SECTION 03360 - PNEUMATICALLY-PLACED CONCRETE

City of San Diego, CWP Guidelines

PART 1 -- GENERAL

1.1 WORK OF THIS SECTION

A. The WORK of this Section includes providing all pneumatically-placed concrete and all appurtenant work, complete.

B. Pneumatically-placed concrete shotcrete as referred to herein shall mean any mixture of portland cement, sand and water deposited by air pressure to its final position in the WORK.

1.2 RELATED SECTIONS

A. The WORK of the following Sections applies to the WORK of this Section. Other Sections of the Specifications, not referenced below, shall also apply to the extent required for proper performance of this WORK.

1. Section 03200 Reinforcement Steel
2. Section 03300 Cast-in-Place Structural Concrete
3. Section 03310 Cast-in-Place Sitework Concrete

1.3 CODES

A. The WORK of this Section shall comply with the current editions of the following codes as adopted by the City of San Diego Municipal Code:

1. Uniform Building Code

1.4 SPECIFICATIONS AND STANDARDS

A. Except as otherwise indicated, the current editions of the following apply to the WORK of this Section:

1.	ANSI/ACI 506	Guide to Shotcrete Specification for Materials, Proportioning, and Application of Shotcrete
2.	ASTM C33	Concrete Aggregates
3.	ASTM C 40	Test Method for Organic Impurities in Fine Aggregates for Concrete
4.	ASTM C 42	Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
5.	ASTM C 87	Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
6.	ASTM C 136	Method for Sieve Analysis of Fine and Coarse Aggregates

7.	ASTM C 150	Specification for Portland Cement
8.	ASTM C 685	Concrete Made by Volumetric Batching and Continuous Mixing
9.	ASTM E 329	Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction

1.5 SHOP DRAWINGS AND SAMPLES

A. The following shall be submitted in compliance with Section 01300:

1. Shop drawings of all steel reinforcement layout.
2. Information concerning source and quality of all materials.
3. Proposed mix design.
4. Test results of specimens obtained from preconstruction test panels.

1.6 OWNER'S MANUAL

A. The following shall be included in the OWNER'S MANUAL in compliance with Section 01300:

1. Certificates from manufacturers or suppliers certifying that the materials supplied conform to the requirements of the Contract Documents.

1.7 PRECONSTRUCTION TESTING

A. The CONTRACTOR shall make test panels at least 30-inch by 30-inch for each mix being considered, and for each slab, vertical and overhead position to be encountered. Test panels shall contain the same reinforcement as in the WORK in at least half of the panel to test for proper embedment of reinforcing steel. Fabricate test panels to the same thickness as the WORK, but not less than 3 inches. Take at least five cubes or cores from the panels for testing.

B. All cut or broken surfaces on test panels shall be dense and free from laminations and sand pockets.

C. Test for compressive strength in compliance with ASTM C 42.

D. Test panels shall be made by each application crew using the equipment, materials, and mix proportions for the project.

1.8 DETERMINATION OF COMPRESSIVE STRENGTH DURING CONSTRUCTION

A. The compressive strength of the concrete will be determined by the CONSTRUCTION MANAGER through the medium of [2-inch diameter by 4-inch long] test cylinders or [4-inch cubes].

B. Cubes may be sawed, or cores may be drilled from slabs prepared especially for testing purposes. All cut surfaces shall be dense and free from sand pockets.

C. To establish a correlation between the cylinders or cubes and 6-inch diameter by 12-inch long cylinders, a series of four, 6-inch diameter by 12-inch long test cylinders shall be made by coring concrete cylinders from 12-inch deep by 30-inch by 14-inch concrete specimen

blocks. The specimen blocks shall be shot in one continuous operation to the required height of the block onto a back form of plywood laid on the ground.

D. One concrete test block shall be made during each day's operation. Three specimens shall be cut from each concrete block 7 days after its placing. One cylinder will be tested for the 7-day strength, the other 2 will be tested at 28 days. The remainder of the concrete blocks shall be cured and stored until after the 28-day test has been made and until the CONSTRUCTION MANAGER has informed the CONTRACTOR, in writing, that no additional specimens have to be cut and tested. All concrete specimens shall be properly numbered and dated and a record shall be made by the CONTRACTOR as to the location of the WORK for which these samples were prepared.

