SECTION 131200 CONCRETE THIN SHELL DOME CONSTRUCTION

General Conditions of Contract and Division 1 govern this Section.

Part 1- General

1.1 SUMMARY

A. This Section specifies concrete thin shell (aka concrete dome) construction including air form, closed cell insulation, reinforcement, concrete materials, mixture design, placement procedures, and finishes.

1.2 DESIGN PERFORMANCE REQUIREMENTS

A. Design dome structural system in compliance with design guidelines, standards and codes listed below:

5. ACI 318 Chapter 19 “Shells and Folded Plate Members”
6. ACI 334.3R (latest revision) “Construction of Concrete Shells Using Inflated Forms”
7. UL1897 “Uplift Tests for Roof Covering Systems” or equivalent

B. Pre-engineered dome design drawings and calculations shall include comprehensive engineering analysis by a qualified professional engineer licensed in the State of Texas, using performance requirements and design criteria listed on the drawings, specifications and herein.

1.3 DEFINITIONS

A. Cementitious Materials: Portland cement alone or with fly ash if the dome subcontractor desires with approval of structural engineer.

B. Air form: is defined as an inflated pre-designed air supported membrane to which insulation, rebar, and shotcrete are attached or applied.

1.4 SUBMITTALS

A. Submittals shall be given to the Architect for review. Items shall be submitted a minimum of (ten) 10 days prior to the execution of the work unless noted otherwise. Allow five (5) days for review and comment. Rejected submittals shall be corrected and returned within five (5) working days.

B. The Owner has the option of requesting a mock-up sample of the complete Dome assembly at an additional cost.

C. Qualification Data:
1. Thin Shell Concrete Dome Builder: Contractor shall be in the business of building thin shell concrete domes and shall document their experience. The submittal shall include, but not be limited to the following:

   a. Thin shell concrete dome builder: Contractor shall provide documentation of their experience building projects of similar size and shape with regard to the geometry specified in the bid documents.

   b. Concrete Thin Shell Construction Plan: The contractor shall present a construction plan regarding the means and methods of his work. The plan shall include, but not be limited to; inflation, insulation, reinforcing, shotcreting, and finishing. Review shall be made only with respect to general industry standards.

2. Air form fabricator: As a basis for qualification of fabrication, the fabricator shall submit prior successful project information including; patterning, sketches, material information design basis, photos, and references to evaluate the fabricator’s qualifications for projects of a similar size and shape. Submittal shall also include:

   a. 15-year warranty.

   b. Fabric Data Sheet.

   c. References from past projects.

D. Field quality-control test and inspection reports by third party as required by the owner, at the owner’s expense.

1.5 QUALITY ASSURANCE

A. Concrete shell construction design is provided in the Bid Documents. Bids shall be based on the concrete shell designed by the Engineer of Record.

   1. If the dome is design/build, the dome builder’s engineer must be registered in the state where the dome will be built.

   2. The dome building shall have the option of changing the height of the dome to meet dome builder’s internal safety and risk criteria.

   3. The dome shall not have a designed diameter to height ratio greater than 1:5 (e.g. 160’ diameter; 32’ tall) unless specified in the construction documents.

B. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products and that complies with ASTM C 94 requirements for production facilities and equipment.

   1. Manufacturer certified according to NRMCA’s "Certification of Ready Mixed Concrete Production Facilities."

C. Testing Agency Qualifications: An independent agency, acceptable to the Engineer of Record, qualified according to ACI 506.4 latest version and ACI 506.2 latest version.

   1. Personnel performing shotcrete inspection shall be certified or experienced with ACI 506.4 latest version and have a minimum prior experience of evaluation shotcrete on at least three (3) prior projects of a similar type or be pre-approved by the structural engineer.

D. Source Limitations: Obtain each type or class of cementitious material of the same brand from the same
manufacturer's plant, obtain aggregate from one source, and obtain admixtures through one source from a single manufacturer.

