TOWER FOUNDATIONS AND ANCHORS

GENERAL

CONTENTS — PAGE

1. GENERAL

1.01 This section outlines the general considerations for installing concrete foundations and anchors associated with self-supporting and guyed towers.

1.02 This section is reissued to include updated information on microwave tower foundations and delete information on grounding which will be covered in Section 760-925-135. Since there are extensive changes, arrows showing changes have been omitted.

1.03 The foundation for a self-supporting tower usually consists of reinforced concrete piers on reinforced concrete footings or mats. (See Fig. 1.) For guyed towers, the foundation consists of a single concrete block containing a wire mesh, while the anchor blocks are single concrete blocks without wire mesh. The foundation for each waveguide support is constructed similar to the guyed tower foundation. (See Fig. 2.)

1.04 Local or state laws may require the approval of foundation and anchor designs by a professional engineer duly registered and licensed to practice in that state. To facilitate checking

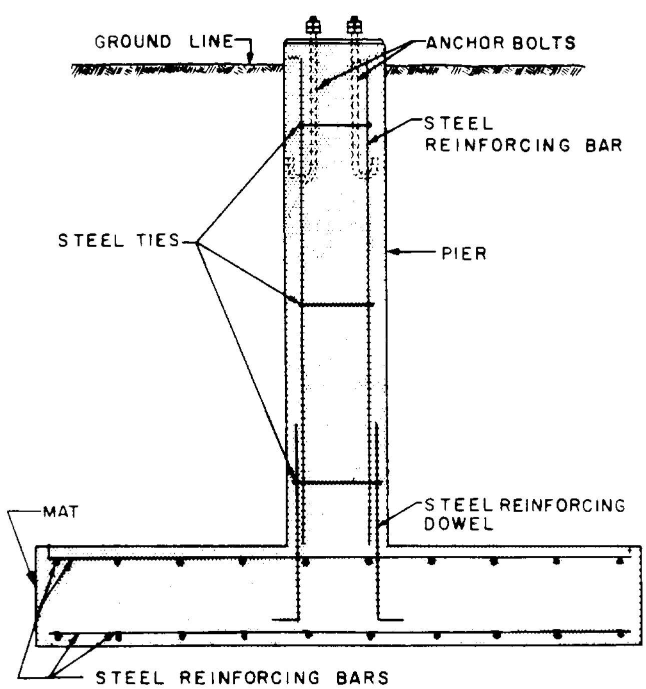


Fig. 1—Cross-Sectional View of Typical Foundation Pier and Mat for One Leg of Self-Supporting Towers

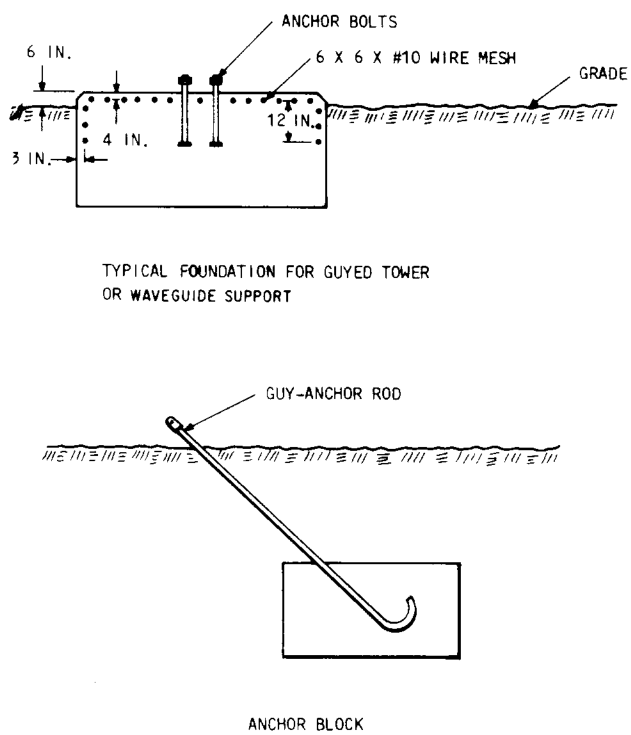


Fig. 2—Cross-Sectional View of Guyed Tower and Waveguide Support and Anchor Block

the designs, the loads imposed by the towers are listed in the sections covering the specific type towers.

