NATURAL RESOURCES CONSERVATION SERVICE
DESIGN AND CONSTRUCTION SPECIFICATION

CONCRETE

SCOPE

This specification consists of the design and construction requirements for concrete structures for Conservation Operations (CO-01) practices. The term "Engineer", used throughout this document, will refer to the NRCS staff person or his/her representative that has construction responsibility for a given construction project. The Engineer may be a NRCS engineer, ODNR/SWCD engineer, NRCS technician, or a licensed professional engineer that supplied the design to the landowner.

DESIGN REQUIREMENTS

1. DESIGN OF THE CONCRETE MIX

The contractor shall be responsible for the design of the concrete mix and for providing a letter certifying that the concrete materials and mix proportions (including admixtures if used) will provide the required compressive strength and include evidence satisfactory to the Engineer that the materials and proportions (the "job mix") will produce concrete conforming to this specification. After a job mix has been approved, neither the source, character, or grading of the aggregates nor the type or brand of cement or admixture shall be changed without prior notice to the Engineer. The letter certifying the materials and job mix shall be provided to the landowner with a copy to the Engineer at the pre-construction meeting.

The proportions of the aggregates shall be such as to produce a concrete mixture that works readily into the corners and angles of the forms and around reinforcement when consolidated but will not segregate or exude free water during consolidation. The Maximum Size Aggregate (MSA) shall be 1.5 inches with a Nominal Maximum Size Aggregate (NMSA) of 1 inch. A #57 aggregate will meet these requirements.

The maximum water to cement ratio (w/c) shall be 0.50 unless otherwise specified. The concrete mix shall have a 28-day compressive strength of 4,000 psi or greater. The minimum cement content shall be 6 bags (564 lbs.) per cubic yard. Water used in mixing and curing concrete shall be clean and free from injurious amounts of oil, salt, acid, alkali, organic matter, or other deleterious substances. Wash water shall not be used as part of the mixing water for succeeding batches.

The following mineral admixtures may be used as partial substitutions for Portland cement:

- Fly ash may be used in an amount not greater than 25 percent by weight of the total required cement in the concrete mix.
- Ground granulated blast furnace slag (GGBFS) may be used in amounts between 25 to 70 percent by weight of the total required cement in the concrete mix.
- Fly ash or GGBFS shall not be used in mixes designed or intended to obtain high early strength.

- The weight of the cement and the combined weight of the cement and fly ash or slag shall be within plus or minus 1 percent of the required weight of the cementitious material.
- Concrete mixes containing fly ash or GGBFS can only be used between April 1 and October 15.

Entrained air shall be used in all concrete that will be exposed to freezing and thawing. The air content by volume shall be 4% to 8% of the volume of the concrete. Air entraining admixtures shall conform to the requirements of ASTM C260.

Unless otherwise specified, the slump shall be within the range of 3 inches minimum to 5 inches (maximum).

Chemical admixtures shall conform to the requirements of ASTM C494 and be of the following types:

- Type A- Water-reducing admixture
- Type B- Retarding admixture
- Type C- Accelerating admixture
- Type D- Water-reducing and retarding admixture
- Type E- Water-reducing and accelerating admixture
- Type F- Water-reducing, high range admixture
- Type G- Water-reducing, high range, and retarding admixture

Superplasticizers (ASTM C494 Types F and G) may be used to increase workability and reduce the water content required to produce a concrete mix within the slump range shown above. The use of superplasticizers will be approved by the Engineer at the pre-construction meeting. Superplasticizers shall be used according to manufacturer's recommendations. The maximum slump before adding superplasticizers shall be within the range of 3 to 5 inches. The maximum slump after adding superplasticizer and prior to placement of the concrete shall be 7 ½ inches.

Fiber-Reinforced Concrete

The addition of synthetic fibers to concrete helps to reduce the bleeding process, reduce segregation of the concrete mix, and helps to control cracking due to plastic shrinkage and to drying shrinkage during the first few hours of curing.

Micro-synthetic fibers or macro-synthetic fibers may be added to the concrete mix. The type of synthetic fibers shall be polypropylene. Micro-synthetic fibers are generally added at low dosage volumes ranging from 0.03% to 0.2% by volume of concrete (0.5 to 3.0 pounds per cubic yard). Macro-synthetic fibers are generally added at dosages of 3.0 to 20 pounds per cubic yard. The dosage rates used should follow the manufacturer's recommendation for the product used.

Synthetic fibers shall not be used as a substitute for steel reinforcement.

2. MATERIAL SPECIFICATIONS

All materials used in concrete construction shall meet the applicable ASTM standards and/or ACI specifications.

3. CONCRETE SLABS

The design of concrete slabs shall take into consideration the required performance and the critical applied loads. Concrete slabs may be used as floors in manure storage structures (excluding those listed in Design Requirements, Sec. 4 "Concrete Manure Storage Tanks"), as heavy use pads, scrape alleys, feed pads, and concrete grade stabilization structures. The in situ subgrade material must be evaluated as to the suitability and denseness. A minimum 4-inch thick layer of AASHTO M43 #57 or #67 crushed gravel or limestone is required under all concrete slabs. Where the in situ subgrade is uniform and dense, a Type S-1 concrete slab is acceptable. A Type S-2 concrete slab shall be used where the in situ subgrade material is non-uniform or has variable density and it is not economical or feasible to improve the subgrade. The in situ subgrade thickness in question is generally 12 inches but could be more depending on the soil profile. A Type S-3 concrete slab shall be used when the contraction (control) joint spacing will be more than 15 feet, when no contraction (control) joints are desired, when reduced seepage is required, or when a watertight slab is required.

