be adjusted so that the total available water in the concrete will not exceed the quantities specified in Paragraphs 4.01 and 4.02.

5. CONSISTENCY

5.01 Classes 1A and 1C concrete for manholes and other form work, to be compacted by hand, shall be of a consistency which will allow it to be readily worked into the corners and angles of the form and around reinforcing bars without excessive spading and without causing the aggregates to separate or free water to collect on the surface. Such concrete shall have a slump of 4 inches to 6 inches when measured by the slump test described in G45.210.1.

5.02 Classes 1B and 1D concrete for manholes and other form work, to be compacted by mechanical vibration, shall be of a stiff plastic consistency. Such concrete shall have a slump of 2 inches to 4 inches when measured by the slump test.

5.03 Class 2A concrete for base and top protection shall be of a stiff plastic consistency that will allow walking on the concrete immediately after it is laid and tamped. It should be wet enough so that when it is tamped a slight film of moisture collects on the surface, indicating that all voids are filled with cement mortar. Such concrete shall have a slump of 1-1/2 inch to 3 inches when measured by the slump test.

5.04 Class 2B concrete for conduit encasement shall be of a consistency that will allow it to be easily worked between and around closely spaced units of different types of

single conduit. Such concrete shall have a slump of 6 inches to 8 inches when measured by the slump test.

5.05 Classes 2C and 2D concrete for pavement base replacement shall be of a stiff plastic consistency. Such concrete shall have a slump of 2 inches to 4 inches when measured by the slump test.

6. PROPORTIONING CONCRETE

6.01 The total quantity of aggregates and the relation between coarse and fine aggregate employed in a given class of concrete shall be so adjusted that a workable, plastic and economical mixture will be produced without exceeding the specified amounts of mixing water. The proper proportions will vary according to the grading and type of the aggregates, the moisture contained in the aggregates and the workability desired of the concrete.

6.02 The combined aggregate shall be of such composition of sizes that when separated by the No. 4 standard sieve, the weight retained on the sieve shall not be less than one-third nor more than two-thirds of the total nor shall the amount of coarse material be such as to produce lack of smoothness in placing or honeycombing in the structure. When forms are removed, the concrete surfaces and corners shall show smooth and sound throughout.

6.03 It is expected that the approximate proportions shown in the following table will produce the various classes of concrete when average materials are used. Aggregates obtained from different localities and at different times may vary considerably in grading or surface water content and, therefore, adjustments determined by trial in the field must usually be made to care for these variations.

SUGGESTED TRIAL MIXES FOR CONCRETE

Class Of Concrete *		Class 1 Concrete Water-Cement Ratio = 6		Class 2 Concrete Water-Cement Ratio = 7½			
		1A & 1C	1B & 1D	2A	2B	2C & 2D	
Slump Range (Inches)		4-6	2-4	1½-3	6-8	2-4	
Max. Size of Coarse Aggregate (In.)		¾	¾	¾	½	1½	
Materials Per Sack Of Cement	With Gravel	Sand (Pounds)	220	230	310	260	290
		Gravel (Pounds)	270	290	390	320	480
		% Sand To Total Aggr. By Wt.	45	44	44	45	38
		Cement-Sand-Gravel Ratio (Volume)	1:2½:2¾	1:2½:3	1:3½:4	1:3:3¼	1:3¼:4¾
		Water (Gallons)	4¾	4½	5½	5¾	5¾
		Yield-Cubic Ft. Of Concrete	4¼	4½	5½	5	6
	With Stone	Sand (Pounds)	220	230	310	260	290
		Stone (Pounds)	220	230	320	270	390
		% Sand To Total Aggr. By Wt.	50	50	50	50	43
		Cement-Sand-Stone Ratio (Volume)	1:2½:2¼	1:2½:2¼	1:3½:3¼	1:3:2¾	1:3¼:4
Materials Per Cubic Yard Of Concrete	With Gravel	Cement (Sacks)	6½	6¼	4¾	5½	4½
		Water (Gallons)	30½	28½	26½	32	25¾
		Sand (Pounds)	1420	1440	1510	1440	1290
		Sand (Cubic Yards)	.59	.60	.63	.60	.54
		Gravel (Pounds)	1750	1780	1860	1770	2130
		Gravel (Cubic Yards)	.65	.67	.70	.66	.80
	With Stone	Cement (Sacks)	7	6¾	5¼	6	5
		Water (Gallons)	33¼	31	29½	35	28
		Sand (Pounds)	1510	1570	1620	1540	1420
		Stone (Pounds)	1530	1560	1640	1560	1910
Stone (Cubic Yards)	.57	.58	.61	.58	.71		

* Classes of concrete 1A, 1B, 2A, 2B and 2C are prepared with Normal Portland Cement.