1.05 A permit to erect and operate a radio system is required by the Federal Communications Commission. Local regulations also may require construction permits. All required permits should be obtained before starting foundation construction.

1.06 The foundation designs are based on a given depth of frost penetration. Where a frost depth greater than the design quantity is suspected, the depth of the foundation should be increased in order to maintain at least 1 foot of concrete below the frost line.

1.07 In some localities, bedrock may be encountered before reaching the required depth for the foundation or anchors. Since rock excavation is comparatively expensive, economies may be realized by using specially designed concrete structures anchored in the bedrock. The type, depth, and number of anchors required are dependent on the type, stratification, inclination of the rift, etc, of the rock. Special designs may require the services of outside engineering consultants. The Tower and Foundation Design Group, Western Electric Company, Merrimack Valley, Massachusetts is available for consultation. The cross section of a typical foundation in rock is shown in Fig. 3.

1.08 Provisions should be made to adequately barricade or cover all excavations which must remain open to prevent childdren or animals from falling into them. Excavations also should be protected from flowing surface water in the event of rain. All water and extraneous materials (paper, rubbish, etc) should be removed from the excavation before any concrete is poured. The contractor must observe the requirements of the Occupational Safety and Health Act covering construction of foundations.

> ***Note:*** Depending on the depth of the excavation and the type of soil, shoring may be required prior to entering an excavation. (See Section 622-020-020.)

1.09 To avoid damage to or possible destruction of the foundations by lightning, steel microwave towers should be grounded. Section 760-925-135 contains information describing the methods and procedures to be used for grounding microwave towers.

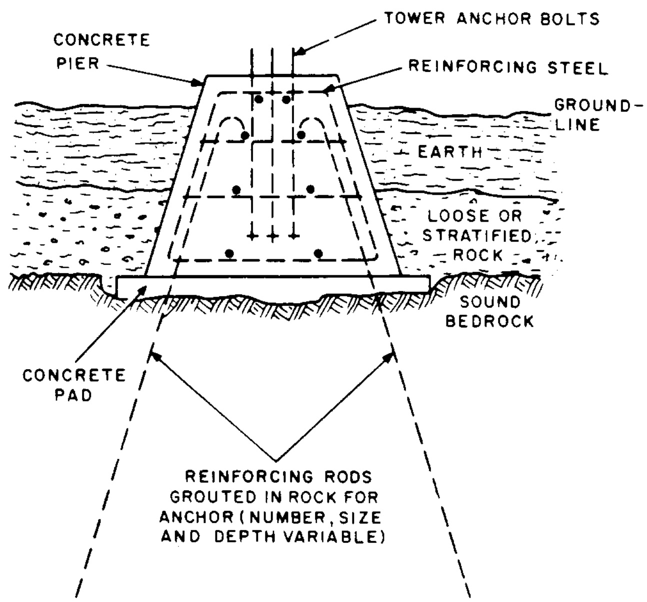


Fig. 3—Typical Foundation in Rock

2. SOIL BEARING REQUIREMENTS

2.01 Standard foundations designed for Bell System towers assume soil adequate to withstand a bearing pressure of 4000 pounds per square foot. If there is any doubt concerning the adequacy of the bearing characteristics at the proposed site, actual bearing characteristics of the soil should be determined by suitable tests performed by specialists in soil mechanics. In locations where it is determined that the soil does not have satisfactory bearing capacity, soil stabilization or foundations specifically designed to meet local conditions will be required. Where soil conditions indicate that a special design is required, the American Concrete Institute's Building Code Requirements for Reinforced Concrete, ACI 318, should be used.

3. CONSTRUCTION DETAILS

3.01 Tower and waveguide foundations and anchor block positions should be checked carefully to ensure that they are located correctly, are of correct size, and include all specified materials, ie, reinforcing bars, wire mesh, anchor bolts, and guy anchors. Foundation details are indicated in the section describing the foundation for a particular type tower.

