BEST PRACTICES MANUAL

PRECAST CONCRETE UTILITY STRUCTURE MANUFACTURING

DEDICATED TO EXPANDING THE USE
OF QUALITY PRECAST CONCRETE

Third Edition
February 2014

NPCA
Precast ... The Concrete Solution

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Precast ... The Concrete Solution

The association of the manufactured concrete products industry

This best practices manual is subject to revision at any time by the NPCA Utility Structures Product Committee, which must review it at least every three years.

Special thanks are given to the Utility Structures Product Committee for updating/compiling this manual.

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NOTES

1. This manual does not claim or imply that it addresses all safety-related issues, if any, associated with its use. The manufacture of concrete products may involve the use of hazardous materials, operations and equipment. It is the user's responsibility to determine appropriate safety, health and environmental practices and applicable regulatory requirements associated with the use of this manual and the manufacture of concrete products.

2. Use of this manual does not guarantee the proper function or performance of any product manufactured in accordance with the requirements contained in the manual. Routine conformance to the requirements of this manual should result in products of an acceptable quality according to current industry standards.

INTRODUCTION

Precast concrete is ideally suited for all types of utility structure applications including electrical, gas, industrial, telecommunications, renewable-energy structures, and water and wastewater structures. A properly manufactured and installed precast concrete structure can last almost indefinitely. Precast concrete is inherently durable, highly impermeable and corrosion-resistant.

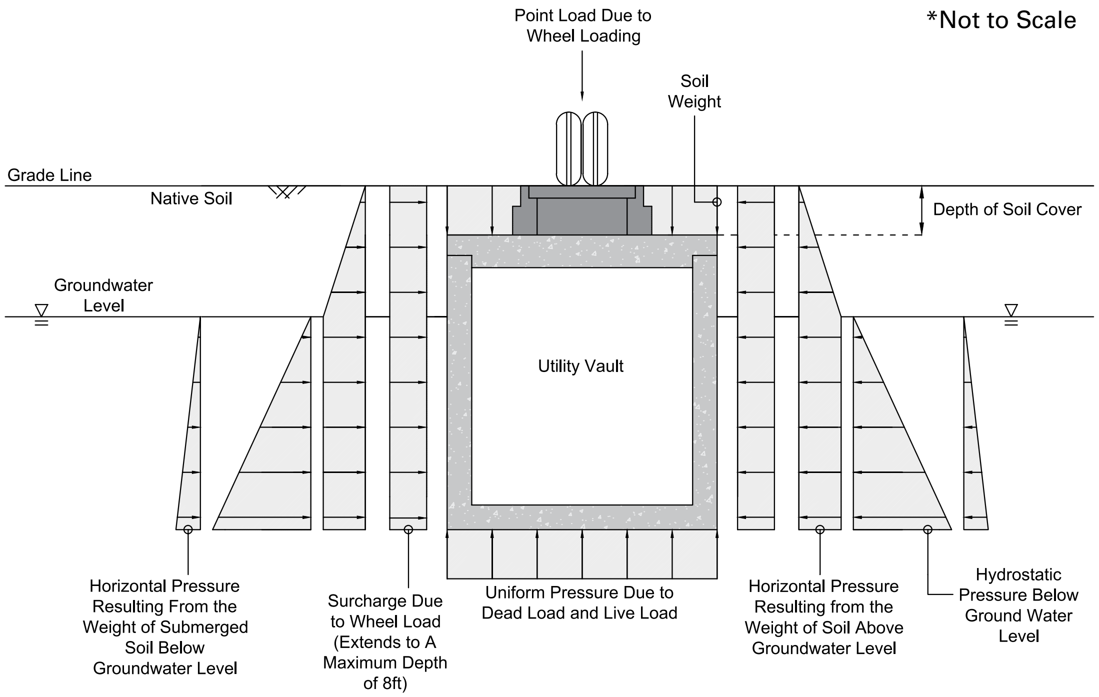
Utility structures are an important segment of the manufactured concrete products industry, and we must continue to provide project owners and end users with the best possible products at competitive prices. It is also important that those products contribute to the quality, timeliness and ease of installation of construction projects. The best practices outlined in this manual are intended to help manufacturers achieve these goals.

When properly designed and manufactured, precast concrete is capable of maintenance-free performance without the need for protective coatings, except in certain circumstances such as highly corrosive environments. The precast advantage is further solidified through precast's strength and ease of installation. Since precast concrete products typically are produced in a controlled environment, they exhibit high quality and uniformity. Adverse factors affecting quality typically found on job sites – variable temperature, uneven curing conditions, inconsistent material quality and craftsmanship – are significantly reduced in a plant environment.

High-quality concrete products are important for many applications, most notably for underground structures that must resist soil pressures and sustain surface loads.

This manual is intended to guide manufacturers in quality production processes for manufacturing utility structures. The manual is not intended to be all-inclusive and the recommendations are not intended to exclude any materials or techniques that would help achieve the goal of providing structurally sound, high-quality products. Attention to detail, quality materials, proper training and a workforce dedicated to quality control will ensure that the utility structure meets or exceeds the expectations of contractors and end users.

STRUCTURAL DESIGN



*Manfacturer to specify the maximum depth of cover

Loading Conditions

A properly designed precast concrete utility structure must withstand a variety of loading conditions, which vary during manufacturing, installation, testing and service. These structures are designed to withstand loading conditions through rational mathematical design calculations, by proof-of-load testing or in accordance with ASTM C857, "Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures."

Consider the following in the design:

- Surface surcharge loads
- Concentrated wheel and other traffic loads
- Lateral loads
- Presumptive soil bearing capacity
- Buoyant forces
- Connections and penetrations
- Point loads
- Additional reinforcement for shipping and handling

Precast concrete utility structures should be designed according to one or more of the following industry codes and standards and as required by any regulatory groups with jurisdiction:

- ACI 318, "Building Code Requirements for Structural Concrete"
- AASHTO Standard Specifications for Highway Bridges
- ASTM C857, "Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures"
- ASTM C858, "Specification for Underground Precast Concrete Utility Structures"

The loading conditions illustrated in the diagram should be analyzed and considered in the design of a utility structure.