Classes of concrete 1C, 1D, and 2D are prepared with High Early Strength Portland Cement.

7. DETERMINING MOISTURE CONTENT OF SAND

7.01 Before the first batch of concrete is mixed, examine the sand for moisture content to determine whether it is necessary to adjust the amount of water required for mixing.

7.02 The quantity of mixing water specified in the table of Suggested Trial Mixes is based on the use of wet sand which is the kind available on most jobs. Wet sand contains about 1/2 gallon of water per cubic foot, feels wet and leaves a little moisture on the hands after being handled.

7.03 Very wet sand, which contains about 3/4 gallon of water per cubic foot, leaves more moisture on the hands than wet sand after being handled and is either dripping wet when delivered or wet from being exposed to rain while stored on the job. If the sand is very wet, the total quantity of mixing water used should be reduced 1/2 to 3/4 gallon below the quantity specified in the table for each sack of cement.

7.04 Damp sand feels slightly moist to the touch but leaves very little moisture on the hands after being handled. If the sand is only damp, the total quantity of mixing water used should be increased 1/4 to 1/2 gallon above the quantity specified in the table for each sack of cement.

7.05 Dry sand contains little or no moisture, flows freely, and is dry as though it were spread out in thin layers and dried in the sun. This kind of sand is very seldom encountered in concrete work. Sand in this condition should preferably be wet by spraying prior to use in order to approximate the moisture content of wet sand as defined in 7.02.

7.06 The quantity of water specified in the table includes some allowance for the moisture content of coarse aggregate. Usually, this moisture content is sufficiently constant that no further adjustment need be made for the water in coarse aggregate.

8. TRIAL MIXES

8.01 Mix one or two batches of concrete using the proportions suggested in the table but with the quantity of mixing water adjusted if necessary according to the moisture content of the sand.

8.02 If the concrete in the trial batches is a smooth, plastic mass having the specified slump, it may be considered well proportioned and the succeeding batches should be mixed with the same quantities of materials. If the first batch is only slightly too stiff, it is probably the result of the mixer absorbing some of the moisture and, therefore, the second and succeeding batches should be satisfactory.

8.03 If the concrete does not have all of the desired characteristics, it may be due to one or more of the causes listed in the following table. After observing the concrete, the

next trial batch should be adjusted as recommended. Usually one additional trial batch after the first one will be sufficient to determine the proper proportions. Unless the trial batches are of decidedly poor quality, they may be used on the job but should be spread over as large an area as practicable rather than have them concentrated in one spot.

ADJUSTMENT OF TRIAL MIXES

NATURE OF CONCRETE	PROBABLE CAUSE	RESULT	REMEDY
Harsh Mixture.	Undersanded.	Difficulty in Placing. Stone Pockets. Honeycomb.	Increase proportions of sand in total amount of aggregate. Reduce quantity of mixing water slightly because of more water being in additional sand.
Excess of Mortar.	Oversanded.	Uneconomical.	Increase proportion of coarse aggregate in total amount of aggregate.
Smooth and plastic but mixture too fluid.	Excess Cement Paste.	Segregation. Uneconomical.	Increase amount of total aggregate.
Crumbly mixture and too stiff.	Lack of Cement Paste.	Difficulty in Placing.	Decrease amount of total aggregate.
Crumbly mixture and too fluid.	Excess Mixing Water.	Segregation. Loss of Strength.	Decrease amount of mixing water.
Plastic mixture but too stiff.	Lack of Mixing Water.	Uneconomical. Difficulty in Placing.	Increase amount of mixing water slightly.

8.04 The ideal mixture is one that is smooth and plastic, as stiff as the workability requirements permit, with just enough cement paste of the specified water-cement ratio to completely fill the spaces between the particles of aggregate. The experienced workman will quickly arrive at the proper proportions to obtain this kind of mixture. Once the proper proportion is determined, the succeeding batches will be suitable also—provided accurate measurement of materials is always maintained and provided the characteristics of the aggregates do not change.

9. CONTROL

9.01 The methods of measuring concrete materials shall be such that the proportions can be accurately controlled and easily checked at any time during the work.

9.02 Wherever practicable, measurement of aggregates shall be done by weight, using suitable and accurate platform scales.

