

SECTION 03300

CONCRETE FOR BUILDING CONSTRUCTION

1 GENERAL

1.1 SUMMARY (NOT APPLICABLE)

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI)

- ACI 211.1 (1981; Rev 1985) Selecting Proportions for Normal, Heavyweight, and Mass Concrete
- ACI 301 (1984; Rev 1988) Structural Concrete for Buildings
- ACI 305R (1989) Hot Weather Concreting
- ACI 318 (1989) Building Code Requirements for Reinforced Concrete
- ACI 347 (1988) Concrete Formwork

AMERICAN HARDBOARD ASSOCIATION (AHA)

- AHA A135.4 (1982; R 1988) Basic Hardboard

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- ASTM A 615 (1989) Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
- ASTM C 31 (1988) Making and Curing Concrete Test Specimens in the Field
- ASTM C 33 (1986) Concrete Aggregates
- ASTM C 39 (1986) Compressive Strength of Cylindrical Concrete Specimens
- ASTM C 42 (1987) Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C 78	(1984) Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading)
ASTM C 94	(1989b) Ready-Mixed Concrete
ASTM C 143	(1989a) Slump of Hydraulic Cement Concrete
ASTM C 150	(1989) Portland Cement
ASTM C 171	(1969; R 1986) Sheet Materials for Curing Concrete
ASTM C 172	(1982) Sampling Freshly Mixed Concrete
ASTM C 173	(1978) Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 192	(1988) Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 231	(1989a) Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 260	(1986) Air-Entraining Admixtures for Concrete
ASTM C 309	(1989) Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 330	(1987) Lightweight Aggregates for Structural Concrete
ASTM C 494	(1986) Chemical Admixtures for Concrete
ASTM C 597	(1983) Pulse Velocity Through Concrete
ASTM C 618	(1989) Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C 803	(1982; R 1989) Penetration Resistance of Hardened Concrete
ASTM C 805	(1985) Rebound Number of Hardened Concrete
ASTM C 1017	(1985) Chemical Admixtures for Use in Producing Flowing Concrete
ASTM D 1751	(1983) Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D 1752	(1984) Preformed Sponge Rubber and Cork

Expansion Joint Fillers for Concrete Paving
and Structural Construction

ASTM E 96 (1990) Water Vapor Transmission of
Materials

CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

CRSI DA4 (1990; 25th Ed) Manual of Standard
Practice

DEPARTMENT OF COMMERCE (DOC)

DOC PS 1 (1983) Construction and Industrial
Plywood

FEDERAL SPECIFICATIONS (FS)

FS CCC-C-467 (Rev C) Cloth, Burlap, Jute (or Kenaf)

FS SS-S-1401 (Rev C; Notice 1) Sealant, Joint,
Non-Jet-Fuel-Resistant, Hot-Applied, for
Portland Cement and Asphalt Concrete
Pavements

NATIONAL READY-MIXED CONCRETE ASSOCIATION (NRMCA)

NRMCA-01 (Jan 1984) Quality Control Manual: Section 3,
Plant Certifications Checklist: Certification
of Ready-Mixed Concrete Production Facilities

NRMCA CPMB-100 (Jan 1986) Concrete Plant Standards

NRMCA TMMB-1 (Jan 1982; 11th Rev) Truck Mixer and Agitator
Standards

1.3 SUBMITTALS

Government approval is required for submittals with a "GA" designation;
submittals having an "FIO" designation are for information only. The
following shall be submitted in accordance with Section 01300 SUBMITTALS:

SD-04 Drawings

Concrete Reinforcement System; GA

Detail drawings showing reinforcing steel schedules, sizes, grades, and
splicing and bending details. Drawings shall show support details
including types, sizes and spacing.

SD-08 Statements

Proportions of Mix; FIO.

The results of trial mix along with a statement giving the maximum nominal coarse aggregate size and the proportions of all ingredients that will be used in the manufacture of each strength of concrete, at least 14 days prior to commencing concrete placing operations. Aggregate weights shall be based on the saturated surface dry condition. The statement shall be accompanied by test results from an independent commercial testing laboratory, attesting that the proportions selected will produce concrete of the qualities indicated. No substitutions shall be made in the materials used in the work without additional tests to show that the quality of the concrete is satisfactory.

SD-09 Reports

Sampling and Testing; FIO.

Certified copies of laboratory test reports, including all test data, for aggregate, admixtures, cement, pozzolan, joint sealant, and curing compound. These tests shall be made by an approved commercial laboratory or by a laboratory maintained by the manufacturers of the materials.

SD-13 Certificates

Cementitious Materials; [_____].

Manufacturer's certification of compliance, accompanied by mill test reports attesting that the materials meet the requirements of the specification under which it is furnished, for cement and pozzolan.

Reinforcing Steel; FIO

Certified copies of mill reports attesting that the reinforcing steel furnished meets the requirements specified, prior to the installation of reinforcing steel.