PART 2 -- PRODUCTS

2.1 MATERIALS

A. **Cement:** Cement shall comply with the requirements of ASTM C 150 [Type II low alkali] [Type V, low alkali].

B. **Sand:** Sand shall consist of natural sand obtained from a source acceptable to the CONSTRUCTION MANAGER and shall in all cases be washed. The control of the washing of sand shall be such that the finer particles are retained or removed as required. Washed or saturated sand shall be allowed to drain at least 24 hours to a uniform moisture content before batching. Dry sand shall be moistened before handling when necessary to prevent segregation. The sand shall be screened through a horizontal vibrating screen having square openings, and the grading as determined in accordance with the methods prescribed by ASTM C 136 shall be within the following limits:

	Percent
Passing a 3/8-inch square sieve	95 to 100
Passing a No. 4 sieve	80 to 100
Passing a No. 8 sieve	50 to 85
Passing a No. 16 sieve	25 to 60
Passing a No. 30 sieve	10 to 30
Passing a No. 50 sieve	30 to 50
Passing a No. 100 sieve	2 to 10
Passing a No. 200 sieve	0 to 4

C. The difference between the percentages passing the No. 30 and the No. 50 sieves shall not exceed 32.

D. Sand shall be composed of clean, hard, strong, durable, uncoated grains, free from shale, lumps, and soft or flaky particles and from injurious amounts of dust, alkali, organic matter, loam, mica, or other deleterious substances. When tested in accordance with the methods prescribed by ASTM C 40, the color of the supernatant liquid shall not be darker than the standard specified therein and shall not contain more than a total of 3 percent by volume of clay, silt, mica, or other objectionable inorganic materials, as determined by settlement after thoroughly mixing and shaking the sample with 2-1/2 times its volume of a 3 percent (by weight) solution of sodium hydroxide in a graduated column.

E. Sand which in any respect varies from the foregoing requirements shall not be used in the work, and the CONTRACTOR shall do all sorting, crushing, screening, blending, washing, and other operations necessary to make the available material conform to said requirements, and shall receive no extra compensation therefor, nor for the necessity of separating and wasting any part of the natural materials. In case the finer particles from the crushed coarse aggregate are permitted or required to be mixed with the sand from natural deposits, the two products shall be uniformly blended before washing or screening to insure a combined product of constant composition.

F. Sand as prepared for use shall be of such quality that 2-inch diameter by 4-inch long test cylinders made with a mixture of cement and the sand under test shall develop compressive strengths at 7 and 28 days of not less than 90 percent of those developed by a concrete mix prepared in the same manner with the same cement and graded Ottawa testing sand, all in accordance with the method prescribed in ASTM C 87.

G. **Water:** Water for pneumatically-applied concrete shall be furnished by the CONTRACTOR. All water shall be clean and free from objectionable quantities of organic matter, alkali, salts, and other impurities which might reduce the strength, durability, or other quality of the pneumatically placed concrete.

H. **Reinforcement:** Steel reinforcement shall conform to the requirements of Section 03200.

2.2 EQUIPMENT

A. **Dry-Mixed Shotcrete**

1. Mixers: Mixers shall be of a type and size which is sufficient to supply all materials required by the nozzles used while providing a mixing time of not less than 1-1/2 minutes after all the cement and aggregate have been placed in the mixer.

2. Placing Machines: Pneumatically-applied concrete shall be placed by the dry-mix process using machines operated at an air pressure of not less than 50 pounds nor more than 75 pounds per square inch when no more than 200 feet of material hose is used. These pressures shall be increased 5 pounds for each additional 50 feet of hose, and not more than 400 feet of hose shall be attached to any machine. The water pressure at the nozzles shall be at least 15 pounds greater than the air pressure in the machine, and the discharge nozzle shall be equipped with a manually operated water-injection system for directing an even distribution of water through the sand-cement mixture. The water valve shall be capable of ready adjustment to vary the quantity of water, and shall be convenient to the nozzleman. A properly operated air compressor of ample capacity to maintain a supply of clean, dry air adequate for maintaining sufficient nozzle velocity for the application to be performed and at the same time operate a blow pipe for clearing rebound shall be used.