3.02 Four anchor bolts are used to secure the baseplate to the tower foundation. These bolts are threaded at one end and equipped with two hex nuts each. The other end has a conventional hex head or a J-shape. The center of the anchor bolt group should coincide with the center of the tower foundation. Bolt positioning is critical, so no difficulty is encountered when setting the baseplate. Care should be exercised to ensure that the anchor bolts are not pulled out of alignment when connections are made to the wire mesh or the reinforcing bars in foundations.

3.03 The guyed towers are guyed in three directions, with the anchors spaced 120 degrees apart. Each guy is attached to a separate guy-anchor rod, which is embedded in a concrete anchor block. The anchor block locations should be oriented so as to avoid any transmission interference problems. The size of the anchor block is dependent on the number and size of the guys which it restrains.

3.04 The anchor rods should be installed with the proper rake and pitch. A sloping trench is required for each guy-anchor rod, with the trench width kept to a minimum to limit disturbing the earth forming the front face of the anchor block. Although reinforcing bars are not required in the anchor blocks, bars may be used to stabilize the guy rods while pouring the concrete.

3.05 The waveguide and tower foundations should be located so the waveguide support location is compatible with the location of the waveguide window in the equipment building. Anchor bolts are used to secure the legs of the waveguide support to the foundations. Each grouping of anchor bolts must be located correctly with reference to other anchor bolt groupings and to the tower center pier. Anchor bolts should be plumb within 1/16 inch and the hook portion should be oriented to assure a minimum concrete cover of 3 inches.

4. CONCRETE FORMS

4.01 Unless shoring of the excavation is necessary to prevent cave-ins (see Section 622-020-020), forms usually are not required when pouring the mats for self-supporting towers. The concrete for the mats should be poured on undisturbed earth. The pier is poured after the mat has hardened. Forms are required when pouring the piers. If the excavation for the foundation is inadvertently carried too deep, it should ***not*** be backfilled with earth. The extra depth should be compensated for by pouring additional concrete to give a thicker mat, and not by increasing the height of the pier.

4.02 For guyed towers, the above-grade portion of the foundation requires the use of a form, but it need not extend below grade more than a few inches unless shoring of the excavation is required. No forms are required for the anchor blocks unless shoring is a problem. The faces of the anchor blocks, which are oriented toward the tower, must be poured against a vertical wall of undisturbed earth.

4.03 Forms are required for that portion of the waveguide foundation that extends above gound level, and the need for further forming is the same as that noted for guyed tower foundations. One side of the foundation should be parallel to the wall of the equipment building.

4.04 The forms may be made of wood, fiber, or metal. All joints in the forming material must be tight enough to prevent leakage of the cement binder paste. The forms must be rigidly constructed, accurately placed, and well braced to prevent any possible movement during concrete placing.

4.05 Edges and corners of the concrete piers exposed aboveground should be beveled approximately 1 inch. This may be done by placing a triangular piece of wood, fiber, or metal inside the forms.

4.06 It may be economically desirable to reuse forms when several piers are to be installed in the same general area. Forms to be reused should be so constructed as to afford easy removal without destruction.

4.07 Ready-made tubular forms for the piers may be substituted for rectangular forms. The inside diameter of the tube should be at least equal to the diagonal of a horizontal cross section of an equivalent rectangular pier.

4.08 A foundation consisting of a group of bell-bottomed columns may be used to support towers; however, special engineering design will be required. This type of foundation is constructed by boring a hole in the earth and flaring the bottom to form a bell-shaped footing. Special equipment is required for this work. Forms are necessary only for the portion of the column that projects above grade.

5. REINFORCING

5.01 Reinforcing steel should consist of deformed rods that conform to American Society for Testing Materials (ASTM) Specification A 615-72 as to deformation and grade.