Type S-1 Concrete Slab

The Type S-1 slab may be used where the subgrade is uniform and dense. This slab is considered to be manure tight. Vehicles of the following types may be used on this slab (maximum 12 ton Gross Vehicle Weight):

- Light (small) Farm Tractor
- Light (small) Tractor Loader/Backhoe
- Skid Steer
- Light (small) Dump Truck
- Standard pull-type rear-discharge Manure Spreader

Design Requirements:

a. The concrete strength shall be 4,000 pounds per square inch (psi) or greater.

b. The slab thickness shall be 5 inches.

c. Steel reinforcement is not required but may be used if desired. If reinforcement bars are used, the slab thickness shall be increased in an amount needed to provide the required clear covers on the bars (see Construction Requirements, Sec. 5, "Form and Steel Placement", and the list below). Reinforcing bars, if used, shall not extend across contraction (control) joints.

   - #3 Bars 5.25" min. slab thickness
   - #4 Bars 5.50" min. slab thickness
   - #5 Bars 5.75" min. slab thickness
   - #6 Bars 6.50" min. slab thickness
   - #7 Bars 6.75" min. slab thickness
   - #8 Bars 7.00" min. slab thickness

d. Contraction (control) joints shall be used and be placed at a maximum spacing of 15 feet in both directions. The joints shall be continuous and not staggered or offset.

e. An aspect ratio (length to width) of 1 to 1 is preferred for slab panels, with a maximum allowed ratio of 1.5 to 1. L-shaped and T-shaped panels shall be avoided.

f. Expansion joints are not required.

g. Isolation joints are required for complete freedom of vertical movement between the slab and any adjoining new or existing structures such as a wall, column, footing, or another slab.

Type S-2 Concrete Slab

The Type S-2 slab shall be used in lieu of the Type S-1 slab when the subgrade is not uniform or it has a variable density and it would not be feasible to improve it. This slab is considered to be manure tight. This slab shall also be used if the slab will be subjected to vehicular traffic with vehicles larger than those listed above for the S-1 Concrete Slab.

Design Requirements:

a. The concrete strength shall be 4,000 pounds per square inch (psi) or greater.

b. The slab thickness shall be 6 inches.

c. Steel reinforcement is required and shall meet the following requirements:

   1) Grade 60 (f_y = 60,000 psi)
   2) #4 bar (minimum size)
   3) 18 in. minimum and 36 in. maximum bar spacing center-to-center in both orthogonal directions
   4) Reinforcement shall be located in the top portion of the slab so that the top reinforcement bars have 2 inches of clear concrete cover.

d. Steel reinforcement shall extend across contraction (control) joints if dowel bars are not used.

   1) For bar spacing in the range of 18" to less than 36"- only every other bar shall extend across a joint
   2) For 36 in. bar spacing- all bars shall extend across a joint

e. If steel reinforcement is not extended across a contraction (control) joint, steel dowel bars shall be used meeting the following requirements:

   1) Dowels shall be round, smooth, and lightly oiled
   2) ¾ inch diameter
   3) 13 inches long for a slab thickness of 6 inches
   4) Placed in the center of the slab thickness at 12 inches center to center

f. Contraction (control) joints shall be used and be placed at a maximum spacing of 18 feet in both directions. The joints shall be continuous and not staggered or offset.

g. An aspect ratio (length to width) of 1 to 1 is preferred for slab panels, with a maximum allowed ratio of 1.5 to 1. L-shaped and T-shaped panels shall be avoided.

h. Expansion joints are not required.

i. Isolation joints are required for complete freedom of vertical movement between the slab and any adjoining new or existing structures such as a wall, column, footing, or another slab.

Type S-3 Concrete Slabs:

The Type S-3 slab shall be used when a watertight slab is required or when reduced seepage is required. This slab may also be used as the floor of a manure storage tank (Design Requirements, Sec. 4, "Concrete Manure Storage Tanks").

Design Requirements:

a. The concrete strength shall be 4,000 pounds per square inch (psi) or greater.

b. The slab thickness shall be as shown in Table 1 below.

c. Steel reinforcement shall be located in the top portion of the slab so that the top steel bars have a minimum of 1.5 inches of clear concrete cover for #4 and #5 bars and a minimum of 2 inches of clear concrete cover for #6 and larger bars. No other tolerance is permitted. The reinforcement in the longest direction shall be placed nearest the top of the concrete slab.

d. Steel reinforcement shall not extend across contraction (control) joints.

e. Vertical displacement at contraction (control) joints shall be controlled by installing smooth lightly oiled steel dowels meeting the following requirements:

    a. Diameter and Length of Dowel
        i. Slab thickness of less than 7 inches- ¾" x 13"
        ii. Slab thickness of 7.0 inches- 1" x 16"
    b. Placed in the center of the slab thickness at 12 inches center to center

f. Isolation joints are required for complete freedom of vertical movement between the slab and any adjoining new or existing structures such as a wall, column, footing, or another slab.

g. Expansion joints are not required.

h. Required steel reinforcement shall be based upon the contraction (control) joint spacing selected from Table 1 (below).

    For slabs that have joint spacings greater than 40 feet and/or for slabs without contraction or isolation joints (movement joints), use the steel requirements shown in column one of Table 1 for 40 foot and greater (40 >) joint spacings.