E. Pre-installation Conference:

1. A pre-installation conference will be held a minimum of five (5) days prior to air form inflation to discuss the following:
   a. air form installation,
   b. polyurethane preparation and application,
   c. shotcrete and reinforcing installation,
   d. thin shell concrete thickness control and finish requirements,
   e. opening block out procedure and plan,
   f. shotcrete placement review,
   g. design mixture,
   h. Architect review mock up sample, if requested, to determine if any modifications are required.

2. Require representatives of each entity directly concerned with the tasks outlined above and the concrete thin shell to attend, including the following:
   a. Owner’s Representative and/or Architect.
   b. Independent testing agency responsible for concrete testing and shotcrete inspection as needed.
   c. Ready-mix concrete manufacture as needed.
   d. Thin shell contractor superintendent and/or project manager.
   e. Structural Engineer of Record.

F. Air form Fabricator shall document fabric roll tickets indicating batch and roll number with bar code.

G. Mill certification sheets shall be furnished for all purchased rebar.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Steel Reinforcement: Deliver, store, and handle steel reinforcement to prevent bending and damage.

B. Air form: Deliver, store, and handle air form to prevent tearing or scuffing.

Part 2 Products

2.1 MATERIALS

A. Form-Facing Materials
   1. Forms for block outs (wood, metal, PVC or Styrofoam).

B. Steel Reinforcement

1. Reinforcing Bars: ASTM A 615, ASTM A706 (weldable) Grade 60, deformed.

C. Reinforcement Accessories

1. Joint Dowel Bars: Product: “Speed Dowel” or equal ASTM A 615, Grade 60, plain-steel bars, cut bars true to length with ends square and free of burrs.

2. Bar Supports: Bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire reinforcement in place. Manufacture bar supports from steel wire, plastic, or precast concrete according to CRSI’s "Manual of Standard Practice," of greater compressive strength than concrete and as follows:
   a. For concrete surfaces exposed to view where legs of wire bar supports contact forms, use CRSI Class 1 plastic-protected steel wire or CRSI Class 2 stainless-steel bar supports.

D. Concrete Materials

1. Cementitious Material: Use the following cementitious materials, of the same type, brand, and source, throughout Project:
   a. Portland Cement: ASTM C 150, Type I/II. Supplement with the following:
   b. Fly Ash: ASTM C 618, Class F, if the dome subcontractor desires and all design parameters are met, and if structural engineer approves.

2. Normal-Weight Aggregates: ASTM C 33, Class 3M coarse aggregate or better, graded. Provide aggregates from a single source with documented service record data of at least 10 years' satisfactory service in similar applications and service conditions using similar aggregates and cementitious materials.
   b. Fine Aggregate: Free of materials with deleterious reactivity to alkali in cement.


E. Admixtures


2. Chemical Admixtures: Provide admixtures certified by manufacturer to be compatible with other admixtures and that will not contribute water-soluble chloride ions exceeding those permitted in hardened concrete. Do not use calcium chloride or admixtures containing calcium chloride.
   a. Water-Reducing Admixture: ASTM C 494, Type A.
   b. High-Range, Water-Reducing Admixture: ASTM C 494, Type F.
   c. Super Plasticizing Admixture: ASTM C 1017, Type II.
F. Curing Materials


2. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz./sq. yd. when dry.


G. Related Materials


2. Semi-rigid Joint Filler: Two-component, semi-rigid, 100 percent solids, epoxy resin with a Type A shore durometer hardness of 80 per ASTM D 2240.

3. Bonding Agent: ASTM C 1059, Type II, non-redispersible, acrylic emulsion or styrene butadiene.

H. Repair Materials

1. Cement Binder: ASTM C 150, Portland cement or hydraulic or blended hydraulic cement as defined in ASTM C 219.

2. Aggregate: Well-graded, washed gravel, 1/8 to 1/4 inch or coarse sand as recommended by underlayment manufacturer.

3. Compressive Strength: Not less than 4000 psi at 28 days when tested according to ASTM C 109.

I. Concrete Mixtures, General

1. Prepare design mixtures for each type and strength of concrete, proportioned on the basis of laboratory trial mixture or field test data, or both, according to ACI 301.

   a. Use a qualified independent testing agency for preparing and reporting proposed mixture designs based on laboratory trial mixtures.

   b. Use of fly ash: Under no circumstances shall fly ash reduce the total amount of Portland cement by more than 25 percent.