1.4 GENERAL REQUIREMENTS

1.4.1 Strength Requirements

Structural concrete for all work except slabs on-grade shall have a 28-day compressive strength of 4000 pounds per square inch. Concrete slabs on-grade shall have a 28-day flexural strength of 600 pounds per square inch. Concrete made with high-early strength cement shall have a 7-day strength equal to the specified 28-day strength for concrete made with Type I or II portland cement.

1.4.2 Air Entrainment

Concrete exposed to freeze-thaw cycles shall contain from 5 to 7 percent total air. Other concrete may, at the option of the Contractor, be air entrained to produce concrete with 3 to 5 percent total air.

1.4.3 Special Properties

Concrete may contain other admixtures, such as water reducers, superplasticizers, or set retarding agents to provide special properties to the concrete, if approved.

1.4.4 Slump

Slump shall be within the following limits:

<u>Structural Element</u>	<u>Slump in inches</u>	
	<u>Minimum</u>	<u>Maximum</u>
Blast and Fragment Resistant Walls	4	6
Foundation walls, substructure walls, footings, pavement, and slabs	1	3
Any structural concrete approved for placement by pumping	None	6

*Where use of superplasticizers are approved to produce flowing concrete these slump requirements do not apply.

1.5 PROPORTIONS OF MIX

1.5.1 Mixture Proportioning

Trial batches shall contain materials proposed to be used in the project. Trial mixtures having proportions, consistencies and air content suitable for the work shall be made based on methodology described in [ACI 211.1](#), using at least three different water-cement ratios. Trial mixes shall be proportioned to produce concrete strengths specified. Trial mixtures shall be designed for maximum permitted slump and air content. The temperature of concrete in each trial batch shall be reported. For each water-cement ratio at least three test cylinders for each test age shall be made and cured in accordance with [ASTM C 192](#). They shall be tested at 7 and 28 days in accordance with [ASTM C 39](#). From these test results a curve shall be plotted showing the relationship between water-cement ratio and strength.

1.5.2 Average Strength

In meeting the strength requirements specified, the selected mixture proportion shall produce an average compressive strength exceeding the specified strength by the amount indicated below. Where a concrete production facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated shall represent materials, quality control procedures, and conditions similar to those expected; shall represent concrete produced to meet a specified strength or strengths within 1000 psi of that specified for proposed work; and shall consist of at least 30 consecutive tests. A strength test shall be the average of the strengths of two cylinders made

from the same sample of concrete and tested at 28 days or at other test age designated for determination of the specified strength.

1.5.2.1 Test Records Exceeding 29

Required average compressive strength used as the basis for selection of concrete proportions shall be the larger of the specified strength plus the standard deviation multiplied by 1.34 or the specified strength plus the standard deviation multiplied by 2.33 minus 500.

1.5.2.2 Test Records Less Than 29

Where a concrete production facility does not have test records meeting the above requirements but does have a record based on 15 to 29 consecutive tests, a standard deviation may be established as the product of the calculated standard deviation and a modification factor from the following table:

No. of tests (1)	Modification factor for standard deviation
less than 15	See Note
15	1.16
20	1.08
25	1.03
30 or more	1.00

(1) Interpolate for intermediate numbers of tests.

When a concrete production facility does not have field strength test records for calculation of standard deviation or the number of tests is less than 15, the required average strength shall be:

- a. The specified strength plus 1000 specified strength of less than 3000 psi.
- b. The specified strength plus 1200 for specified strengths of 3000 to 5000 psi.
- c. The specified strength plus 1400 for specified strengths greater than 5000 psi.

1.6 STORAGE OF MATERIALS

Cement and pozzolan shall be stored in weathertight buildings, bins, or silos which will exclude moisture and contaminants. Aggregate stockpiles shall be arranged and used in a manner to avoid excessive segregation and to prevent contamination with other materials or with other sizes of aggregates. Reinforcing bars and accessories shall be stored above the ground on platforms, skids or other supports. Other materials shall be stored in such a manner as to avoid contamination and deterioration.

Admixtures which have been in storage at the project site for longer than 6 months or which have been subjected to freezing shall not be used unless retested and proven to meet the specified requirements. Sealants shall be delivered in the manufacturer's original unopened containers. Sealants whose shelf life has expired shall be removed from the site.

1.7 FORM DESIGN

Formwork shall be designed in accordance with methodology of **ACI 347** for anticipated loads, lateral pressures, and stresses. Forms shall be capable of producing a surface which meets the requirements of the class of finish specified in Section **03300 CONCRETE FOR BUILDING CONSTRUCTION**. Forms shall be capable of withstanding the pressures resulting from placement and vibration of concrete.

2 PRODUCTS

2.1 ADMIXTURES

Admixtures shall conform to the following:

2.1.1 Accelerating Admixture

ASTM C 494, Type C or E.

2.1.2 Air-Entraining Admixture

ASTM C 260.

2.1.3 Flowing Concrete Admixture

ASTM C 1017, Type 1 or 2.