TABLE 1 [1/]
Type S-3 Slab Requirements

Contraction Joint Spacing (ft)	Steel Size	Steel Spacing (in c-c)	Slab Thickness (in)	Steel Lap Splice (in)
20	#4	12	5.5	16
30	#4	9	5.5	16
40	#4	7	5.5	16
20	#4	11	6.0	16
20	#5	17	6.0	19
30	#4	8	6.0	16
30	#5	12	6.0	19
40 >	#4	6	6.0	16
40 >	#5	10	6.0	19
20	#4	10	6.5	16
20	#5	15	6.5	19
20	#6	18	6.5	23
30	#4	7	6.5	16
30	#5	11	6.5	19
30	#6	16	6.5	23
40 >	#4	6	6.5	16
40 >	#5	9	6.5	19
40 >	#6	13	6.5	23
20	#4	9	7.0	16
20	#5	14	7.0	19
20	#6	18	7.0	23
30	#4	7	7.0	16
30	#5	11	7.0	19
30	#6	15	7.0	23
30	#7	18	7.0	33
40 >	#4	5	7.0	16
40 >	#5	8	7.0	19
40 >	#6	12	7.0	23
40 >	#7	17	7.0	33
40 >	#8	18	7.0	37

1/ Table values adapted from ACI 350 Sec. 7.12

4. CONCRETE MANURE STORAGE TANKS

Several standard drawings exist for different types of concrete manure storage tanks, both above-ground and below-ground. Many of these drawings can be found on the Ohio NRCS web site under Technical Resources/Engineering/CADD Resources/Standard Drawings. A complete list of approved designs is contained in the National Engineering Manual, Part 536 "Structural Engineering", Amendment OH3 (current version).

The design of reinforced concrete walls and floors for manure storage tanks shall meet the requirements as stated in Ohio Practice Standard 313 "Waste Storage Facility". Two of the references in that practice standard, namely Midwest Plan Service 36 (MWPS-36) "Rectangular Concrete Manure Storages" and MWPS Technical Resource 9 (TR-9) "Circular Concrete Manure Tanks", contain their own design procedures that shall be followed. The other reference listed, namely the American Concrete Institute (ACI) "Building Code Requirements for Structural Concrete" [ACI 318], shall be used for all other designs.

Design Requirements for Walls:

The following requirements shall be used when a pre-approved standard design/drawing is <u>not</u> being used or if neither of the MWPS-36 or MWPS TR-9 references is being used.

a. ACI 318 Chapter 10 "Flexure and Axial Loads" shall be used for tensile (principal) reinforcement design in flexure.
b. For walls subjected to axial loads, ACI 318 Chapter 14 "Wall" shall be used in addition to Chapter 10.
c. Minimum concrete compressive strength (f'_c) of 4,000 psi
d. Minimum wall thickness shall be 8 inches for manure storage structures and 6 inches for all other retaining walls.
e. Minimum steel reinforcement yield strength (f'_y) of 60,000 psi (Grade 60)
f. Minimum area of steel reinforcement provided shall be determined by the procedures in ACI 318 Chapter 10 and shall not be less than 0.20 in^2 (#4@12") for the vertical (principal) steel. Minimum horizontal steel shall be as required by ACI 318 Chapter 7 "Details of Reinforcement" for shrinkage and temperature steel.
g. Spacing of steel reinforcement shall be as computed by design but not greater than 18".
h. Minimum steel reinforcement splice lengths:

#4 Bar- 16 in.	#7 Bar- 33 in.
#5 Bar- 19 in.	#8 Bar- 37 in.
#6 Bar- 23 in.	

i. Minimum concrete cover on steel reinforcement:
    a. 3 in. for concrete cast against and permanently exposed to earth surfaces (sides or base) and/or granular base surfaces
    b. 2 in. for concrete placed in forms
    c. Concrete with exposed surfaces
        1) 1.5 in. for #5 reinforcing bars and smaller
        2) 2.0 in. for #6 reinforcing bars and larger
j. Spacing of contraction (control) joints in the walls may be matched to the contraction joint spacings of the slab but shall not exceed 30 feet.
k. Steel reinforcement shall not extend across contraction (control) joints.

l. When leakage cannot be allowed, the walls shall be designed to be watertight. The contraction joints shall be caulked on the liquid (manure) side with an elastomeric joint sealant with a foam backer rod. A flexible waterstop shall also be used. Refer to Construction Requirements, Sec. 12 "Contraction (Control) Joints" and Sec. 13 "Waterstops" for additional information.

5. CONCRETE FOR AGRICHEMICAL HANDLING FACILITIES

The design of reinforced concrete walls and floors for concrete secondary containment facilities shall meet the requirements as stated in Ohio Practice Standard 309 "Agrichemical Handling Facility". Several non-NRCS designed standard drawings are available and a complete list of those approved designs/drawings is contained in the National Engineering Manual, Part 536 "Structural Engineering", Amendment OH3 (current version).

Design Requirements:

a. Wall Height
   i. Minimum- 1.0 ft.
   ii. Maximum- 3.0 ft.
b. Wall thickness shall be 8 inches.
c. Concrete floor slabs and walls/curbing shall be watertight.
d. The chemical loading/mixing pad shall be designed for equipment wheel loads.
e. Structural design of the walls must account for the hydrostatic loading of the material to be contained.
f. American Concrete Institute (ACI) "Building Code Requirements for Structural Concrete" [ACI 318] shall be used for all designs.
g. Maximum water cement ratio (w/c) shall be 0.45.
h. Minimum concrete compressive strength (f'_c) of 4,000 psi
i. Minimum steel reinforcement yield strength (f'_y) of 60,000 psi (Grade 60)
j. The mixing pad slab shall be a minimum of 6 inches thick.
k. A mixing pad slab placed as a landowner preference in lieu of an aggregate pad shall meet the requirements of either the Type S-1 slab or the Type S-2 slab as described in the Design Requirements, Sec. 3, "Concrete Slabs".
l. Maximum spacing of contraction (control) joints for walls and floor slabs shall be 30 feet.
m. The walls shall be designed to be watertight. The contraction joints shall be caulked on <u>both</u> sides of the wall with an elastomeric joint sealant with a foam backer rod. A flexible waterstop shall also be used.
n. Contraction (control) joints in floor slabs may be sawn or hand tooled and shall be filled with an elastomeric joint sealant with a foam backer rod.
o. Locate floor and wall contraction (control) joints in line with each other.
p. Reinforcing steel shall not extend across contraction (control) joints.
q. Floor steel design shall be taken from Table 21 in MWPS-37 "Designing Facilities for Pesticide and Fertilizer Containment". The minimum floor thickness shall be 9 inches.
r. Wall and footing steel shall be as shown in MWPS-37, Figures 71-76.