2. Admixtures: Use admixtures according to manufacturer's written instructions, at the discretion of the dome subcontractor.

   a. Use water-reducing, or plasticizing admixture in concrete, as required, for placement and workability.

   b. Use water-reducing and retarding admixture when required by high temperatures, low humidity, or other adverse placement conditions.

   c. Use water-reducing admixture in pumped concrete, concrete for heavy-use industrial slabs and parking structure slabs, concrete required to be watertight, and concrete with a water-cementitious materials ratio below 0.50.
J. Concrete Mixtures for Building Elements

1. Concrete thin shell: Proportion normal-weight concrete mixture as follows:
   a. Minimum Compressive Strength: 4,000 (Four Thousand) psi at 28 days.
   b. Maximum Water-Cementitious Materials Ratio: 0.45.
   c. Slump Limit: 4 inches for concrete with verified slump of 2 to 4 inches before adding high-range water-reducing admixture or plasticizing admixture, plus or minus 1 inch.
   d. Air Content: 4-5%

K. Fabricating Reinforcement

1. Fabricate steel reinforcement according to CRSI's "Manual of Standard Practice."

L. Concrete Mixing

1. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete according to ASTM C 94 and furnish batch ticket information.

K. Polyurethane Product shall be NCIF, GACO Western or approved equal and shall meet the minimum design basis:

1. Core Density – ASTM 1622 2.0 pcf
2. Compressive Strength ASTM D 1621 33 psi
3. Moisture Vapor Transmission ASTM E 96 1.3 perm-in
4. Closed Cell Content ASTM D6226 >90%
5. R-value @ 1” ASTM C 518 6.6
6. Flammability
   a. Flame Spread
      i. ASTM E-84 @4” ≤25
      ii. Smoke Dev ≤450
7. Max Service Temperature 180° F

M. Air form

1. The air form shall be fabricated to meet the minimum design basis:
   a. Weight: 28oz/yd² min.
   b. Breaking/Tensile strength: 515lbs
   c. Tear strength: 155lbs
   d. Adhesion: 10lbs/in
Part 3 Execution

3.1 AIR FORM MANUFACTURER

A. The air form fabricator shall ensure the patterned shape to be cut. A CNC machine is preferred for air form cutting. The fabricator’s CAD file shall also provide information for weld match lines indicating the required seam width and vertical alignment.

B. Match lines on patterns shall indicate the weld width and vertical alignment with tick marks along the length of the seam. Measurements across the cut pattern width shall be within a 10 mm tolerance of the shop drawings. The overall cut length of the pattern shall be within a 25 mm tolerance of the shop drawings.

C. Welding of the cut fabric pieces shall be performed using high frequency welding technology. The sealing bar shall be the full width of the required weld. The actual weld width alignment shall be within 10 mm of the design width indicated by the match line and shop drawings.

D. Seam strength testing shall be performed as part of the fabricator’s QA/QC program. Test welds shall be performed before starting each gore seam of the air form, anytime settings on the machine are changed, and anytime deemed necessary by QA/QC personnel. Test welds shall be performed per manufacturer QA/QC program.

3.2 CONSTRUCTION

A. Air form Installation and Inflation

1. The Air Form shall be installed by qualified installers with experience as referenced in ACI 334. Installer shall protect air form during installation from rips, tears, and or dirt, grime, and deleterious material accumulation, by preparing the footprint of the thin shell site with plastic or suitable covering over open earth areas and equipment or material there within. Sharp or pointed edges shall be covered.