The following design characteristics have a critical impact on the performance of utility structures.

Concrete Thickness

The concrete dimensions must be designed to withstand design loading conditions and to meet minimum reinforcement cover requirements.

Concrete Mix Design

Concrete must have a minimum compressive strength of 4,000 psi at 28 days. Consider methods to reduce permeability, improve durability and increase strength. Maintain a low water-to-cementitious materials ratio at or below 0.45.

Reinforcement

Proper design and placement is critical to withstand the significant loads applied to utility structures. Reinforcement

must be sufficient for required strength and service conditions, including temperature and shrinkage effects. Control cracking by using multiple small-diameter steel bars rather than fewer large-diameter steel bars. Synthetic fiber reinforcement also helps to reduce cracking and may add some strength, but should not replace primary reinforcement. Steel fibers have been recognized for use as primary and temperature/shrinkage reinforcement. Steel fiber reinforced concrete design methods based on evaluation reports from providers accredited to ISO/IEC Guide 65 including ICC-ES and Uniform-ES may be used. European design codes such as the fib and DafStb may be considered as well. Please check with the authorizing body before using steel fibers. Welded-wire reinforcement can also be used, but pay particular attention to design and location. All reinforcement should meet applicable ASTM specifications.

Proof of Design Testing

Many projects will require evidence of structural design either by review of calculations or by a performance test to demonstrate that failure will not occur under specified loading conditions.

ASTM C857 should be used as a basis for determining design loads.

When required, proof testing is used to demonstrate the strength of the structure to resist anticipated uniform loads such as:

- Internal and external hydrostatic pressure
- Vertical and lateral soil loads
- Self weight of structure
- Uniform live load

Structures may be tested by means of vacuum testing to simulate the actual anticipated uniform loads.

When vacuum testing, make sure the structure is resting on a yielding foundation such as a sand bed to ensure that dead load from self-weight does not control the bottom slab design. Also, keep in mind that the top and bottom slabs may have greater structural capacity than the side walls. The vacuum pressure is applied equally to all surfaces of the structure, so additional uniform loads may be applied to the top slab to increase the allowable capacity of the top and bottom slabs.

The required target vacuum pressure may be specified by the project engineer, but often it is set at 150% of the anticipated actual loads. Once the vacuum target value has been reached and held for the required time, drop the vacuum gradually to avoid damage to the structure.

Concentrated live loads such as truck wheel loads shall be tested in a manner that simulates the anticipated wheel footprint and axle spacing. Test load shall include the design wheel load plus impact and live load factor, as required by design.

A licensed professional engineer should evaluate the test results to determine the allowable live loads and placement depth of the tank under various soil conditions.

MATERIALS

The primary constituents of precast concrete are cement, fine and coarse aggregates, water and admixtures. The following discussion covers relevant factors in the selection and use of these fundamental materials.

Cement

The majority of cement used in the manufactured concrete products industry is governed by ASTM C150, "Specification for Portland Cement."

The five primary types of ASTM C150 cement are:

Type I	Normal
Type II	Moderate Sulfate Resistance
Type III	High Early Strength
Type IV	Low Heat of Hydration
Type V	High Sulfate Resistance

Select the cement type based on project specifications or individual characteristics that best fit the operation and regional conditions of each manufacturer. Note that certain types of cement may not be readily available in certain regions. A Type I/II cement can be blended with Type "F" fly ash or slag to meet Type V specification.

Store cement in a manner that will prevent exposure to moisture or other contamination. Bulk cement should be stored in watertight bins or silos. If different types of cement are used at a facility, store each type in a separate bin or silo. Clearly identify delivery locations.

Design and maintain bin and silo compartments to discharge freely and independently into the weighing hopper. Cement in storage should be drawn down frequently to prevent undesirable caking. Stack bagged cement on pallets to permit proper air circulation and to avoid undesirable moisture and condensation. On a short-term basis (less than 90 days), stack the bags no more than 14 high. For long-term storage, do not exceed seven bags in height (or per manufacturer's recommendations). Use the oldest stock first. Discard any cement with lumps that cannot be reduced by finger pressure.

Aggregates

Ensure aggregates conform to the requirements of ASTM C33, "Specification for Concrete Aggregates." The maximum size of coarse aggregate should be as large as practical, but should not exceed 20% of the minimum thickness of the precast concrete utility structure or 75% of the clear cover between reinforcement and the surface of the structure. Larger maximum sizes of aggregate may be used if evidence shows that satisfactory concrete products can be manufactured.

Aggregates are an important constituent of precast concrete utility structures. Nearly 75% of a precast concrete utility structure's structure consists of coarse and fine aggregates.

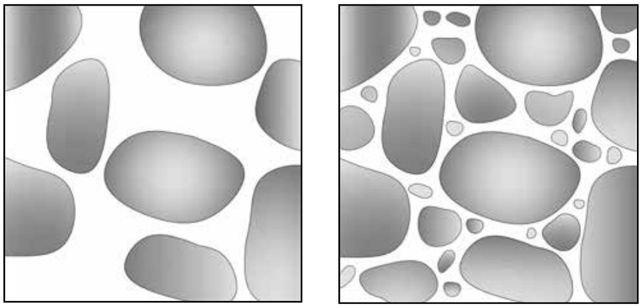
The selection of appropriate aggregates is largely a regional concern. The selection process is based on using the best available clean, hard, durable aggregates and proper gradations. Aggregates should conform to ASTM C33 and ACI 318.