2.1.4 Water-Reducing or Retarding Admixture

ASTM C 494, Type A, B, or D.

2.2 CEMENTITIOUS MATERIALS

Cementitious materials shall each be of one type and from one source when used in concrete which will have surfaces exposed in the finished structure. Cementitious materials shall conform to one of the following:

2.2.1 Cement

ASTM C 150, Type I or II or III.

2.2.2 Pozzolan

ASTM C 618, Class N.

2.3 AGGREGATES

Aggregates shall conform to [ASTM C 33](#). Maximum size of coarse aggregate shall be 1/2 inch for Blast and Fragment Resistant Walls and 1 inch for all other work.

2.4 CURING MATERIALS

2.4.1 Burlap

[FS CCC-C-467](#).

2.4.2 Impervious Sheets

[ASTM C 171](#), type optional, except that polyethylene film, if used, shall be white opaque.

2.4.3 Membrane-Forming Compounds

[ASTM C 309](#), Type 1-D, Class A or B.

2.5 EMBEDDED ITEMS

Embedded items shall be of the size and type indicated or as needed for the application.

2.6 FORM MATERIALS

2.6.1 Forms For Class B Finish

Forms for Class B finished surfaces shall be plywood panels conforming to [DOC PS 1](#), Grade B-B concrete form panels, Class I or II. Other form materials or liners may be used provided the smoothness and appearance of concrete produced will be equivalent to that produced by the plywood concrete form panels.

2.6.2 Forms For Class C Finish

Forms for Class C finished surfaces shall be shiplap lumber; plywood conforming to [DOC PS 1](#), Grade B-B concrete form panels, Class I or II; tempered concrete form hardboard conforming to [AHA A135.4](#); other approved concrete form material; or steel, except that steel lining on wood sheathing shall not be used.

2.6.3 Form Ties

Form ties shall be factory-fabricated metal ties, shall be of the removable or internal disconnecting or snap-off type, and shall be of a design that will not permit form deflection and will not spall concrete upon removal. Solid backing shall be provided for each tie. That portion of the tie remaining permanently in the concrete shall not project beyond the surface of the concrete and shall be at least 1 inch back from any concrete surface that will be exposed or dampproofed. Except where removable tie rods are used, ties shall not leave holes in the concrete surface less than 1/4 inch

nor more than 1 inch deep and not more than 1 inch in diameter. Removable tie rods shall not be more than 1-1/2 inches in diameter.

2.6.4 Form Releasing Agents

Form releasing agents shall be commercial formulations that will not bond with, stain or adversely affect concrete surfaces. Agents shall not impair subsequent treatment of concrete surfaces depending upon bond or adhesion nor impede the wetting of surfaces to be cured with water or curing compounds.

2.7 REINFORCING STEEL

Reinforcing steel shall be deformed bars conforming to [ASTM A 615](#) Grade 60, sizes as indicated.

2.8 WIRE TIES

Wire ties shall be 16-gauge or heavier black annealed steel wire.

2.9 SUPPORTS

Bar supports for formed surfaces shall be designed and fabricated in accordance with [CRSI DA4](#) and shall be precast concrete blocks. Precast concrete blocks shall be not less than 4 inches square when supporting reinforcement on ground. Precast concrete block shall have compressive strength equal to that of the surrounding concrete. Concrete supports used in concrete exposed to view shall have the same color and texture as the finish surface. For slabs on grade, supports shall be precast concrete blocks.

2.10 CONTRACTION-JOINT STRIPS

Contraction-joint strips shall be 1/8-inch thick tempered hardboard conforming to [AHA A135.4](#), Class 1.

2.11 EXPANSION-JOINT FILLER

Expansion-joint filler shall be premolded material conforming to [ASTM D 1751](#) or [ASTM D 1752](#). Unless otherwise indicated, filler material shall be 3/8-inch thick and of a width applicable for the joint formed.

2.12 JOINT SEALANT

Joint sealant shall be hot-poured type conforming to [FS SS-S 1401](#).

2.13 VAPOR BARRIER

Vapor barrier shall be polyethylene sheeting with a minimum thickness of 6 mils or other equivalent material having a vapor permeance rating not exceeding 0.5 perms as determined in accordance with [ASTM E 96](#).

2.14 WATER

Water shall be potable. Water for curing shall not contain any substance injurious to concrete, or which causes staining.

3 EXECUTION

3.1 PREPARATION OF SURFACES

Surfaces to receive concrete shall be clean and free from frost, ice, mud, and water. Conduit and other similar items shall be in place and clean of any deleterious substance.

3.1.1 Foundations

Earthwork shall be as specified in Section 02221 EXCAVATION, FILLING, AND BACKFILLING FOR BUILDINGS. Flowing water shall be diverted without washing over freshly deposited concrete. Rock foundations shall be cleaned by high velocity air-water jets, sandblasting, or other approved methods. Debris and loose, semi-detached or unsound fragments shall be removed. Rock surfaces shall be moist but without free water when concrete is placed. Semiporous subgrades for foundations and footings shall be damp when concrete is placed. Pervious subgrades shall be sealed by blending impervious material with the top 6 inches of the in-place pervious material or by covering with an impervious membrane.