CONSTRUCTION REQUIREMENTS

1. CONSTRUCTION DRAWING INFORMATION

The following items are to be included on the construction drawings as a minimum:

Concrete

- Minimum cement content shall be 6 bags/cu.yd.
- Maximum water/cement ratio shall be 0.50
- 28-day compressive strength of 4,000 psi or greater
- All concrete to be air entrained with an air content of 4%-8% of the concrete volume
- Slump shall be in the range of 3" to 5"

Reinforcing Steel

- Minimum steel clearances (in notes or labeled on a detail view, or a combination of both)
- Steel Grade 60
- Minimum lap splices for each size of bar used (in notes, tables, or labeled on detail views, or any combination of these)
- Sizes and spacings of bars labeled on detail views (lengths of bars as necessary)
- Joint information for types specified:
    - Contraction Joints- spacing and location
    - Isolation Joints- location; size; type of joint filler
    - Dowels- size; length; spacing

2. REINFORCING STEEL

Reinforcing steel shall be Grade 60 deformed bars manufactured specifically for use as concrete reinforcement. Reinforcing steel shall be free from loose rust, concrete, oil, grease, paint, or other deleterious coatings.

Reinforcing steel shall be cold-bent if bends are required.

Welding of reinforcing steel is not permitted.

Synthetic fibers shall not be used a substitute for steel reinforcement. Refer to Design Requirements, Sec. 1, "Design of the Concrete Mix", for guidance on the use of synthetic fibers as an additive.

Welded wire reinforcement shall not be used as a substitute for steel reinforcement.

3. FORMS

Forms shall be of wood, plywood, steel, or other approved materials and shall be mortar tight. The forms and associated falsework shall be substantial and unyielding and shall be constructed so the finished concrete will conform to the specified dimensions and contours. Formed surfaces shall be smooth and free from holes, dents, sags, or other irregularities.

4. PREPARATION OF SUBGRADE

The subgrade shall be prepared for the type of footer or concrete slab that is to be installed.

The uniformity can be checked with the use of a tile probe. If the subgrade is found to have a soft spot, it should be excavated and backfilled with granular material.

A 4-inch thick layer of AASHTO M43 #57 or #67 crushed gravel or limestone is required under all concrete slabs.

Placement of concrete on mud, dried earth, uncompacted fill, or frozen subgrade will not be permitted.

Unless required or allowed to be used, do not use earth cuts as forms for vertical or sloping surfaces. When allowed, the original construction drawings shall clearly show the locations where earth cuts may be used as forms.

The subgrade shall be inspected and approved by the Engineer prior to the placement of forms, steel (if required), and concrete.

5. FORM AND STEEL PLACEMENT

Forms shall be coated with a non-staining form release agent before being set into place.

Form ties shall have a minimum 2-inch clearance from reinforcing steel.

Items to be embedded in the concrete shall be positioned accurately and anchored firmly.

Weepholes in walls or slabs shall be formed with non-ferrous materials.

Reinforcement shall be accurately placed and secured in position in a manner that will prevent its displacement during the placement of concrete. Reinforcing steel shall be supported by precast concrete bricks or manufactured chairs. Except for dowel rods, placing steel reinforcement into concrete already in place will not be permitted.

Splices of reinforcing bars shall be made only at the locations shown on the drawings unless otherwise approved by the Engineer.

Unless otherwise indicated on the drawings, minimum splice lengths of reinforcing bars shall be as shown in the following list. If two different size bars are to be spliced, the splice length shall be determined by the larger bar to be spliced.

- #4 Bar 16 in.
- #5 Bar 19 in.
- #6 Bar 23 in.
- #7 Bar 33 in.
- #8 Bar 37 in.

The concrete cover on reinforcing bars shall not be less than:

- 3 in. for concrete cast against and permanently exposed to earth surfaces (sides or base) and/or granular base surfaces
- 2 in. for concrete placed in forms
- Concrete with exposed surfaces
    - 1.5 in. for #5 reinforcing bars and smaller
    - 2.0 in. for #6 reinforcing bars and larger
- Placement Tolerances for concrete cover (measured perpendicular to concrete surface)
    - –3/8 in. for member thickness 12 in. or less
    - –1/2 in. for member thickness greater than 12 in.
    - A (-) tolerance decreases the amount to which it applies
- Vertical deviation for slab reinforcement
    - ±3/4 in. (a (+) deviation increases and a (-) deviation decreases the amounts to which they apply)

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Maximum variation from the indicated bar spacing is 1/12 of the indicated bar spacing but the required number of bars shall not be reduced.

Steel tying and form construction adjacent to concrete in place shall not be started until the concrete has cured at least 12 hours. Before new concrete is deposited on or against concrete that has hardened, the forms shall be retightened.