Quality of Aggregates

Concrete is exposed to continuous moist and potentially corrosive conditions in underground applications. Consequently, two important selection parameters are the aggregate's reactivity and its porosity. It is important to specify a well-graded, sound, nonporous aggregate in accordance with ASTM C33. When receiving aggregate from an area known to have potential problems with alkali-aggregate reaction, alkali-silica reaction or alkali-carbonate reaction, the aggregate supplier should provide sufficient laboratory data on the aggregate's potential reactivity. It is important to avoid using aggregates containing materials that are deleteriously reactive with the alkalis in cement.

If the only available aggregates in your area have been found to cause excessive expansion of mortar or concrete, appropriate precautionary measures should be taken during the mix design process. The use of mineral admixtures, a low water-to-cementitious materials ratio or a low-alkali cement can all aid in controlling such expansive reactions. When using mineral admixtures or a low-alkali cement, trial batches should be tested to establish their viability in controlling the expansive reactions.

Gradation of Aggregates



Poorly Graded vs. Well Graded Aggregate

Aggregate gradation influences both the economy and strength of a finished utility structure. The purpose of proper gradation is to produce concrete with a maximum density along with good workability to achieve sufficient strength.

Well-graded aggregates help improve workability, durability and strength of the concrete. Poorly graded or gap-graded aggregates rely on the use of excess mortar to fill voids between coarse aggregates, leading to potential durability problems. Concrete mixes containing rounded coarse aggregates tend to be easier to place and consolidate. However, crushed aggregates clearly are acceptable. The use of elongated, flat and flaky aggregates is discouraged. Gap-graded aggregates lacking intermediate sizes are also discouraged.

Aggregate Deleterious Substances

Ensure all aggregates are free of deleterious substances, including:

- Substances that cause an adverse chemical reaction in fresh or hardened concrete
- Clay, dust and other surface-coating contaminants
- Structurally soft or weak particles

For good bond development, ensure aggregate surfaces are clean and free from excessive dust or clay particles. Excessive dust or clay particles typically are defined as material passing a No. 200 sieve, the limit of which is no more than 3%. Friable aggregates may fracture in the mixing and placement process, compromising the integrity of the hardened concrete product.

The standard test for measuring organic impurities in fine aggregates is outlined in ASTM C40, "Test Method for Organic Impurities in Fine Aggregates for Concrete.

Moisture Content of Aggregate

The measurement of aggregate moisture content is important in the control of concrete workability, strength and quality. Aggregates – particularly fine aggregates (sands) – can collect considerable amounts of moisture on their surfaces. Fine aggregates can hold up to 10% moisture by weight; coarse aggregates can hold up to 3%.

The ideal aggregate state for batching concrete is saturated surface dry, where all aggregate pores are filled with water but no liquid film exists on the aggregate's exterior. Water on the surface of an aggregate that is not calculated into the mixture proportions will increase the water-to-cementitious materials ratio. Aggregate with a moisture content lower than that of a saturated surface dry state can increase water demand by absorbing mix water during batching and placement, which can lead to workability and durability issues. The moisture content of aggregates will vary throughout a stockpile and will be affected by changes in weather conditions. Therefore, adjust mixture proportions as necessary throughout the production day to compensate for moisture content changes in the aggregate.

The following methods will increase the likelihood of uniform moisture content:

- Enclose storage of daily production quantities
- Store aggregates in horizontal layers
- Have at least two stockpiles
- Allow aggregate piles to drain before use
- Avoid the use of the bottom 12 in. of a stockpile
- Sprinkle aggregate stock piles (climate dependent) continuously
- Store entire stockpile indoors or under cover

Careful monitoring of aggregate moisture content during batching will reduce the need to add additional cement to offset excess water. This will maintain high quality standards and save on expensive raw materials.

The plant should have a program in place that manages surface moisture content or accounts for moisture variation during batching.

Handling and Storage of Aggregate

Aggregate handling is an important operation. Handle and store aggregates to prevent contamination, and minimize segregation and degradation. Accurately graded coarse aggregate can segregate during a single improper stockpiling operation, so handling should be minimized to reduce the risk of particle size segregation. Also minimize material drop heights and the number of handling operations to avoid breakage.

The following methods can prevent segregation:
- Store aggregates on a clean, hard, well-drained base to prevent contamination. Bin separation walls should extend high enough to prevent overlapping and cross-contamination of different-sized aggregates.
- Avoid steep slopes in fine aggregate stockpiles. Fine aggregate stockpiles should not have slopes greater than the sand's angle of repose (i.e., natural slope, typically 1:1.5) to prevent unwanted segregation.
- Remove aggregates from a stockpile by working horizontally across the face of the pile. Avoid taking aggregate from the exact same location each time.

Water

Water used in mixing concrete should meet the requirements of ASTM C1602, "Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete." Avoid water containing deleterious amounts of oils, acids, alkalis, salts, organic material or other substances that may adversely affect the properties of fresh or hardened concrete.

Chemical Admixtures

Commonly used chemical admixtures in precast concrete manufacturing include:
- Accelerating admixtures (ASTM C494, "Specification for Chemical Admixtures for Concrete")
- Air entraining admixtures (ASTM C260, "Specification for Air-Entraining Admixtures for Concrete")
- Water-reducing admixtures (ASTM C494)
- High-range water-reducing admixtures or superplasticizers (ASTM C1017, "Specification for Chemical Admixtures for Use in Producing Flowing Concrete")

Store admixtures in a manner that avoids contamination, evaporation and damage. Protect liquid admixtures from freezing and extreme temperature changes, which could adversely affect their performance. It is also important to protect admixture batching components from temperature extremes and dust. Ensure they are accessible for visual observation and periodic maintenance. Perform periodic recalibration of the batching system as recommended by the manufacturer or as required by local regulations.

Chemical admixture performance can vary. Exercise caution, especially when using new products. Test some trial batches and document the results before using a new admixture for production. Follow the manufacturers' recommendations exactly. Carefully check admixtures for compatibility with the cement and any other admixtures used. Do not mix similar admixtures from different manufacturers without the manufacturers' agreement or testing to verify compatibility.