5.02 The size and quantity of reinforcing bars is indicated in the section describing the foundations for a particular type tower. The numbered size designation of reinforcing bars refers to the nominal diameter of the bar expressed in eighths of an inch (a No. 6 bar has a 6/8- or 3/4-inch diameter). The designation number of wire mesh refers to the wire gauge and spacing.

5.03 Reinforcing steel and wire mesh should be distributed as shown on detail figures in the appropriate part of the sections covering the foundations for a particular tower. The steel should be securely supported, and all joints properly tied and held in place with No. 14 or 16 AWG annealed iron wire to prevent movement when the concrete is poured. The anchor bolts in the foundations should be wire-wrapped to the adjacent steel.

5.04 Although some rusting of reinforcing steel is almost inevitable, care should be exercised to keep it to a minimum by proper storage. Wire brushing may be justified if rust appears excessive. Oil or grease, if present, should be removed before concrete is poured because it will weaken or prevent the formation of a strong bond between concrete and steel.

6. CONCRETE

6.01 Good materials, accurate proportioning, and careful control of all operations, including placing, are essential for making good concrete of adequate strength and durability for its intended use. Concrete made without regard to these requirements results in a mass of cement, sand, coarse aggregate, and water, which will attain varying degrees of hardness, and unpredictable strength.

6.02 Concrete is composed of fine and coarse aggregate held together in a solid mass by a binder paste made of cement and water. In properly made concrete, each particle of aggregate is surrounded completely by paste, and all spaces between the aggregate particles are filled with the paste. The binding properties of the paste result from chemical reactions between the cement and water. Only a relatively small amount of water is necessary to complete the chemical reactions; however, greater quantities of water are used to provide workability and to permit the use of more aggregate for economy. The quality of the paste is lowered as it is thinned with water. A proper proportion of water to cement is essential to obtain satisfactory results. Figure 4 shows typical compressive strength curves for normal portland cement concrete and high-early strength portland cement concrete using 5, 6, and 7 gallons of water per sack of cement. These curves were derived from data obtained from test specimens made and cured under laboratory conditions (moist cured at 70°. Test specimens made and cured under field conditions will yield slightly different results, since concrete gains strength more rapidly at high curing temperatures than at low temperatures. If the concrete is allowed to dry out during the curing period, the strength gaining process will be interrupted.

6.03 Concrete for foundations may be either job-mixed or ready-mixed. The water-cement ratio should not exceed 6-1/2 gallons of mixing water per sack (1 cubic foot bulk, 94 pounds) of cement (see note). The concrete may be made with normal portland cement (Type I), high-early strength portland cement (Type III), or air-entraining portland cement (Type IA or IIIA). Clear, potable water should be used in the concrete. Cement used in concrete for foundations should conform to ASTM Specification C 150 Type I, IA, III, or IIIA. If cement from an unknown or questionable source is to be used, compressive strength test methods described in ASTM C 109 should be requested.

> ***Note:*** The mixing water includes surface moisture on the aggregate but excludes water absorbed by the aggregate.

6.04 Generally, air-entrained concrete should be used for the foundations and anchors, particularly in areas subject to cold temperatures. Air-entrained concrete contains a myriad of minute, completely separated air bubbles, and may be made with any of the cements listed in 5.03. With portland cements conforming to ASTM Specification C 150, an air-entraining admixture must be used. Portland cements conforming to ASTM Specification C 175 contain proper amounts of air-entraining agents.