6. CONCRETE MIXERS AND MIXING

Concrete may be furnished by ready-mix methods, by volumetric batching and continuous mixing at the site, or by batch mixing at the site. Ready-mixed concrete shall be mixed, transported, and placed in a freshly mixed and unhardened state and meet the requirements as described in ASTM C94 “Standard Specification for Ready-Mixed Concrete”. The contractor shall furnish a batch ticket (refer to Construction Requirements, Sec. 7, “Batch Ticket Information”) upon the arrival of a load to the construction site.

No mixing water in excess of the amount called for by the job mix shall be added to the concrete during mixing or hauling or after arrival at the delivery point. Withholding some of the water until the concrete arrives on the job and then adding the remaining water and turning the mixer 30 revolutions at mixing speed is allowed to overcome transporting conditions. Water to compensate for up to a 1-inch loss in slump may be added one time prior to discharging any of the load, not to exceed the design maximum water cement (w/c) ratio.

7. BATCH TICKET INFORMATION

A delivery ticket for each batch of concrete shall be provided to the contractor by the concrete supplier prior to the concrete being unloaded at the work site. Upon completion of the placement of all concrete, copies of all batch tickets shall be provided to the landowner.

The following minimum information shall be included on each Batch Ticket:

a. Name of purchaser and the work location (address)
b. Name of the concrete supplier (ready-mix batch plant)
c. Batch plant location
d. Ticket serial number
e. Design mix designation
f. Delivery date
g. Time the concrete was loaded onto the truck at the plant
h. Time the concrete arrived at the site
i. Amount of concrete delivered to the site (batch size)
j. Time the concrete was unloaded at the site
k. Actual weight of Cement (also Fly Ash and/or other mineral admixtures if used)
l. Actual weight of Aggregates (Coarse and Fine)
m. Actual weight of Water added at the plant
n. Actual volume of Admixture(s) – Type(s) and Quantity(s) added at the plant (if used)
o. Actual weight and type of fiber reinforcement (if used)
p. Water/Cement ratio of batch leaving the plant
q. Quantity of water added at the site by the receiver of the concrete
r. Admixture(s) added at the site – type(s), quantity(s), and time admixture(s) added to the concrete

The contractor shall be responsible for any changes to the certified design mix.

8. CONCRETE DELIVERY

Concrete shall be delivered to the site and discharged into the forms within 90 minutes after the introduction of the cement to the aggregates. In hot weather or under conditions contributing to quick stiffening of the concrete or when the temperature of the concrete is 85° F or above, the time between the introduction of the cement to the aggregates and discharge shall not exceed 45 minutes.

Concrete shall be conveyed from the mixer to the forms as rapidly as practicable by methods that will prevent segregation of the aggregates or the loss of mortar.

9. CONCRETE PLACEMENT

Reasonable notice shall be given to the Engineer for the required inspection and approval prior to the time of concrete placement. Such notice shall be far enough in advance to give adequate time to inspect the subgrade, forms, steel reinforcement, and other preparations for compliance with the specifications before the concrete is delivered to the site.

All subgrade surfaces shall be firm and damp prior to placement of concrete.

Prior to the placement of concrete, the forms and reinforcement steel (if required) shall be inspected and approved by the Engineer. The forms shall be free of chips, sawdust, debris, water, ice, snow, extraneous oil, mortar, or other harmful substances or coatings. Any oil on the reinforcing steel or other surfaces required to be bonded to the concrete shall be removed.

The concrete shall be deposited as closely as possible to its final position in the forms and shall be worked into the corners and angles of the forms and around all reinforcement and embedded items in a manner to prevent segregation of aggregates or excessive laitance. The depositing of concrete in either forms or slabs shall be regulated so that the concrete can be consolidated by the use of a vibrator with a minimum of lateral movement.

Slab concrete shall be placed to the design thickness in one continuous layer. Formed concrete shall be placed in horizontal layers not more than 20 inches thick. Hoppers and chutes, concrete pumps, pipes, or "elephant trunks" shall be used when the vertical drop is in excess of 5 feet to prevent splashing of mortar on the forms and reinforcing steel and to prevent segregation.

Slump testing shall meet the requirements of ASTM C143 "Slump of Hydraulic-Cement Concrete" to ensure the quality as specified in Design Requirements, Sec. 1, "Design of the Concrete Mix". The contractor and/or Engineer shall perform an adequate number of slump tests to ensure that the slump for all concrete delivered to the work site is within the ranges specified in Section 1. Samples used for slump testing shall be obtained from the concrete as it is delivered from the mixer as specified in ASTM C172 "Sampling Freshly Mixed Concrete". If concrete is conveyed to the placement location by pumping or conveyor belts, the samples shall be collected at the discharge end.

The minimum number of Slump Tests to perform:

1. on the first load delivered to the site each day
2. on one other load during each work day
3. before the addition of superplasticizer and after it is mixed into the load

The contractor shall keep a record of all Slump Tests performed. At a minimum, the record shall show:

1. date(s) and time(s) of delivery of tested batches and batch number
2. name of person performing the test(s)
3. all slump measurements taken

This record will become part of the as-built documentation to be included with the as-built drawings.

Superplasticizer may be used with the approval of the Engineer (refer to Design Requirements, Sec. 1, "Design of the Concrete Mix"). When superplasticizer is added to the load at the site, a slump test shall be taken before the addition of the superplasticizer and after the superplasticizer is mixed into the load prior to the placement of the concrete. This "retempering" of the load may be performed again if the slump is still testing below the maximum slump allowed (7 ½ in.) prior to the placement of the concrete. The load may also be retempered after a portion of the load has been dispensed and placed. The contractor shall follow the manufacturer's recommendation on the methods to use and the number of times that retempering may be done with the specific product being used. The time requirements for concrete delivery and discharging shall not be exceeded as specified in Construction Requirements, Sec. 8, "Concrete Delivery". At no time shall the maximum allowable slump of 7 ½ inches be exceeded.