3.1.2 Vapor Barrier

Subgrades for slabs in buildings shall be covered with a vapor barrier. Vapor barrier edges shall be lapped at least 4 inches and ends shall be lapped not less than 6 inches. Patches and lapped joints shall be sealed with pressure-sensitive adhesive or tape not less than 2 inches wide and compatible with the membrane.

3.1.3 Preparation of Previously Placed Concrete

Concrete surfaces to which other concrete is to be bonded shall be roughened in an approved manner that will expose sound aggregate uniformly without damaging the concrete. Laitance and loose particles shall be removed. Surfaces shall be moist but without free water when concrete is placed.

3.2 FORMWORK

Forms shall be mortar tight, properly aligned and adequately supported to produce concrete surfaces meeting the surface requirements specified and conforming to construction tolerance given in TABLE 1. Where forms for continuous surfaces are placed in successive units, care shall be taken to fit the forms over the completed surface so as to obtain accurate alignment of the surface and to prevent leakage of mortar. Forms shall not be reused if there is any evidence of surface wear and tear or defects which would impair the quality of the surface. Surfaces of forms to be reused shall be cleaned of mortar from previous concreting and of all other foreign material

before reuse. Form ties that are to be completely withdrawn shall be coated with a nonstaining bond breaker.

3.3 CHAMFERING

Except as otherwise shown, external corners that will be exposed shall be chamfered, beveled, or rounded by moldings placed in the forms.

3.4 COATING OF FORMS

Forms for exposed surfaces shall be coated with a form releasing agent before the form or reinforcement is placed in final position. The coating shall be used as recommended in the manufacturer's printed or written instructions. Forms for unexposed surfaces may be wet with water in lieu of coating immediately before placing concrete, except that in cold weather with probable freezing temperatures coating shall be mandatory. Surplus coating on reinforcing steel and construction joints shall be removed before placing concrete.

3.5 REMOVAL OF FORMS

Forms shall be removed in a manner that will prevent injury to the concrete and ensure the complete safety of the structure. Formwork for parts not supporting the weight of concrete may be removed when the concrete has attained sufficient strength to resist damage from the removal operation but not before at least 24 hours has elapsed since concrete placement. Supporting forms and shores shall not be removed until the structural units are strong enough to carry their own weight and any other construction or natural loads. In no case will supporting forms or shores be removed before the concrete strength has reached 70 percent of design strengths as determined by field cured cylinders or other approved methods. This strength shall be demonstrated by job-cured test specimens, and by a structural analysis considering the proposed loads in relation to these test strengths and the strength of forming and shoring system. The job-cured test specimens for form removal purposes shall be provided in numbers as directed and shall be in addition to those required for concrete quality control. The specimens shall be removed from molds at the age of 24 hours and shall receive, insofar as possible, the same curing and protection as the structures they represent.

TABLE 1

TOLERANCES FOR FORMED SURFACES

1. Variations from the plumb:	In any 10 feet of length ---- 1/4 inch Maximum for entire length --- 1 inch
2. Variation from the level or from the grades indicated on the drawings:	In any 10 feet of length ---- 1/4 inch In any 20 feet of length ---- 3/8 inch

a.	In slab soffits and ceilings, measured before removal of supporting shores	Maximum for entire length --- 3/4 inch
b.	In exposed lintels, sills, parapets, horizontal grooves, and other conspicuous lines	In any bay or in any 20 feet of length ----- 1/4 inch Maximum for entire length --- 1/2 inch
3.	Variation of the linear building lines from established position in plan	In any 20 feet ----- 1/2 inch Maximum ----- 1 inch
4.	Variation of distance between walls	1/4 inch per 10 feet of distance, but not more than 1/2 inch in any one bay, and not more than 1 inch total
variation		
5.	Variation in the sizes and locations of wall openings	Minus ----- 1/4 inch Plus ----- 1/2 inch
6.	Variation in the thickness of slabs and walls	Minus ----- 1/4 inch Plus ----- 1/2 inch
7.	Footings:	
a.	Variation of dimensions in plan	Minus ----- 1/2 inch Plus ----- 2 inches when formed or plus 3 inches when placed against unformed excavation
b.	Misplacement of eccentricity	2 percent of the footing width in the direction of misplacement but not more than ----- 2 inches
c.	Reduction in thickness	Minus ----- 5 percent of specified thickness

3.6 REINFORCEMENT

Reinforcement shall be fabricated to shapes and dimensions shown and shall conform to the requirements of **ACI 318**. Reinforcement shall be cold bent unless otherwise authorized. Bending may be accomplished in the field or at the mill. Bars shall not be bent after embedment in concrete. Safety caps shall be placed on all exposed ends of vertical concrete reinforcement bars that pose a danger to life safety.