B. **Wet-Mixed Shotcrete**:

1. Mixers: Equipment for mixing shotcrete components shall comply with the requirements of Section [03300] [03310].

2. Placing Machines: The pumping system utilized to convey mixed concrete shall deliver a uniform and uninterrupted flow of material, without segregation or loss of the ingredients. The main run from the pump to the WORK shall be at least 3-inch diameter steel pipe or flexible hose reduced to 2-inch diameter at the point of

expulsion. Aluminum pipe will not be permitted. The air compressor shall have the capacity to deliver at least 100 cubic feet per minute for each operating nozzle.

3. Continuous Mixing: Equipment for continuously mixed shotcrete, for dry or wet application shall comply with the requirements of ASTM C 685.

2.3 PROPORTIONING

A. The proportion of constituents of shotcrete mix shall be determined in accordance with ACI 506.2.

B. The CONTRACTOR shall make and test, in accordance with paragraph 1.7 herein, specimens from three or more different mix proportions and shall submit proposed mix proportions and test results for review of the CONSTRUCTION MANAGER.

PART 3 -- EXECUTION

3.1 GENERAL

A. Pneumatically-placed concrete shall be used on the work where shown; and, where not shown, may be used only with written approval of the CONSTRUCTION MANAGER.

3.2 RESTRICTIONS ON PLACING PNEUMATICALLY-PLACED CONCRETE

A. **Wind:** Pneumatically-placed concrete shall not be applied under strong wind conditions, as evidenced by the removal of a considerable amount of cement and moisture from the concrete spray; provided, that in areas where strong winds prevail and work must proceed, a richer mix than specified which is acceptable to the CONSTRUCTION MANAGER, shall be used. The nozzleman shall work against the direction of the wind to avoid concrete being applied on rebound that has been carried with the wind. Shields shall be placed around the nozzleman to prevent the loss of cement carried away by the wind.

B. **Rain:** Whenever rain has damaged newly-placed concrete, the CONSTRUCTION MANAGER may order such concrete to be removed when it has been determined that a significant amount of cement has been washed out. The CONTRACTOR prior to placing any new layers shall consult with the CONSTRUCTION MANAGER as to whether or not the concrete damaged by rain is acceptable to the CONSTRUCTION MANAGER or must be replaced.

C. **Low Humidity:** Under low humidity conditions (below 50 percent) in conjunction with wind, the CONTRACTOR shall immediately cease placing operations until there has been an improvement in the wind and humidity conditions as determined by the CONSTRUCTION MANAGER. Continuous water-curing shall be started as soon as the concrete has hardened sufficiently to prevent a washout of cement.

3.3 PROTECTION OF ADJACENT WORK

A. The CONTRACTOR shall take every possible precaution to protect adjacent work, concrete surfaces, vehicles, equipment, etc., from being damaged by overshooting concrete and by materials carried by the wind. Overshot concrete and rebound concrete shall be removed before it adheres.

3.4 PROPORTIONING

A. Unless otherwise indicated, the minimum 28-day compressive strength of structural pneumatically-placed concrete shall be [4,000 psi].

B. All other pneumatically-placed concrete shall ordinarily be mixed in the proportions of one sack of cement (94 pounds) to 4-1/2 cubic feet of sand.

3.5 BATCHING MIXING

A. Mixing and placing of pneumatically-placed concrete shall conform to the requirements specified herein and to the applicable recommendations given in ANSI/ACI 506.

B. Mix proportions shall be controlled by weight batching or by volume batching meeting the requirements of ASTM C 685.

C. Use batching and mixing equipment capable of proportioning and mixing all ingredients (except water in the case of dry-mix equipment) at a rate that will provide adequate production, and with an accuracy that will ensure uniformity.

D. Ready-mixed concrete shall comply with ASTM C 94 or with ASTM C 685, in which case the ingredients shall be delivered dry and proportioned and mixed at the site.

E. In case of dry-mix application, the sand and cement shall be thoroughly mixed in a dry state before being deposited in the placing machine or its hopper. Machine mixing will be required unless specific authority to use hand mixing is given by the CONSTRUCTION MANAGER. The machine and its operation shall be acceptable to the CONSTRUCTION MANAGER. The mixing operation shall continue for a period of not less than 1-1/2 minutes after all sand and cement has been placed in the mixer. The sand shall contain or be moistened with 6 to 10 percent of water by volume and shall not be mixed with the cement until just before placing in the hopper in order to insure against partial setting of the cement. Dry-mixed materials shall be used promptly after mixing. Any materials that remain in the hopper longer than 45 minutes after mixing shall be discarded.