Immediately after the concrete is placed, it shall be consolidated by vibrating as necessary to ensure smooth surfaces and dense concrete. Each layer shall be consolidated to ensure a monolithic bond with the preceding layer. If the surface of a layer of concrete in place sets to the degree that it will not flow and merge with the succeeding layer when vibrated, the placement of concrete will be discontinued and a construction joint will be made.

If placing is discontinued when an incomplete horizontal layer is in place, a vertical bulkhead shall form the unfinished end of the layer.

New concrete, whether reinforced or non-reinforced, shall not be placed next to concrete in place until the hardened concrete in place has cured at least 12 hours.

10. CONSTRUCTION JOINTS

Construction joints are stopping places in the process of construction. A true construction joint should bond new concrete to existing concrete and permit no movement. Because extra care is needed to make true construction joints, they are usually designed and built to function as and align with contraction and/or isolation joints.

Construction joints are placed in a slab or wall where concreting operations have concluded for the day, generally in conformity with a predetermined joint layout. If at any time concreting is interrupted long enough for the placed concrete to harden, a construction joint must be used.

Construction joints shall be made at the locations shown on the drawings. If construction joints are needed that are not shown on the drawings, they shall be placed in locations and in a manner approved by the Engineer.

Construction joints on unformed surfaces shall have a roughened surface.

Construction joints shall be moist cured for seven (7) days or until the adjoining concrete is placed.

Surfaces of all construction joints shall be cleaned of all unsatisfactory concrete, laitance, coatings, or debris by washing and scrubbing with a wire brush or wire broom, or by other means approved by the Engineer. The surfaces shall be kept moist for at least one hour prior to placement of the new concrete if the initial curing period has passed.

Keyed construction joints are not recommended for slabs where load transfer is required.

11. ISOLATION (EXPANSION) JOINTS

Isolation joints are often called expansion joints because they are intended to isolate structural units that behave in different ways. They permit both horizontal and vertical differential movements at adjoining parts of a structure. They are used to isolate walls from floors, columns from floors, and slabs from existing structures or slabs. Isolation joints are also used in locations where restraint or transmission of secondary forces is not desired.

An isolation joint requires the use of an expansion joint material which can be as thin as ¼ inch but a commonly used thickness is ½-inch. Preformed expansion joint filler material shall be bituminous, cork, or rubber.

Isolation joints shall be made only at the locations shown or noted on the drawings.

Exposed concrete edges at isolation joints shall be carefully tooled or chamfered and the joints shall be free of mortar and concrete. Joint filler shall be left exposed for its full length with clean true edges.

Preformed expansion joint filler shall be held firmly in the correct position as the concrete is placed.

12. CONTRACTION (CONTROL) JOINTS

Contraction joints are often called control joints because they are intended to control crack location. Contraction (control) joints are purposely made planes of weakness and are designed to regulate cracking caused by drying and thermal shrinkage of the concrete.

The maximum spacing of contraction (control) joints in concrete slabs on ground and concrete walls shall be as specified in Design Requirements, Sec. 3 “Concrete Slabs”, Sec. 4 “Concrete Manure Storage Tanks, and Sec. 5 “Concrete for Agrichemical Handling Facilities”.

The slab panels created by the joints shall be as square as possible but with a maximum aspect ratio (length to width) of 1.5 to 1. Avoid L- or T-shaped panels. Add a joint at reentrant corners. Contraction (control) joints shall be made only at locations shown or noted on the drawings.

Contraction (control) joints are to be made to a depth of ¼ the thickness of the slab or wall but not less than 1 inch. Sawing is a commonly used method to make contraction (control) joints.

Contraction (control) joints also can be formed in the fresh concrete with hand groovers or by using inserts (strips of plastic, e.g., “zip-strip”, or other suitable material) at the joint location. The edges of these open joints shall be finished with an edging tool prior to removal of the joint filler strips. Inserts are not recommended for use on slabs that will be subjected to wheeled traffic.

Contraction (control) joints in concrete walls that are to be liquid-tight shall be caulked as described in Design Requirements, Sec. 4 “Concrete Manure Storage Tanks” and Sec. 5 “Concrete for Agrichemical Handling Facilities”. Use an elastomeric sealant with a foam backer rod. A waterstop shall also be used (see the following section).

13. WATERSTOPS

Waterstops shall be held firmly in the correct position as the concrete is placed. Joints in metal waterstops shall be soldered, brazed, or welded. Joints in rubber or plastic waterstops shall be cemented, welded, or vulcanized as recommended by the manufacturer. Hydrophilic strips may be used as waterstops.

Wall pours shall not be continuous past waterstops. Vertical waterstops shall be held firmly in place by a bulkhead attached to the wall forms. Flexible (rubber or PVC) waterstops with center bulbs are preferred and shall be used when required in contraction joints.

14. FINISHING UNFORMED SURFACES

All exposed surfaces of the concrete shall be accurately screeded to grade and then float finished.

Excessive floating or troweling of surface while the concrete is soft will not be permitted.

The addition of dry cement or water to the surface of the screeded concrete to expedite finishing will not be allowed.

Joints and edges on surfaces that will be exposed to view shall be chamfered or finished with molding tools.

15. REMOVAL OF FORMS

Forms for walls and columns shall remain tight and in place for a minimum of 24 hours and a maximum of 48 hours after placing the concrete. Forms for slabs shall not be loosened or removed for at least 12 hours after placing concrete.