3.6.1 Placement

Reinforcement shall be free from loose rust and scale, dirt, oil, or other deleterious coating that could reduce bond with the concrete.

Reinforcement shall be placed in accordance with [ACI 318](#) at locations shown plus or minus one bar diameter. Reinforcement shall not be continuous through expansion joints. Concrete coverage shall be as indicated or as required by [ACI 318](#). If bars are moved more than one bar diameter to avoid interference with other reinforcement or embedded items, the resulting arrangement of bars, including additional bars required to meet structural requirements, shall be approved before concrete is placed.

3.6.2 Splicing

Splices of reinforcement shall conform to [ACI 318](#) and shall be made only as required or indicated. Splicing shall be by lapping. Lapped bars shall be placed in contact and securely tied or spaced transversely apart to permit the embedment of the entire surface of each bar in concrete.

Lapped bars shall not be spaced farther apart than one-fifth the required length of lap or 6-inches.

3.7 INSTALLATION OF EMBEDDED ITEMS

Embedded items shall be free from oil, loose scale or rust, and paint.

Embedded items shall be installed at the locations indicated and required to serve the intended purpose. Voids in sleeves, slots and inserts shall be filled with readily removable material to prevent the entry of concrete.

3.8 BATCHING, MIXING AND TRANSPORTING CONCRETE

Ready-mixed concrete shall be batched, mixed and transported in accordance with [ASTM C 94](#), except as otherwise specified. Truck mixers, agitators, and nonagitating units shall comply with [NRMCA TMMB-1](#). Ready-mix plant equipment and facilities shall be certified in accordance with [NRMCA-01](#). Site-mixed concrete shall be mixed in accordance with [ACI 301](#). On-site plant shall conform to the [NRMCA CPMB-100](#).

3.8.1 Admixtures

Admixtures shall be batched within an accuracy of 3 percent. Where two or more admixtures are used in the same batch, they shall be batched separately and must be compatible. Retarding admixture shall be added within one minute after addition of water is complete or in the first quarter of the required mixing time, whichever is first. Superplasticizing admixtures shall be added at the project site, and the concrete with the admixture shall be mixed 4 to 5 minutes before placing. Concrete that shows evidence of total collapse or segregation caused by the use of admixture shall be removed from the site.

3.8.2 Control of Mixing Water

No water from the truck system or elsewhere shall be added after the initial introduction of mixing water for the batch except when on arrival at the jobsite, the slump of the concrete is less than that specified. Water

added to bring the slump within the specified range shall not change the total water in the concrete to a point that the approved water-cement ratio is exceeded. The drum shall be turned an additional 30 revolutions, or more, if necessary, until the added water is uniformly mixed into the concrete. Water shall not be added to the batch at any later time.

3.9 SAMPLING AND TESTING

Sampling and Testing is the responsibility of the Contractor and shall be performed by an approved testing agency.

3.9.1 Aggregates

Aggregates for normal weight concrete shall be sampled and tested in accordance with [ASTM C 33](#). Lightweight aggregate shall be sampled and tested in accordance with [ASTM C 330](#). Gradation tests shall be performed on the first day and every other day thereafter during concrete construction.

3.9.2 Sampling of Concrete

Samples of concrete for air, slump, unit weight, and strength tests shall be taken in accordance with [ASTM C 172](#).

3.9.2.1 Air Content

Test for air content shall be performed in accordance with [ASTM C 173](#) or [ASTM C 231](#). A minimum of 1 test per day shall be conducted.

3.9.2.2 Slump

At least 2 slump tests shall be made on randomly selected batches of each mixture of concrete during each day's concrete placement. Tests shall be performed in accordance with [ASTM C 143](#).

3.9.3 Evaluation and Acceptance of Concrete

3.9.3.1 Frequency of Testing

Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 150 cubic yards of concrete, nor less than once for each 5000 square feet of surface area for slabs or walls. If this sampling frequency results in less than 5 strength tests for a given class of concrete, tests shall be made from at least 5 randomly selected trucks or from each truck if fewer than 5 truck loads are used. Field cured specimens for determining form removal time or when a structure may be put in service shall be made in numbers directed to check the adequacy of curing and protection of concrete in the structure. The specimens shall be removed from the molds at the age of 24 hours and shall be cured and protected, insofar as practicable, in the same manner as that given to the portion of the structure the samples represent.

3.9.3.2 Testing Procedures

Cylinders and beams for acceptance tests shall be molded and cured in accordance with [ASTM C 31](#). Cylinders shall be tested in accordance with [ASTM C 39](#) and beams shall be tested in accordance with [ASTM C 78](#). A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days unless otherwise specified or approved.