Additional guidelines for the use of admixtures are included in ACI 212.3R, "Report on Chemical Admixtures for Concrete." Avoid accelerating admixtures that contain chlorides in order to prevent possible corrosion of reinforcing steel elements and other embedded metal objects.

Supplementary Cementitious Materials (SCMs)

SCMs are often incorporated into a concrete mix to reduce cement contents, improve workability, increase strength and enhance durability. The most common types of SCMs are fly ash, silica fume and ground granulated blast furnace slag (GGBFS), known simply as slag. More than one SCM may be incorporated into a mix while various types of blended cements using SCMs are also available. The following standards establish the minimum requirements for some of the common SCMs and blended cements.
- ASTM C595, "Specification for Blended Hydraulic Cements"
- ASTM C618, "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete"
- ASTM C989, "Specification for Slag Cement for Use in Concrete and Mortars"
- ASTM C1240, "Specification for Silica Fume Used in Cementitious Mixtures"

It is important to review the precast product standards to determine if there are any limits on the amount of SCMs permitted in the concrete mix.

Ready-Mixed Concrete

Verify that the ready-mixed concrete supplier is operating in accordance with ASTM C94, "Specification for Ready-Mixed Concrete." Perform plastic concrete tests (slump, temperature, air content and density) at the plant prior to casting products. Record any added water on the delivery batch ticket for each truck and keep it on file.

CONCRETE MIXTURE PROPORTIONING

Concrete mix design, also known as mix proportioning, is a broad subject – one that is specific to concrete in general but not necessarily to utility structures in particular. This discussion will focus on critical factors that should be considered when casting high-quality precast concrete utility structures.

Mix designs are selected based on performance factors including permeability, consistency, workability, strength and durability. The elements necessary to achieve high-quality precast concrete include:

- Low water-to-cementitious materials ratio (less than 0.45)
- Minimum compressive strength of 4,000 psi at 28 days
- Use of quality aggregates
- Appropriate concrete consistency (concrete that can be readily placed by traditional methods; this is typically measured by slump)

High water-to-cementitious materials ratios lead to undesirable increased capillary porosity within the concrete. Capillary pores are voids resulting from the consumption and evaporation of water during the hydration or curing process. Enlarged and interconnected capillary voids serve as pathways for water and other contaminates to infiltrate the concrete system. Lower water-to-cementitious materials ratios result in smaller and fewer pores, reducing the concrete's permeability.

Aggregate quality and gradation have a tremendous impact on the concrete's overall quality. Mix designs with well-graded aggregates and sufficient quantities of fine aggregate have reduced water demands (i.e., lower water-to-cementitious materials ratios) while maintaining adequate workability and ease of placement.

Proper consistency of fresh concrete is a critical element in producing high-quality precast concrete. Fresh concrete must be sufficiently plastic (flowable or deformable) to be properly placed, consolidated and finished. The size, shape and grading of aggregates, cement content, water-to-cementitious materials ratio and admixtures affect the workability of a mix.

Water-reducing admixtures and superplasticizers can greatly increase the workability of fresh concrete without changing the water-to-cementitious materials ratio. Experience has shown that concrete with low water-to-cementitious materials ratios (less than 0.45) can be properly placed and consolidated with the appropriate use of admixtures. However, air entrainment is usually limited to 3% to 7.5% for moderate freeze-thaw exposure and 4.5% to 9% for severe freeze-thaw exposure (page 33 of *NPCA QC Manual*).

The use of chemical admixtures for wet-cast concrete (such as air-entraining admixtures, water-reducing admixtures and superplasticizers) helps to attain workable concrete with a low water-to-cementitious materials ratio. Their use is particularly important, since most utility structures require heavier reinforcing and have large penetrations that require special attention to ensure full consolidation. In certain circumstances, and where local regulations allow, properly designed and tested self-consolidating concrete (SCC) can be used to improve the likelihood of proper bond between concrete and reinforcement.

Air-entraining admixtures are designed to disperse microscopic air bubbles throughout the concrete's matrix to function as small "shock absorbers" during freeze-thaw cycles. The required air content for frost-resistant concrete is determined by the maximum aggregate size and severity of in-service exposure conditions (ACI 318). Air entrainment improves workability and reduces bleeding and segregation of fresh concrete while greatly improving the durability of hardened concrete.

LIFTING INSERTS

Commercially manufactured lifting inserts come furnished with documented and tested load ratings. Use the devices as prescribed by the manufacturer's specification sheets. The capacity of commercial lifting devices must be marked on the devices. Verify lifting inserts for capacity, and ensure an adequate safety factor for lifting and handling products taking into account the various forces acting on the device.

Lifting inserts that are embedded or otherwise attached to precast concrete members shall be capable of supporting at least four times the maximum intended load applied or transmitted to them, as required by OSHA 29 CFR 1926.704 (c). Other applicable codes and standards are ANSI A10.9, "Safety Requirements for Concrete and Masonry Work" and ASTM C857, ASTM C890, "Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures" and ASTM C913, "Specification for Precast Concrete Water and Wastewater Structures."

Lifting inserts designed in the plant and not commercially manufactured must be load tested or evaluated by a professional engineer.

Because of their brittle nature, reinforcing bars should not be used as lifting devices. Instead, smooth bars made of steel conforming to ASTM A36 can be used.

REINFORCEMENT

Fabrication drawings must be a part of every QC program. Fabrication drawings should detail the reinforcement requirements and all necessary information pertaining to the product prior to casting.

Conventional Reinforcement

Fabricate reinforcing steel cages by tying or welding the bars, wires or welded wire reinforcement into rigid structures. The reinforcing steel cages should conform to the tolerances defined on the fabrication drawings. If not stated, minimum bend diameters on reinforcement should meet the requirements set forth in ACI 318, as defined in Table 1. Make all bends while the reinforcement is cold. The minimum bend diameter for concrete reinforcing welded wire reinforcement is $4d_b$.