2. Air form shall not be inflated in wind speeds greater than 20 mph of sustained wind and expected gusts greater than 50 mph to avoid deformation and damage to the air form. The air form shall be designed with maximum internal pressure, recommended working internal pressure and minimum safe working pressure. Gores shall run in the meridional direction. The patterning shall be designed...
with a CAD program and take into account the aforementioned design basis. The outside diameter at the base of the dome shall not vary more than plus or minus 2 inches from the design diameter. The vertical height of the dome shall not vary more than plus or minus 24 inches from the design height. All dimensional tolerances should be considered in the design of equipment or other structures to be connected to the dome. The actual shape and height of the dome will be checked by the Architect/Owner once the air form is inflated to its designed pressure.

B. Polyurethane Installation

1. Install polyurethane as referenced in ACI 334.3.

2. Applicator shall have a minimum experience of 500 hours in similar circumstances using similar equipment.

3. Polyurethane shall be a nominal 3" thick and trimmed if needed to a +/- 1/2 inch tolerance.

C. Reinforcing Installation

1. Pre-mat reinforcing shall be used as referenced in ACI 334.3.


3. Clean reinforcement of loose rust and mill scale, earth, ice, and other foreign materials that would reduce bond to concrete.

4. Accurately position, support, and secure reinforcement against displacement. Locate and support reinforcement with bar supports to maintain minimum concrete cover. Do not tack weld crossing reinforcing bars.

5. Wire ties with ends directed into concrete, not toward exposed concrete surfaces.

6. Place and embeds and other items required for adjoining work that is attached to or supported by the thin shell concrete. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

D. Shotcrete Placement

1. Before placing Shotcrete, verify that installation of the air form, polyurethane, reinforcement, and embedded items is complete and that required inspections have been performed.

2. Do not add water to concrete during delivery, at Project site, or during placement unless approved by Structural Engineer.

3. Do not add water to concrete after adding high-range water-reducing admixtures to mixture. Use of a high range water reducing admixture shall be subject to review and approved by the Engineer of Record in the mix design.

4. Place shotcrete as referenced in ACI 334.3 and in accordance with ACI 506.

E. Finishing Concrete Thin Shell Surfaces

1. Interior Shotcrete Finish: Thickness control measures shall be taken (depth gauges) to insure engineered shotcrete thickness in accordance with the design documents. Thin shell interior finish texture shall be consistent throughout. Depth gauges shall be a minimum of 1/4" steel rod or similar
and be placed on a minimum grid of 10’ x 10’, left in place and covered over with the final finish shotcrete coat(s). Upon reaching the above noted tolerance a final shotcrete finish shall be applied. The interior finish shall be sprayed shotcrete with care taken with the final mix sprayed with regard to consistency in aggregate, cement type, moisture content, etc. to ensure a consistent curing pattern. The mix design of the final finish shotcrete shall maintain the properties of the approved mix design with the following exceptions: aggregate size shall be reduced to avoid large pock marks on the finish product.

F. Concrete Protecting and Curing

1. General: Protect freshly placed concrete from premature drying and excessive cold or hot temperatures. Comply with ACI 306.1 for cold-weather protection and ACI 301 for hot-weather protection during curing.

G. Concrete Surface Repairs

1. Defective Concrete: Repair and patch defective areas when approved by Architect.

2. Remove and replace concrete that cannot be repaired and patched to satisfaction of Architect and Owner.

3. Patching Mortar: Mix dry-pack patching mortar, consisting of one part Portland cement to two and one-half parts fine aggregate passing a No. 16 sieve, using only enough water for handling and placing.

4. Repairing Unformed Surfaces:

   a. Repair finished surfaces containing defects. Surface defects include spalls, pop outs, honeycombs, rock pockets, crazing and cracks in excess of 0.05 inch wide or that penetrate to reinforcement or completely through unreinforced sections regardless of width, and other objectionable conditions.

   b. Every effort shall be made in repaired areas to match and blend repaired area finish to the finish level depicted throughout the remainder of the shell.

5. Perform structural repairs of concrete, subject to Structural Engineers approval, using methods outlined by the Structural Engineer.