Forms that support beams or covers shall not be removed for at least 7 days or as otherwise stated on the drawings. Forms for beams or covers that are to support additional forms or shoring shall not be removed for at least 14 days.

Removal of forms shall be done in a manner that will not damage the concrete surface nor induce sudden or excessive stresses.

16. FINISHING FORMED SURFACES

Immediately after the removal of the forms, the surfaces shall be kept wet until all defects, holes, and other irregularities have been repaired.

All fins and irregular projections shall be removed from exposed surfaces.

Holes produced on all surfaces by the removal of form ties, cone-bolts, she-bolts, and other items shall be cleaned, wetted, and filled with a dry-pack mortar consisting of one part Portland cement, three parts sand that will pass a No. 16 sieve, and sufficient water to produce a consistency such that the filling is at the point of becoming rubbery when the material is solidly packed. The Engineer must approve other patching material and procedures prior to their use.

17. CONCRETE REPAIR

Concrete that is honey combed, damaged, or otherwise defective shall be repaired or removed and replaced.

The Engineer will determine the required extent of removal, replacement, or repair. The plan for implementing the repair must be approved by the Engineer prior to the beginning of the repair work. The contractor shall perform all repair work in the presence of the Engineer or his or her representative. The Engineer will have the final approval of all repair work.

18. CONCRETE CURING

Concrete shall be prevented from drying for a curing period of at least 7 days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period or until curing compound is applied as specified below. Moisture shall be maintained by sprinkling, flooding, fog spraying or by covering with continuously moistened canvas, cloth mats, straw, sand, or other approved materials. Formed surfaces shall be thoroughly wetted immediately after forms are removed and shall be kept wet until patching and repairs are completed. Water or covering shall be applied in such a way that the concrete surface is not eroded or otherwise damaged. Exposed and unformed concrete surfaces, especially flat work placed with large surface areas, shall be kept completely and continuously wet for the duration of the curing period or until curing compound is applied as specified below.

Concrete, except at construction joints, may be coated with an approved curing compound in lieu of continued application of moisture. The compound shall be sprayed on the moist concrete surface as soon as free water has disappeared but shall not be applied to any surface until patching, repairs, and finishing of that surface are completed. The compound shall be applied at a uniform rate of not less than one gallon per 150 square feet of surface (or at the manufacturer's recommended rate) and shall form a continuous adherent membrane over the entire surface. Curing compound shall not be applied to surfaces requiring a bond to subsequently placed concrete, such as construction joints, shear plates, reinforcing steel and other embedded items. If the membrane is damaged during the concrete curing period, the damaged areas shall be re-sprayed at the rate of application specified above.

The use of white curing compound is strongly recommended if curing compound is used.

19. BACKFILLING NEW CONCRETE WALLS

Placement and/or compaction of backfill adjacent to a new concrete wall shall not begin until 14 days have elapsed since the placement of the concrete. Walls that will be backfilled on both sides simultaneously may be backfilled after 7 days.

Heavy equipment shall not be allowed within 3 feet of a new concrete wall. Provide compaction near the wall by means of hand tamping or small, manually directed equipment. Vibrating equipment is not permitted to be used for compacting backfill.

20. CONCRETING IN COLD WEATHER

Cold weather concreting procedures shall be used for all concrete mixed and placed between November 1 and April 1, regardless of weather forecasts.

Cold weather concreting procedures may be required before November 1 and after April 1, when the atmospheric temperature is less than 40° at the time of placement or predicted to fall below 32° in the following 24 hours.

The contractor shall submit a written plan detailing how the concrete is going to be protected from freezing and how the required temperatures of the concrete will be maintained. The written plan shall be approved by the Engineer prior to any work on the project except for earthwork.

In the event that there is no plan or no cold weather provisions available, concrete placement will not be permitted.

Cold weather concreting requirements are:

a. Concrete temperatures (for the required curing period) shall meet the requirements shown in the following table [1/] :

Air Temperature	Section Size (minimum dimension)	
	< 12”	12” – 36”
	Minimum Concrete Temperature as Placed	
All	55° F	50° F
	Maximum Concrete Temperature as Placed	
All	75° F	70° F
	Minimum Concrete Temperature as Mixed	
Above 30° F	60° F	55° F
0° F to 30° F	65° F	60° F
	Max. Allowable Gradual Temp. Drop in First 24 hours After End of Protection	
All	50° F	40° F

1/ From information in ACI 306 Sec. 5.1

b. When the cement is added to the mix, the temperature of the mixing water shall not exceed 140° F nor shall the temperature of the aggregate exceed 150° F.

c. The use of antifreeze compounds and/or calcium chloride is not allowed.

d. The surface temperature of the concrete shall not go below 40° F for seven (7) days following placement of the concrete. The concrete shall be immediately protected after placement. Protection methods to maintain the minimum temperature adjacent to the concrete surface include but are not limited to the following (applies to both walls and slabs):

1) Using canvas tarpaulins, polyethylene film (plastic sheeting), or waterproof paper as protective covers over at least 3 in. of dry straw or hay; heating may be added if necessary.

2) Using commercial insulating blankets or batt insulation in single or multiple layers; plastic sheeting may also be used as an additional layer with the blankets or batting; heating may be added if necessary.