Table 1: Concrete Reinforcing Steel

ASTM A615 and A706 In.-Pound Bar Sizes	Minimum Bend Diameter	ASTM A615 and A706 Soft Metric Bar Sizes
# 3 through # 8	$6d_b$	# 10 through # 25
# 9, # 10 and # 11	$8d_b$	# 29, # 32 and # 36
# 14 and # 18	$10d_b$	# 43 and # 57

d_b = nominal diameter (in. or mm) of bar

Weld reinforcement (including tack welding) in accordance with AWS D1.4, "Structural Welding Code-Reinforcing Steel." This code requires either special preheat requirements (when required) or weldable grade reinforcement as defined by ASTM A706, "Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement," for any welding of reinforcing steel, including tack welds. Take special care to avoid undercutting or burning through the reinforcing steel.

Reinforcing bars conforming to ASTM A615, "Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement," are is produced from recycled metals that have higher carbon contents and are likely to become brittle if improperly welded. A brittle weld is a weak link, which can compromise the structural integrity of the finished product. ASTM A615/615M states, "Welding of material in this specification should be approached with caution since no specific provisions have been included to enhance the weldability. When the reinforcing steel is to be welded, a welding procedure suitable for the chemical composition and intended use or service should be used."

Ensure lap splices for steel reinforcement (rebar and welded-wire reinforcement) meet the requirements of ACI 318. Adequate development length is required to develop the design strength of the reinforcement at a critical section. A qualified engineer should determine development length and clearly indicate it on shop drawings.

Deformed steel reinforcement should be free of materials other than those addressed by the ASTMs, which would prohibit concrete from adequately bonding to the rebar. Reinforcement with rust shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a wire hand-brushed test specimen are not less than that required by applicable ASTM standards. Cut, bend and splice reinforcing steel in accordance with fabrication drawings and applicable industry standards. Inspect reinforcing cages for proper size, spacing, bends and length. Secure the reinforcing cage in the form so that shifting will not occur during casting. Use only chairs, wheels and spacers made of noncorrosive materials.

It is important to place and hold reinforcement in position as shown in the fabrication drawings. A maximum recommended placement tolerance for reinforcement is within ¼ in. of the design location, while in no case causing the concrete cover to be less than ¾ in. As a general rule, the variation in spacing between bars should not exceed more than 1⁄10 of the designed bar spacing nor exceed 1.5 in. in variation, except for welded wire mesh conforming to ASTM A1064, "Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete". The recommended minimum concrete cover over reinforcing steel is ¾ in. (ASTM C858).

Fiber Reinforcement

Data must be available to show conclusively that the type, brand, quality and quantity of fibers to be included in the concrete mix are not detrimental to the concrete nor to the precast concrete product. Fiber-reinforced concrete must conform to ASTM C1116, "Specification for Fiber-Reinforced Concrete." The two most popular types of fibers are synthetic and steel fibers. Steel fibers must conform to ASTM A820, "Specification for Steel Fibers for Fiber-Reinforced Concrete." Synthetic fibers must conform to

Photo courtesy of Lindsay Precast Inc.

ASTM D7508, "Standard Specification for Polyolefin Chopped Strands for Use in Concrete."

Synthetic macrofibers may replace secondary reinforcement when compared with welded wire reinforcement and light-gauge steel reinforcement. Typical dosage rates for synthetic macrofibers vary depending on product and/or application.

Steel fibers have been recognized as primary and temperature/shrinkage reinforcing with long-term material properties. In some cases, steel fibers can be used alone or in conjunction with traditional reinforcing. Steel fibers will improve impact resistance and help prevent chipping of the hardened concrete. Steel fiber dosage rates may vary depending on product and/or application.

Steel and macro synthetic fiber's design shall be based on ASTM C1609, "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)" or EN 14651 beam performance testing. Proof of the fibers performance should be submitted to manufacture in the form of ASTM C1609 or EN 14651 testing.

Synthetic microfibers in concrete typically reduce plastic shrinkage cracks and improve impact resistance. They can help reduce chipping when products are stripped. Dosage rates will vary depending on product and/or application.

Fibers must be approved by a regulatory agency or specifying engineer prior to concrete placement.

Design the concrete mix so that it is workable and the fibers are evenly distributed. Chemical admixtures or adjustments to the concrete mixture design may be necessary to achieve proper consolidation and workability. It is important to adhere to the manufacturer's safety precautions and to follow instructions when introducing the fibers into the mix.

Embedded Items

Items such as plates and inserts must be held rigidly in place during casting. All embedded items should be resistant to corrosion. Special consideration and code complience should be given when welding operations are required.

PRODUCTION PRACTICES

Quality Control

All plants must have a quality control program and manual, including but not limited to the following:

- Documented mix designs
- Pre-pour inspection reports
- Form maintenance logs
- Post-pour inspection reports
- Documentation of structural and watertightness testing discussed in this manual
- Plant quality control procedures
- Raw materials testing reports
- Production practices
- Reinforcement fabrication and placement
- Concrete testing
- Storage and handling
- Documentation of personnel training

Records of the above listed items should be available for review by appropriate agencies upon request. Participation in the NPCA Plant Certification Program is recommended as an excellent way to ensure product quality. Use the *"NPCA Quality Control Manual for Precast Concrete Plants"* as the basis for developing a strong quality control program.

Forms

Forms must be in good condition. Frequent inspection intervals and regular maintenance ensure that forms are free of any damage that could cause concrete placement difficulties or dimensional problems with the finished product.

Use forms that prevent leakage of cement paste and are sufficiently rigid to withstand the vibrations encountered in the production process. Maintain forms properly, including cleaning after each use and inspection prior to each use, to ensure uniform concrete surfaces. Ensure forms are level and on a solid base.

At a minimum, forms should be taken out of production every year and checked for dimensional accuracy and needed repairs. Records should be kept to track inspections and possibly identify recurring problems.