3.6 PREPARATION OF FOUNDATION

A. The foundation for areas to receive pneumatically-placed concrete shall be evenly graded before the concrete is applied, and no point on the graded slope shall be above the slope plane indicated or as otherwise acceptable to the CONSTRUCTION MANAGER. The areas shall be thoroughly compacted, with sufficient moisture to provide a firm foundation and to prevent absorption of water from the concrete, but shall not contain free surface water. When indicated, joints, side forms, and shooting strips shall be provided for backing or paneling. Ground or gaging wires shall be used where necessary to establish thicknesses, surface planes, and finish lines.

3.7 JOINTS

A. Contraction (dummy) joints shall be provided in the locations indicated; where not indicated, such joints shall be provided at approximately 15 ft spacing each direction in the case of unreinforced pneumatically-placed concrete, and at approximately 30-ft spacing each direction in the case of reinforced pneumatically-placed concrete. Construction joints shall be provided as indicated, or if not indicated, as placing stops at locations selected by the CONTRACTOR and acceptable to the CONSTRUCTION MANAGER.

3.8 REBOUND

A. Rebound recovered which is clean and free of foreign material may be reused as fine aggregate in quantities not to exceed 20 percent of the total fine aggregate requirements.

3.9 PLACING WHERE NO FORMS ARE USED

A. **Preparation of Subgrade:** All cleaning, excavation, fill, backfill, grading of compacted fill, and disposal of excess earth shall be done prior to the application of pneumatically-placed concrete. The surfaces against which pneumatically-placed concrete are to be applied shall be left in a thoroughly compacted condition, and shall be neatly trimmed to line and grade. All surfaces shall be wetted before application, but pneumatically-placed concrete shall not be placed on any surface on which free water exists.

B. **Minimum Thickness:** Minimum thickness shall be 1-1/2 inches unless otherwise indicated.

C. **Reinforcement:** Reinforcement shall be as shown; provided, that where welded wire fabric is indicated it shall be spliced as follows: (1) side splices of sheets or roll shall be spliced a minimum of one mesh plus 2 inches; (2) longitudinal splices, or direction of principal stress, shall be spliced a minimum of 2 mesh plus 2 inches. Tie wires shall only be used on cross wires on side splices and on longitudinal wires on end splices.

D. **Ground Wires:** Ground wires shall be installed in channels or ditches in such a manner that they accurately outline the finished surface of the lining as indicated. They shall be located at intervals sufficient to insure proper thickness throughout. Wires shall be stretched tight and shall not be removed prior to application of the finish coat.

E. **Headers:** Headers shall be installed along the channel where indicated. Headers shall be securely fastened to line and grade.

F. **Placing:** Pneumatically-placed concrete shall be placed in the most expeditious manner as determined by the location of the work. There shall be a nozzleman's helper in attendance at the nozzle whose duty shall be to raise the reinforcement mat sufficiently to permit placing of concrete beneath the mat at frequent intervals to insure proper location of reinforcement. The reinforcing mat shall not be pulled through already placed concrete.

G. **Finishing:** After the concrete has been placed as nearly as practicable to the required depth, the surface shall be checked with a straight edge and any low spots or depressions shall be brought up to proper grade by placing additional pneumatically-placed concrete in such a manner that the finished surface is reasonably smooth. Following this, the surface shall receive a [steel trowel] [wood float] [rubber float] [gun] finish.

H. **Weep Holes:** Where weep holes are indicated, they shall be installed so that they are flush with the surface of the lining, and open.

3.10 PLACING AGAINST FORMS

A. **Forms:** Forms shall be of plywood or sheathing and shall be true to line and level. They shall be substantially braced to insure against excessive vibration. Forms shall be built so as to permit the escape of air and rebound and to facilitate the placing of pneumatically-placed concrete. Wall intersections shall be formed in such a manner as to afford a minimum loss of time in pneumatically placing the concrete at the intersection. This may be accomplished by the installation of short removable bulkheads at these points. Columns

shall be formed on 2 adjacent sides only where practicable. Forms for beams shall be constructed of a soffit and one side. Where acceptable to the CONSTRUCTION MANAGER, such forms may be constructed of a soffit form only and a vertical backing of fine wire mesh near the center. Wood beams and shores shall be provided below the soffit in such a manner that no deflection will occur under the load to be superimposed.