3.9.3.3 Evaluation of Results

Concrete specified on the basis of compressive strength will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the specified strength and no individual strength test result falls below the required strength by more than 500 pounds per square inch. For flexural strength concrete, the strength level of the concrete will be considered satisfactory if the averages of all sets of five consecutive strength test results equal or exceed the required flexural strength, and not more than 20 percent of the strength test results fall below the required strength by more than 100 pounds per square inch.

3.9.4 Investigation of Low-Strength Test Results

When any strength test of standard-cured test cylinder falls below the specified strength requirement by more than 500 pounds per square inch, or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that load-carrying capacity of the structure is not jeopardized. Nondestructive testing in accordance with [ASTM C 597](#), [ASTM C 803](#) or [ASTM C 805](#) may be permitted by the Contracting Officer to determine the relative strengths at various locations in the structure as an aid in evaluating concrete strength in place or for selecting areas to be cored. Such tests, unless properly calibrated and correlated with other test data, shall not be used a basis for acceptance or rejection. When strength of concrete in place is considered potentially deficient, cores shall be obtained and tested in accordance with [ASTM C 42](#). At least three representative cores shall be taken from each member or area of concrete in place that is considered potentially deficient. The location of cores shall be determined by the Contracting Officer to least impair the strength of the structure. If the concrete in the structure will be dry under service conditions, the cores shall be air dried (temperature 60 to 80 degrees F, relative humidity less than 60 percent) for seven days before testing and shall be tested dry. If the concrete in the structure will be more than superficially wet under service conditions, the cores shall be tested after moisture conditioning in accordance with [ASTM C 42](#). Concrete in the area represented by the core testing will be considered adequate if the average strength of the cores is equal to or at least 85 percent of the specified strength requirement and if no single core is less than 75 percent of the specified strength requirement. If the core tests are inconclusive or impractical to obtain, or if structural analysis does not confirm the safety of the structure, load tests may be directed by the Contracting Officer in accordance with the requirements of [ACI 318](#). Concrete work evaluated by structural analysis or by results of a load test and found deficient shall be corrected in a manner satisfactory to the Contracting Officer. All investigations, testing, load tests, and correction of

deficiencies shall be performed, and approved by the Contracting Officer, at the expense of the Contractor.

3.10 CONVEYING CONCRETE

Concrete shall be conveyed from mixer to forms as rapidly as possible and within the time interval specified in paragraph "CONCRETE PLACEMENT" by methods which will prevent segregation or loss of ingredients.

3.10.1 Chutes

When concrete can be placed directly from a truck mixer or other transporting equipment, chutes attached to this equipment may be used. Separate chutes will not be permitted except when specifically approved.

3.10.2 Buckets

Bucket design shall be such that concrete of the required slump can be readily discharged. Bucket gates shall be essentially grout tight when closed. The bucket shall provide means for positive regulations of the amount and rate of deposit of concrete in each dumping position.

3.10.3 Belt Conveyors

Belt conveyors may be used when approved. Belt conveyors shall be designed for conveying concrete and shall be operated to assure a uniform flow of concrete to the final place of deposit without segregation or loss of mortar. Conveyors shall be provided with positive means for preventing segregation of the concrete at transfer points and point of placement.

3.10.4 Pumps

Concrete may be conveyed by positive displacement pumps when approved. The concrete shall be designed for pumping. Pump shall be the piston or squeeze pressure type. Pipeline shall be steel pipe or heavy duty flexible hose. Inside diameter of the pipe shall be at least three times the maximum size of the coarse aggregate. Distance to be pumped shall not exceed the limits recommended by the pump manufacturer. Concrete shall be supplied to the pump continuously. When pumping is completed, the concrete remaining in the pipeline shall be ejected without contaminating the concrete in place. After each use, the equipment shall be thoroughly cleaned. Flushing water shall be wasted outside the forms.

3.11 CONCRETE PLACEMENT

Mixed concrete which is transported in truck mixers or agitators or concrete which is truck mixed, shall be discharged within 1-1/2 hours or before the drum has revolved 300 revolutions, whichever comes first after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. These limitations may be waived by the Government if the concrete is of such slump after the 1-1/2 hour time or 300 revolution limit has been reached that it can be placed, without the addition of water to the batch. When the concrete temperature exceeds 85 degrees F, the time shall be reduced to 45 minutes. Concrete

shall be placed within 15 minutes after it has been discharged from the truck.

3.11.1 Placing Operation

Concrete shall be handled from mixer to forms in a continuous manner until the approved unit of operation is completed. Adequate scaffolding, ramps and walkways shall be provided so that personnel and equipment are not supported by in-place reinforcement. Placing will not be permitted when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing and curing. Concrete shall be deposited as close as possible to its final position in the forms, and there shall be no vertical drop greater than 8 feet except where suitable equipment is provided to prevent segregation and where specifically authorized. Depositing of the concrete shall be so regulated that it will be effectively consolidated in horizontal layers not more than 12 inches thick, except that all slabs shall be placed in a single layer. Concrete to receive other construction shall be screeded to the proper level to avoid excessive shimming or grouting.