3) Using heated enclosures made of wood, canvas tarpaulins (tents), or polyethylene to protect the concrete; prefabricated rigid-plastic enclosures may also be used.

e. The contractor or landowner shall record temperatures at least once a day at the same time each day (two sets of readings are preferred) for seven (7) days. A maximum/minimum thermometer shall be used to monitor the temperature at the concrete surface. There should be a sufficient number of temperature measurement locations to show the range of concrete temperatures throughout the structure. The following minimum information is to be recorded for each set of readings:

1) Date and Time
2) Name of person taking readings
3) Outside air temperature
4) Weather conditions
5) Maximum and minimum temperature readings in each 24 hour period using a max/min thermometer at the concrete surface.

f. At the end of the protection period, the concrete shall be allowed to cool gradually. The maximum decrease in temperature at the concrete surface in the first 24 hours shall not exceed the values shown in the above table.

21. CONCRETING IN HOT WEATHER

For the purpose of this specification, hot weather is defined as any combination of the following conditions that may potentially impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and the rate of cement hydration or otherwise produce detrimental results:

a. High ambient temperature
b. High concrete temperature
c. Low relative humidity
d. Wind velocity
e. Solar radiation

Whenever the above conditions exist or when climatic conditions are such that the temperature of the concrete may reasonably be expected to exceed 90°F at the time of delivery to the work site or during the placement operations, the following provisions shall apply:

a. The contractor shall maintain the temperature of the concrete below 90°F during mixing, conveying, and placing. The usual method of cooling concrete is to lower the temperature of the concrete materials before mixing.

b. Exposed concrete surfaces that tend to dry or set too rapidly, reinforcing steel, and subgrade shall be continuously moistened using fog sprays or other means to maintain adequate moisture during the time between placement and finishing. Water shall not be sprinkled or added directly to the surface of the concrete prior to finishing.

c. Finishing of slabs and other exposed surfaces shall be started as soon as the condition of the concrete allows and shall be completed without delay. Water shall not be sprinkled or added to the surface of the concrete during the darbying, bull floating, or other finishing operations to facilitate finishing.

d. When any single or combination of conditions may result in very rapid setting or drying of the concrete, extreme conditions exist. For flatwork and slab construction, extreme conditions exist when the evaporation rate exceeds 0.2 $lb/ft^2/hr$. The evaporation rate for flatwork and slab construction may be determined by calculating the evaporation rate from a shallow cake pan having a surface area of at least 1 square foot or by other methods approved by the Engineer. Retarding admixtures may be used.

e. The Engineer may (1) restrict placement to the most favorable time of the day, (2) restrict the depth of layers to ensure coverage of the previous layer while it will still respond readily to vibration, (3) suspend placement until conditions improve, and (4) restrict the removal of forms, repair, and patching to small areas which can be protected with curing compound immediately.

f. The need for moist curing is greatest during the first few hours after finishing. Moist curing should commence as soon as the surfaces are finished and continue for a least 24 hours. If moist curing cannot be continued beyond 24 hours, while the surfaces are still damp, the concrete should be protected from drying with curing paper, heat-reflecting plastic sheets, or membrane-forming curing compounds.

g. Application of a curing compound should be preceded by 24 hours of moist curing. If this is not practical, the curing compound should be applied immediately after final finishing. The concrete surfaces should be moist.

h. The contractor shall submit a written plan detailing procedures of mixing, using admixtures, placing, protection, curing, and temperature monitoring during hot weather. The Engineer shall approve the written plan prior to the ordering of the concrete.

i. The contractor or landowner shall maintain a record of the placement of the concrete. The following minimum information is to be recorded for each set of readings:

    a. Date and Time
    b. Name of person taking readings
    c. Outside air temperature
    d. Weather conditions
    e. Concrete temperature at the time of delivery and after the concrete is placed
    f. Protection method(s) used
    g. Initial curing method used
    h. Final curing method used
    i. When curing compound is used, the time and rate of application
    j. The duration and termination of curing

22. LOADING

This section addresses loads being applied to each structure after the construction has been approved.

Slabs- Do not drive on or load slabs before 14 days have elapsed after concrete placement unless specified differently on the drawings.

Walls- No loading shall be applied to new concrete walls before 14 days have elapsed after concrete placement unless specified differently on the drawings. Backfill is considered to be a load condition (refer to Construction Requirements, Sec. 19, "Backfilling New Concrete Walls"). Walls backfilled on both sides simultaneously may be loaded after 7 days have elapsed.

Columns and Beams-

No loading shall be applied to new concrete columns or beams before the concrete obtains a compressive strength of 4,000 psi or before 28 days have elapsed, whichever comes first unless specified differently on the drawings.

23. SAFETY CONCERNS

All work shall be conducted within applicable Federal, State, and local regulations. Utility locations, overhead obstacles, excavation safety, steel placement, impalement protection, and working with fresh concrete are of particular concern. Contractors shall have necessary safety equipment and procedures in place prior to commencement of construction.

24 INFORMATION REQUIRED AT THE END OF THE PROJECT

At the end of the project, the contractor, the landowner's technical representative, or the Engineer shall provide as a minimum the following items to the landowner (to be included with the as-built construction drawings):

- Certified Concrete Design Mix (including all admixtures used)
  (Design Requirements, Sec. 1)

- All concrete Batch Tickets
  (Construction Requirements, Sec. 7)

- Slump Test results
  (Construction Requirements, Sec. 9)

- Types and extent of Concrete Repairs made
  (Construction Requirements, Sec. 17)

- Method used for Concrete Curing; Type/Color of Curing Compound (if used)
  (Construction Requirements, Sec. 18)

- Cold Weather Concreting Plan
  (Construction Requirements, Sec. 20)

- Cold Weather Concreting Temperature Readings and Logs for the required seven (7) day period after concrete placement
  (Construction Requirements, Sec. 20)

- Concreting in Hot Weather Plan
  (Construction Requirements, Sec. 21)

- Concreting in Hot Weather Readings and Logs
  (Construction Requirements, Sec. 21)

- As-Built Construction Drawings