B. Sufficient time shall be allowed for installing such elements of the work which must be attached to forms. Forms shall be thoroughly wetted with water prior to application of the concrete.

C. **Reinforcement:** Reinforcement shall be of the sizes and configuration. Adequate chairs, ties, or other supports shall be used to maintain the reinforcing in the position required.

D. **Ground Wires:** Adequate ground wires to be used as screeds shall be installed to establish the thickness and surface planes of the work. Both horizontal and vertical ground wires shall be installed at corners and offsets not clearly established by the form work. Ground wires shall be placed so that they are tight and true to line and in such a manner that they may be easily tightened up. Ground wires shall not be removed until application of the finish coat.

E. **Placing:** Whenever possible, except when enclosing reinforcing steel, the nozzle shall be held at right angles to the surface and at a distance of 2-1/2 to 3-1/2 feet. When enclosing steel, the nozzle shall be held so as to direct the material behind the bars. Each side of individual bars shall be shot separately. When enclosing reinforcing steel, a nozzleman's helper equipped with an air blow-out jet shall precede the nozzleman and blow out all rebound, sand, etc., which may have lodged behind the bars. Pneumatically-placed concrete shall emerge from the nozzle in a steady, uninterrupted flow. When flow becomes intermittent for any cause, the nozzle shall be diverted from the work until the stream again becomes constant. Hydration shall be thorough and uniform without the use of excessive water.

F. In shooting walls or columns, application shall begin at the bottom and the first coat shall completely embed the reinforcement adjacent to the form. The limit of thickness and height shall be determined when the materials begin to sag.

G. In shooting beams, a surface at right angles to the nozzle shall be maintained. Beams, in general, shall not be shot from the top. Where beams are formed of a soffit and a mesh backing at the centerline, they shall be shot from both sides in such a manner that no sags occur.

H. In shooting slabs, the nozzle shall be held at a slight angle to the work so that rebound is blown on to the finished portion where it shall be removed. The air blow-out jet shall be constantly employed to keep the work free of rebound. The limit of material to be placed in one layer shall be reached when it begins to show evidence of too much moisture. All loose material or rebound shall be removed from the surface being concreted before placing succeeding layers. Reinforcement shall be cleaned of any previously deposited concrete which might prevent proper bond to reinforcement. Sufficient time shall be allowed between layers for the material to set. Before set has taken place and before placing any succeeding layer, laitance shall be removed by wire brushing. Any laitance which has set shall be removed by sandblasting. Surfaces shall be damp at all times. Rebound pockets, sags, or other defects shall be carefully cut out and replaced with new pneumatically-placed concrete.

I. **Finishing:** Upon reaching the thickness and planes outlined by forms and ground wires, the surface shall be rodded off to true lines. Low spots shall be built out to proper thickness. Upon completion of rodding, ground wires shall be removed. The finish coat shall be applied starting from the top of walls and working down so that pneumatically-placed concrete is not shot over the finished work. All exposed surfaces shall be finished to straight and true lines, as shown.

J. Finish shall be a [steel trowel] [wood float] [sponge float] [rubber float] [sack] [broom] [rodded] [gun] finish.

3.11 JOINTS

A. **Construction Joints:** Particular care shall be given to formation of construction joints. They shall be sloped to a thin edge and the edge shall be thoroughly wetted before adjacent section of pneumatically-placed concrete is placed. No square joints will be allowed. The location of all construction joints in structural members shall be acceptable to the CONSTRUCTION MANAGER.

B. **Formed Joints:** All formed joints shall be constructed as detailed, at the locations shown.

3.12 CURING

A. Pneumatically-placed concrete shall be damp cured for at least 5 days after placing or by proper application of an approved sealing compound. Curing shall conform to the applicable requirements of Sections 03300 and 03310.

B. When required by the CONSTRUCTION MANAGER the CONTRACTOR shall provide longer curing times or supplemental methods for curing concrete in structural members, and no additional payment will be allowed therefor.

3.13 CLEANUP

A. Upon completion of the WORK indicated in this Section, the CONTRACTOR shall remove all forming, shoring, rebound, excess material, and protective materials from the project site.

** END OF SECTION **