3.11.2 Consolidation

Immediately after placing, each layer of concrete shall be consolidated by internal vibrators, except for Blast and Fragment Resistant Walls and slabs 4 inches or less. The vibrators shall at all times be adequate in effectiveness and number to properly consolidate the concrete; a spare vibrator shall be kept at the jobsite during all concrete placing operations. The vibrators shall have a frequency of not less than 8000 vibrations per minute, and the head diameter and amplitude shall be appropriate for the concrete mixture being placed. Vibrators shall be inserted vertically at uniform spacing over the area of placement. The distance between insertions shall be approximately 1-1/2 times the radius of action of the vibrator so that the area being vibrated will overlap the adjacent just-vibrated area by a few inches. The vibrator shall penetrate rapidly to the bottom of the layer and at least 6 inches into the preceding layer if there is such. Vibrator shall be held stationary until the concrete is consolidated and then withdrawn slowly. Concrete in Blast and Fragment Resistant Walls shall be consolidated by placing manual vibration bars on the outside of the walls or by tapping with a rubber mallet. The use of form vibrators must be specifically approved. Vibrators shall not be used to transport concrete within the forms. Slabs 4 inches and less in thickness shall be consolidated by properly designed vibrating screeds or other approved technique.

3.11.3 Cold Weather Requirements

Special protection measures, approved by the Contracting Officer, shall be used if freezing temperatures are anticipated before the expiration of the specified curing period. The ambient temperature of the air where concrete is to be placed and the temperature of surfaces to receive concrete shall be not less than 40 degrees F. The temperature of the concrete when placed shall be not less than 50 degrees F nor more than 75 degrees F. Heating of the mixing water or aggregates will be required to regulate the concrete placing temperature. Materials entering the mixer shall be free from ice,

snow, or frozen lumps. Salt, chemicals or other materials shall not be incorporated in the concrete to prevent freezing. Upon written approval, chemical admixture conforming to ASTM C 494 Type C or E may be used.

3.11.4 Warm Weather Requirements

The temperature of the concrete placed during warm weather shall not exceed 85 degrees F except where an approved retarder is used. The mixing water and/or aggregates shall be cooled, if necessary, to maintain a satisfactory placing temperature. In no case shall the placing temperature exceed 95 degrees F.

3.12 CONSTRUCTION JOINTS

Construction joints shall be located as indicated or approved. Where concrete work is interrupted by weather, end of work shift or other similar type of delay, location and type of construction joint shall be subject to approval of the Contracting Officer except horizontal construction joints shall not be used in Blast and Fragment Resistant walls. Unless otherwise indicated and except for slabs on grade, reinforcing steel shall extend through construction joints. Construction joints in slabs on grade shall be keyed or doweled as shown. Concrete walls shall be in place at least 2 hours, or until the concrete is no longer plastic, before placing concrete for slabs thereon. In walls having door openings, lifts shall terminate at the top and bottom of the opening. Other lifts shall terminate at such levels as to conform to structural requirements or architectural details. Where horizontal construction joints are required, a strip of 1-inch square-edge lumber, bevelled and oiled to facilitate removal, shall be tacked to the inside of the forms at the construction joint. Concrete shall be placed to a point 1 inch above the underside of the strip. The strip shall be removed 1 hour after the concrete has been placed, and any irregularities in the joint line shall be leveled off with a wood float, and all laitance shall be removed. Prior to placing additional concrete, horizontal construction joints shall be prepared as specified in paragraph "PREPARATIONS OF SURFACES."

3.13 FINISHING CONCRETE

3.13.1 Formed Surfaces

3.13.1.1 Repair of Surface Defects

Surface defects shall be repaired within 24 hours after the removal of forms. Honeycombed and other defective areas shall be cut back to solid concrete or to a depth of not less than 1 inch, whichever is greater. Edges shall be cut perpendicular to the surface of the concrete. The prepared areas shall be dampened and brush-coated with neat cement grout. The repair shall be made using mortar consisting of not more than 1 part cement to 2-1/2 parts sand. The mixed mortar shall be allowed to stand to stiffen (approximately 45 minutes), during which time the mortar shall be intermittently remixed without the addition of water. After the mortar has attained the stiffest consistency that will permit placing, the patching mix shall be thoroughly tamped into place by means approved by the Contracting Officer and finished slightly higher than the surrounding surface. For

Class B finished surfaces the cement used in the patching mortar shall be a blend of job cement and white cement proportioned to produce a finished repair surface matching, after curing, the color of adjacent surfaces. Holes left after the removal of form ties shall be cleaned and filled with patching mortar. Holes left by the removal of tie rods shall be reamed and filled by dry-packing. Repaired surfaces shall be cured as required for adjacent surfaces. The temperature of concrete, mortar patching material, and ambient air shall be above 50 degrees F while making repairs and during the curing period. Concrete with defects which affect the strength of the member or with excessive honeycombs will be rejected, or the defects shall be corrected as directed.