Pre-Pour Inspection

A typical pre-pour checklist, as illustrated on page 14, provides a means of documenting the required quality checks. A qualified individual should make inspections prior to each pour. Correct any deviations prior to the start of placement activities. Anchor locations and tolerances should be as per ASTM C858.

Pre-Pour Operations Include:

- Preparing and setting forms
- Positioning steel reinforcement according to structural design
- Placing blockouts
- Positioning embedded items

PRE-POUR CHECKLIST

PRODUCT: ______________________________ Job No. ______________

Casting Date	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Form Condition							
Form Cleanliness							
Form Joints							
Release Agent/ Retarder							
Design Length (ft/in.)							
Set-Up Length (ft/in.)							
Design Width (ft/in.)							
Set-Up Width (ft/in.)							
Design Depth (ft/in.)							
Set-Up Depth (ft/in.)							
Blockouts							
Squareness							
End and Edge Details							
Reinforcing Steel							
Size of Reinforcement							
Spacing							
Rustification							
Plates and Inserts							
Lifting Devices							
Top Finish (wet)							

REMARKS: ____

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____

QC Supervisor ____________________ Date __________ Inspector ____________________

CASTING CONCRETE

Transporting Fresh Concrete

When transporting concrete from mixer to form, use any method that does not contaminate the concrete or cause segregation or delay in placing. Concrete can be discharged directly from the mixer into the forms. ACI 304R, "Guide for Measuring, Mixing, Transporting, and Placing Concrete," is a valuable reference.

Placing Concrete

Conventional Concrete

Keep the free fall of the concrete to a minimum and deposit it as near to its final location as possible. Do not use vibration equipment to move fresh concrete laterally in the forms.

Fiber Reinforced Concrete (FRC)

Follow the same practices as described for conventional concrete, but note that the workability of the FRC may be slightly reduced.

SCC

Place SCC at a consistent rate and constant pressure head from one end or corner of the form, allowing air to escape as the concrete flows into and around steel reinforcement. Avoid placement practices that add additional energy to the mix and cause unwanted segregation, such as excessive vibration, increased pour heights or increased discharge rates.

Consolidating Concrete

SCC generally requires minimal consolidation efforts. However, when using conventional concrete, consolidation operations are required that minimize segregation and honeycombing. Consolidation can be improved on particular molds by using vibrators with variable frequency and amplitude. Three types of vibration are prevalent in the precast industry:

- Internal – stick vibrator
- External – vibrator mounted on forms or set on a vibrating table
- Surface – vibrator can be moved across the surface

Lower internal vibrators vertically and systematically into the concrete without force until the tip of the vibrator reaches the bottom of the form. When using internal vibrators, concrete should be placed in wall sections using lifts not exceeding 2 feet. Do not drag internal vibrators horizontally. Once consolidation is complete in one area, remove the vibrator vertically and move the vibrator to the next area. Regardless of the vibration method, ensure that the field of vibration overlaps with another insertion point to best consolidate the concrete and minimize defects.

Some external vibrators are mounted on a piece of steel attached to the form. Position them to allow for overlap of vibration areas. Continue the vibration process until the product is completely consolidated. Vibration is considered complete when large bubbles (3⁄8 in. diameter or greater) no longer appear at the surface. Care should be taken to avoid overvibration, because segregation of the aggregate from the cement paste can result in lowering the concrete quality and strength.

Finishing Unformed Surfaces

Each product is to be finished according to its individual specifications. If finishing techniques are not specified, take care to avoid floating either too early or for too long. Premature finishing can trap bleed water below the finished surface, creating a weak layer of concrete susceptible to freeze-thaw cycles and chemical attack. Finishing with a wood or magnesium float is recommended.

Formed Surfaces

Formed surfaces shall be smooth and free of significant honeycombed areas, air voids and "bugholes."

Secondary Pours

For products that require secondary pours, establish procedures to assure that the new concrete bonds adequately to the product and becomes an integral part of it. The surfaces of the product against which the secondary pour is to be made should be free of laitance, dirt, dust, grease or any other material that will affect the bond between the original and new concretes. If the surface is very smooth, roughen it and/or use a bonding agent to help promote a good bond between the two pours. As a minimum, use a high-quality water stop and keyway to ensure a watertight joint. Structural continuity, if required, must be guaranteed and designed for by continuing the reinforcing between pours.

CURING PROCEDURES

Two critical elements in curing concrete are maintaining correct moisture content and maintaining correct concrete temperature. Proper curing is important in developing strength, durability, chemical resistance and watertightness – all important considerations for underground utility structures.

Note: Concrete temperature discussed in this manual refers to the temperature of the concrete itself, not the ambient temperature.

The nature of precast operations poses unique challenges to proper curing. To ensure cost-effective use of forms, precasters often strip the forms at the beginning of the next workday. That is an acceptable standard, according to ACI 308R, "Guide to Curing Concrete." The time necessary to develop enough strength to strip the forms is highly dependent on ambient temperature in the casting area. The Portland Cement Association (PCA) lists three methods of curing:

1. Maintaining water moisture by wetting (fogging, spraying, wet coverings, etc.)
2. Preventing the loss of water by sealing (plastic coverings or applying curing compounds)
3. Applying heat (often in conjunction with moisture, with heaters or live steam)

Choose the methods that best suit the particular production operation. All three are permissible, but preventing the loss of water (method 2) may be the simplest choice for utility structures. Maintaining moisture requires constant wetting, which is labor intensive. Alternate wetting and drying can lead to problems with cracking. Steam curing can also be effective. Concrete temperatures should never exceed 150º F. Both of these techniques are described in ACI 308 and in the PCA publication "Design and Control of Concrete Mixtures." Plastic coverings or membrane-forming curing compounds require less labor efforts. There are some special considerations for both:

1. Plastic sheeting must comply with ASTM C171, "Specification for Sheet Materials for Curing Concrete," which specifies a minimum thickness of 4 mils and be either white or opaque in color. PCA states that other colors can be used depending on sun conditions and temperature. When using multiple sheets, overlap them by approximately 18 in. to prevent moisture loss.
2. Curing compounds can be applied when bleed water is no longer present on the surface. As with plastic, white-colored compounds might reflect sunlight better and limit temperature gain. Follow the manufacturer's recommendations.