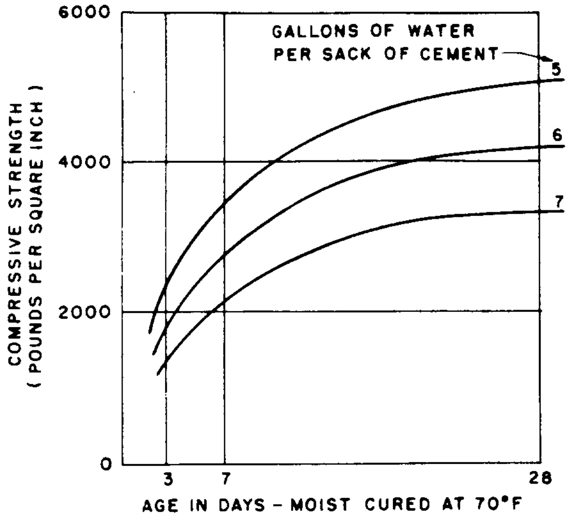


FIG. A NORMAL PORTLAND CEMENT CONCRETE

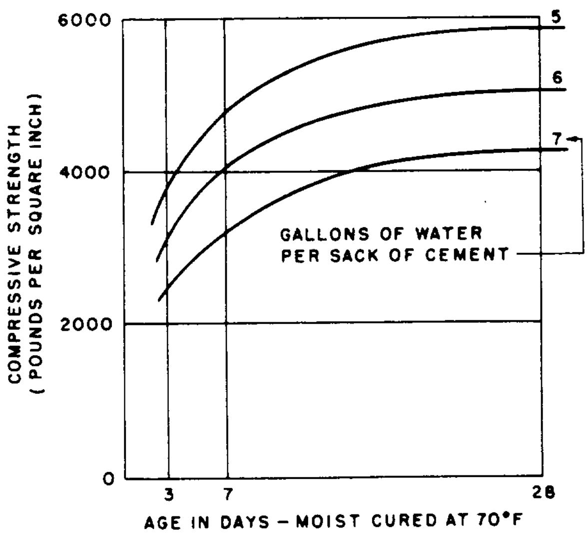


FIG. B HIGH-EARLY STRENGTH
PORTLAND CEMENT CONCRETE

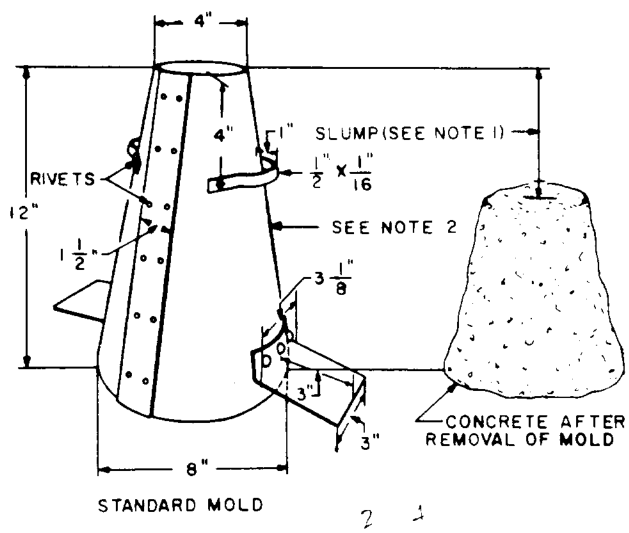
Fig. 4—Compressive Strength Curves

6.05 Experience and tests with air-entrained concrete indicate several advantages over concrete made with normal or high-early strength cement. Air-entrained concrete offers much greater resistance to spalling or surface deterioration brought about by repeated freezing and thawing.

6.06 The amount of air entrained in the concrete should be carefully controlled. Excessive entrained air will decrease the compressive strength of the concrete. Concrete made with 3/4-inch and smaller aggregate should entrain from 4 to 7 percent air by volume, with 5-1/2 percent being optimum. Less air should be entrained in concrete made with larger size coarse aggregate. ASTM methods for tests C 138, C 173, and C 231 outline procedures for measuring the air content of freshly mixed concrete.

6.07 Section 622-020-020 provides information on fine and coarse aggregate for concrete. Well-graded, coarse aggregate up to 2-1/2 inches is acceptable for foundations.

6.08 Concrete for tower foundations should slump from 2 to 4 inches, as measured by the standard slump test shown in Fig. 5. Procedures for making the slump test are described in Section 622-020-020 and ASTM method for test C 143.