3.3 FIELD QUALITY CONTROL

A. Testing and Inspecting: The Owner has engaged an inspector and qualified testing and inspecting agency to perform field tests and inspections and prepare test reports. Refer to 01410 Laboratory Testing Services.

B. Inspections:

1. Steel reinforcement placement.

2. Verification of use of required design mixture.


4. Curing procedures and maintenance of curing temperature.
5. Verification of concrete strength before removal of shores and forms from large opening areas.

C. Concrete Tests: Testing of composite samples of fresh concrete obtained according to ASTM C 172 shall be performed according to the following requirements:

1. Testing Frequency: Obtain at least one (1) composite sample for each 100 cu. yd. or fraction thereof of each concrete mixture placed each day.
   a. When frequency of testing will provide fewer than five (5) compressive-strength tests for each concrete mixture, testing shall be conducted from at least five (5) randomly selected batches or from each batch if fewer than five (5) are used.

2. Slump: ASTM C 143; one (1) test at point of placement for each composite sample, but not less than one (1) test for each day's pour of each concrete mixture. Perform additional tests when concrete consistency appears to change.

3. Air Content: ASTM C 231, pressure method, for normal-weight concrete; one (1) test for each composite sample, but not less than one (1) test for each day's pour of each concrete mixture.

4. Concrete Temperature: ASTM C 1064; one (1) test hourly when air temperature is 40 deg. F and below and when 80 deg. F and above, and one (1) test for each composite sample.

5. Unit Weight: ASTM C 567, fresh unit weight of structural lightweight concrete; one (1) test for each composite sample, but not less than one (1) test for each day's pour of each concrete mixture.

   a. Cast and laboratory cure two (2) sets of two (2) standard cylinder specimens for each composite sample.
   b. Cast and field cure two (2) sets of two (2) standard cylinder specimens for each composite sample.

   a. Test one (1) set of two (2) field-cured specimens at 7 days and one (1) set of two (2) specimens at 28 days.
   b. A compressive-strength test shall be the average compressive strength from a set of two (2) specimens obtained from same composite sample and tested at age indicated.

8. When strength of field-cured cylinders is less than 85 percent of companion laboratory-cured cylinders, Contractor shall evaluate operations and provide corrective procedures for protecting and curing in-place concrete.

9. Strength of each concrete mixture will be satisfactory if every average of any three (3) consecutive compressive-strength tests equals or exceeds specified compressive strength and no compressive-strength test value falls below specified compressive strength by more than 500 psi.

10. Test results shall be reported in writing and via email or facsimile to Structural Engineer and Owner's representative, general contractor, concrete manufacturer, and dome builder within forty-eight (48) hours of testing. Reports of compressive-strength tests shall contain Project identification name and number, date of concrete placement, name of concrete testing and inspecting agency, location of concrete batch in Work, design compressive strength at twenty-eight (28) days, concrete mixture.
proportions and materials, compressive breaking strength, and type of break for both seven (7) and twenty-eight (28) day tests.

11. Nondestructive Testing: Impact hammer, sonoscope, or other nondestructive device may be permitted by Structural Engineer but will not be used as sole basis for approval or rejection of concrete.

12. Additional Tests: Testing and inspecting agency shall make additional tests of concrete when test results indicate that slump, air entrainment, compressive strengths, or other requirements have not been met, as directed by Structural Engineer. Testing and inspecting agency may conduct tests to determine adequacy of concrete by cored cylinders complying with ASTM C 42 or by other methods as directed by Structural Engineer.

13. Additional testing and inspecting:

   a. If Owner or Architect feels additional testing is required to confirm compliance of specification, testing from an independent third party will be performed to determine compliance. If independent third party verifies compliance, owner shall pay for the testing. If independent third party determines work repaired or replaced, contractor shall pay for the test(s) and correct the work to original specification.

14. Correct deficiencies in the Work that test reports and inspections indicate does not comply with the Contract Documents.

END OF SECTION