Cold and Hot Weather Concreting

In hot and cold weather, special precautions are necessary.

Cold Weather

Hydration rates are slower during cold weather. Concrete temperatures below 50° F are considered unfavorable for pouring due to the extended time required for strength gain and the possibility of freezing. However, once concrete reaches a minimum strength of 500 psi (usually within 24 hours) freezing has a limited impact. Ideally, precast concrete operations should be performed in heated enclosures that will provide uniform heat to the products until they reach 500 psi. If necessary, heating the mixing water and/or aggregates can increase the concrete temperature. Do not heat water above 180° F, and do not use clumps of frozen aggregate and ice. ACI 306R, "Guide to Cold Weather Concreting," contains further recommendations on cold-weather concreting. Admixtures such as accelerators are often used in cold weather to accelerate hydration and set. Ensure manufacturer's recommendations are followed.

Hot Weather

High temperatures accelerate hydration. Do not allow fresh concrete temperature to exceed 90° F at the time of placement. Keep the temperature of the concrete mix as low as possible using a variety of means, including:

- Shading the aggregate piles
- Wetting the aggregates (the mix design must be adjusted to account for the additional water)
- Using chilled water

Note: During the curing process, ensure that the concrete temperature does not exceed 150° F. In all cases, protect freshly cast products from direct sunlight and drying wind. ACI 305R, "Guide to Hot Weather Concreting," contains further recommendations on hot-weather concreting.

Admixtures such as retarders are often used to slow down hydration to prevent rapid set. Make sure the manufacturer's recommendations are followed.

Cold Joints

Cold joints require special care and, as a minimum, should include a high-quality water stop, bonding agent and continuation of reinforcing between pours.

POST-POUR OPERATIONS

Stripping and Handling Products

Concrete must gain sufficient strength prior to removal from the forms and prior to handling for temporary storage and shipping. The minimum strength requirements for safe handling must be determined by a professional engineer in charge of the design or plant operations, and verified by compressive strength cylinder testing. Due to the nature of the precast business, the American Concrete Institute (ACI) recognizes that forms will usually be stripped the next workday. Under normal conditions (concrete temperature greater than 50° F), properly designed concrete can reach the minimum designated compressive strength for stripping within this time period. Regular compressive strength testing of one-day or stripping strength cylinders is recommended to confirm that proper concrete strength is attained.

Inspect the product immediately after stripping to check for damage. Handle recently poured and stripped products with care. Perform lifting and handling carefully and slowly to ensure that dynamic loads do not damage the structure, and always follow recognized safety guidelines.

Handling Equipment

Cranes, forklifts, hoists, chains, slings and other lifting equipment must be able to handle the weight of the product and comply with federal and local safety requirements. Routine inspections of all handling equipment are necessary. Qualified personnel should make periodic maintenance and repairs as warranted. Tag all chains and slings with individual load capacity ratings. For U.S. plants, refer to the specific requirements of the Occupational Safety and Health Administration (OSHA). For Canadian plants, refer to the specific requirements of the Canadian Centre for Occupational Health and Safety (CCOHS).

Post-Pour Inspections

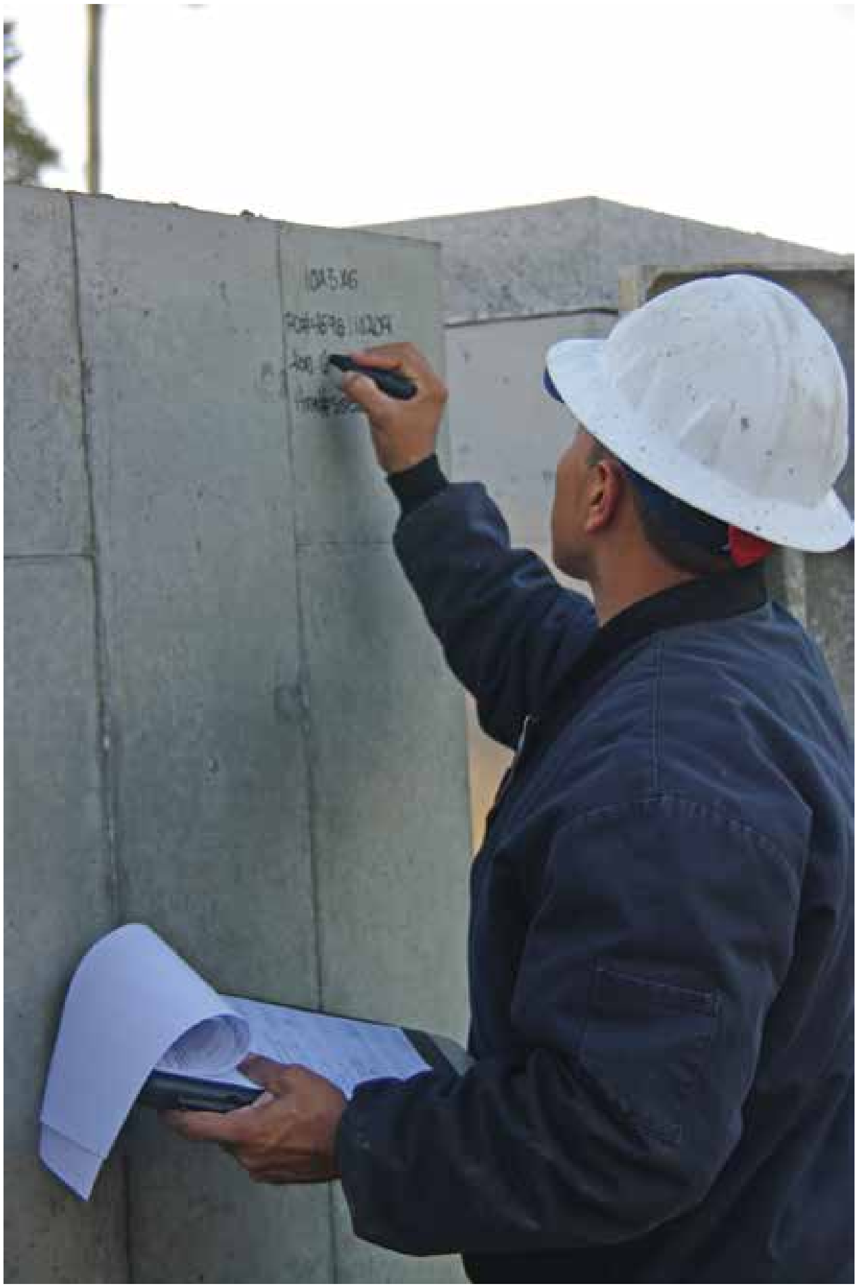
A post-pour inspection checklist, as illustrated on page 21, provides a method of identifying and communicating quality problems as they occur. It serves as a method of gathering data for identification of any trends that may be evident. After a utility structure is stripped from the form, it should be inspected for conformance with the fabrication drawings, and any necessary repairs should be made. All products should be clearly labeled with the date of manufacture and marked in accordance with ASTM C858.