3.13.1.2 Class B Finish

Class B finish shall be provided for permanently exposed surfaces. All fins shall be removed. Concrete surface shall be smooth with a texture at least equal to that obtained through the use of Grade B-B plywood forms.

3.13.1.3 Class C Finish

Class C finish shall be provided for surfaces that are not permanently exposed. All fins shall be removed. Concrete surfaces shall be relatively smooth with a texture imparted by the forms used.

3.13.2 Unformed Surfaces

In cold weather, the air temperature in areas where concrete is being finished shall not be less than 50 degrees F. In hot windy weather when the rate of evaporation of surface moisture, as determined by methodology presented in [ACI 305R](#), may reasonably be expected to exceed 0.2 pounds per square foot per hour; coverings, windbreaks, or fog sprays shall be provided as necessary to prevent premature setting and drying of the surface. The dusting of surfaces with dry materials or the addition of water during finishing will not be permitted. Finished surfaces shall be plane, with no deviation greater than 1/8 inch when tested with a 10-foot straightedge. Surfaces shall be pitched as indicated.

3.13.2.1 Rough-Slab Finish

Slabs shall be screeded with straightedges immediately after consolidation to bring the surface to the required finish level with no coarse aggregate visible.

3.13.2.2 Float Finish

Floor and roof slabs shall be given a float finish. Screeding shall be followed immediately by darbying or bull floating before bleeding water is present, to bring the surface to a true, even plane. After the concrete has stiffened to permit the operation and the water sheen has disappeared, it shall be wood floated.

3.13.2.3 Trowel Finish

Slabs inside the magazine shall be given a trowel finish immediately following floating. Surfaces shall be trowelled to produce smooth, dense slabs free from blemishes including trowel marks. In lieu of hand finishing, an approved power finishing machine may be used in accordance with the directions of the machine manufacturer. A final hard steel troweling shall be done by hand.

3.13.2.4 Broom Finish

After floating, exterior slabs on grade shall be lightly trowelled, and then broomed with a fiber-bristle brush in a direction transverse to that of the main traffic.

3.14 CURING AND PROTECTION

3.14.1 General

All concrete shall be cured by an approved method for the period of time given below:

Concrete with Type III cement	3 days
Concrete with Type I or Type II cement	7 days
Concrete with Type I or Type II cement blended with pozzolan	7 days

Immediately after placement, concrete shall be protected from premature drying extremes in temperatures, rapid temperature change, mechanical injury and injury from rain and flowing water. Air and forms in contact with concrete shall be maintained at a temperature above 50 degrees F for the first 3 days and at a temperature above 32 degrees F for the remainder of the specified curing period. Exhaust fumes from combustion heating units shall be vented to the outside of the enclosure and heaters and ducts shall be placed and directed so as not to cause areas of overheating and drying of concrete surfaces or to create fire hazards. All materials and equipment needed for adequate curing and protection shall be available and at the site prior to placing concrete. No fire or excessive heat shall be permitted near or in direct contact with the concrete at any time. Curing shall be accomplished by any of the following methods, or combination thereof, as approved.

3.14.2 Moist Curing

Concrete to be moist-cured shall be maintained continuously wet for the entire curing period. If water or curing materials used stains or discolors concrete surfaces which are to be permanently exposed, the concrete surfaces shall be cleaned. When wooden forms are left in place during curing, they shall be kept wet at all times. If the forms are removed before the end of the curing period, curing shall be carried out as on unformed surfaces, using suitable materials. Horizontal surfaces shall be cured by ponding, by covering with a 2-inch minimum thickness of continuously saturated sand, or by covering with waterproof paper, polyethylene sheet, polyethylene-coated burlap or saturated burlap.

3.14.3 Membrane Curing

Membrane curing shall not be used on surfaces that are to receive any subsequent treatment depending on adhesion or bonding to the concrete. The curing compound selected shall be compatible with any subsequent paint, roofing, waterproofing or flooring specified. Membrane curing compound shall not be used on surfaces that are maintained at curing temperatures with free steam. Curing compound shall be applied to formed surfaces immediately after the forms are removed and prior to any patching or other surface treatment except the cleaning of loose sand, mortar, and debris from the surface. Surfaces shall be thoroughly moistened with water and the curing compound shall be applied to slab surfaces as soon as the bleeding water has disappeared, with the tops of joints being temporarily sealed to prevent entry of the compound and to prevent moisture loss during the curing period. Compound shall be applied in a one-coat continuous operation by mechanical spraying equipment, at a uniform coverage in accordance with the manufacturer's printed instructions. Concrete surfaces which have been subjected to rainfall within 3 hours after curing compound has been applied shall be resprayed by the method and at the coverage specified. On surfaces permanently exposed to view, the surface shall be shaded from direct rays of the sun for the duration of the curing period. Surfaces coated with curing compound shall be kept free of foot and vehicular traffic, and from other sources of abrasion and contamination during the curing period.