NOTE 1- SLUMP SHOULD MEASURE 2 TO 4 INCHES
2- MOLD MADE OF 16 GAUGE OR THICKER METAL

Fig. 5—Slump Test

6.09 The foundation designs are based on concrete which will attain a minimum compressive strength of 3000 pounds per square inch in 28 days. To assure that concrete of the desired quality has been used, several standard test cylinders should be made as the work progresses. Procedures for making and curing the test cylinders are provided in Section 622-020-020 and ASTM method for test C 31. The cylinders should be allowed to cure in the field under the same conditions as the foundation, and then should be tested by a commercial testing laboratory. Steel erection should not begin until the results of the tests are available. As indicated by the compressive strength curves in Fig. 4, concrete which attains a strength of 2000 pounds per square inch in 7 days may be expected to exceed 3000 pounds per square inch in 28 days; therefore, steel erection may be started if the 7-day test strength is 2000 pounds per square inch or greater.

> ***Note:*** Concrete cured at low temperatures does not build strength as rapidly as concrete cured at moderate temperatures. If air temperatures are expected to be below 40°F during the first 7 days of the curing period, the foundation and test cylinders should be protected by suitable cover, such as straw or tarpaulins, supplemented by auxiliary space heaters, if necessary, to maintain desired curing temperatures.

6.10 The concrete should be mixed for at least 3 minutes after all material, including water, has been placed in the mixer. The mixer should be run at the mixing rate recommended by the manufacturer during the mixing period, and then should be slowed to agitation speed until the concrete is used. The initial set of portland cement in moderate temperatures (about 70°F) does not take place in less than 1 hour, but usually occurs about 2 to 3 hours after the water has been added. Concrete which has been mixed with water and continuously agitated for not more than 1-1/2 hours is acceptable for foundations if it meets the slump requirement in 6.08. If additional water is necessary for the mix to meet the slump requirement, cement in the ratio specified for the mix also should be added. Water alone should not be added to the mix to obtain the required slump, since the added water would increase the water-cement ratio, thus weakening the concrete. Concrete which has been mixed with water for more than 1-1/2 hours should not be used.

6.11 Effective methods should be employed to avoid segregation of the materials in the concrete mix while it is conveyed from the mixer to its final position. Section 622-020-020 describes the cause, effect, and methods of preventing segregation.

6.12 Earth against which concrete is to be placed should be moist, and forms should be wetted or oiled to prevent loss of water from the mix. There should be no standing water or ice in the excavation or on the forms, and concrete should not be placed against frozen ground. Loss of water to the surrounding earth also may be prevented by lining the excavation with a plastic film.

6.13 The top of the pier should be finished with a wooden float. Excessive smoothing tends to depress the coarse aggregate and thus increase the possibility of spalling.

6.14 Occasionally, it may be necessary to pour concrete when temperatures are below freezing. Refer to Section 622-020-020, describing concrete and mortar construction during low temperatures. Certain additives, such as calcium chloride or salt, are used occasionally in concrete for cold weather construction. These additives cause the concrete to set more quickly, thus generating heat more rapidly within the concrete. Accelerator additives will reduce the strength of the concrete, and their use is not recommended in concrete for foundations and anchors.

6.15 The curing process (chemical reaction) which causes concrete to harden requires time, water for hydration, and favorable temperatures. Ideally, the temperature should be about 70°F. Concrete should be protected from temperatures above 100°F and below 40°F. To assure the presence of water for hydration, exposed surfaces of the concrete should be kept continuously moist for at least 5 days by coverings such as wet burlap, canvas, sand, or straw. The concrete should be protected from direct rays of the sun for at least the first three days of the curing period. The covering should be applied as soon as the concrete is strong enough to receive it. This covering, which also may serve as protection from extreme temperatures, should be kept wet except when temperatures are below freezing.

7. JOINTS

7.01 Usually the foundations for self-supporting towers will be poured in two parts; the mat, and then the pier or piers. The surface of the mat should be prepared to assure a strong bond at the construction joint between the mat and the pier. The mat should be cleaned of all foreign matter such as dirt, sawdust, and any laitance (an accumulation of fine materials of the mix which is carried to the surface of a concrete mass, usually by excess water in the mix). A grout of cement and water, the consistency of thick cream, should be brushed on the clean, damp surface just before the fresh concrete is poured.