Coatings

High quality concrete with a water-to-cementitious materials ratio less than 0.45 and a compressive strength greater than 4,000 psi is sufficient for utility structures. Under normal conditions, there is no need for additional applications of asphalt, bituminous, epoxy or cementitious coatings. However, a protective exterior coating may be specified when a soil analysis indicates a potential for chemical attack.

Final Product Inspection

Utility structures should be visually checked for required supplementary items, embedded items and quality at the plant prior to shipping, in addition to ensuring the products have received apppropriate markings and identification.



POST-POUR CHECKLIST

PRODUCT: ______________________________ Job No. ______________

Casting Date	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Mark Number							
Stripping Strength							
Top Finish							
Bottom Finish							
Surface Texture							
As Cast Length (ft/in.)							
As Cast Width (ft/in.)							
As Cast Depth (ft/in.)							
Cracks or Spalls							
Squareness							
Chamfers							
Honeycomb/Grout Leak							
Bowing							
Exposed Reinforcement							
Exposed Chairs							
Plates and Inserts							
Chamfer & Radius Quality							
Openings/Blockouts							
Lifting Devices							
Top Finish (wet)							

REMARKS: ______________________________

QC Supervisor ______________ Date ________ Inspector ______________

REPAIRING CONCRETE

Repairing Minor Defects

Defects that do not impact the use or performance of the product are considered minor or cosmetic and may be repaired in any manner that does not impair the product.

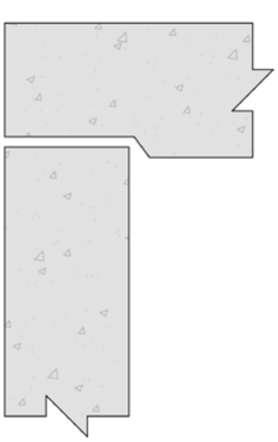
Repairing Honeycombed Areas

Remove all loose material from the damaged area. Cut back the unsound zone in horizontal or vertical planes deep enough to remove the honeycombed/damaged concrete. Coarse aggregate particles should break rather than merely dislodge when chipped. Use only materials that are specifically developed for concrete repair, and make repairs according to the manufacturer's specifications.

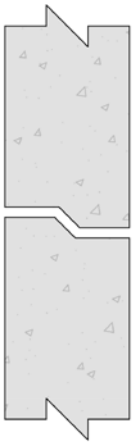
Repairing Major Defects

Major defects are defined as those that impact the intended use or structural integrity of the product. After evaluation by a qualified person, repair products with major defects by using established repair and curing procedures.

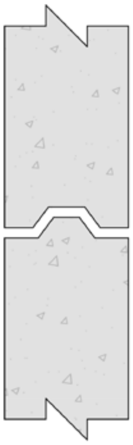
SEALS, FITTINGS AND JOINTS



Lap Joint



Shiplap Joint



Tongue &
Groove Joint

Careful attention to joint details, sealing materials and penetration fittings are important to ensure quality utility structures. Systems in areas of high water tables may require special methods for joint and penetration seal designs.

Joint Designs

The most common joint designs are tongue-and-groove or lap joints.

For the manufacture of utility structures, it is recommended that only interlocking joints be used. In cases of potentially significant frost heave, differential settlement and groundwater exposure, greater attention to joint design detail is needed. Mechanical fasteners or secondary pours for lids on bases may be necessary in areas with severe site conditions. The key to preventing most differential settlement is proper bedding preparation (especially compaction) of the site.

Sealing Materials

High-quality, preformed flexible joint sealants can achieve a dependable joint. Use only sealants that contain less than 3% volatiles as defined in ASTM C990, "Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants."

The characteristics of a high-quality sealant include:

- Workability over a wide temperature range
- Adhesion to clean, dry surfaces
- Good performance over time (must not shrink, harden or oxidize)

It is important that all joints be properly cleaned and prepared, according to the sealant manufacturer's recommendations. Preformed flexible joint sealants must be sufficiently pliable to compress a minimum of 50% at the temperature during assembly. Utility structure sections sealed on site should not be backfilled until the sealant has settled.

Properly splice the sealant by one of the following methods:

- Overlap – Place one piece on top of the other and carefully mold together
- Side-by-side – Place parallel and carefully mold the two pieces together

Sealant Size

A critical factor when evaluating the sealing potential of a sealant is the cross-sectional area. The cross-sectional area is defined as the geometric shape of the sealant (e.g., ¾ in. high by 1 in. wide). Industry experience has shown that a sealant's cross-sectional height must be compressed a minimum of 30% to create a good seal; 50% compression is desirable.

Connections and Hardware

The functionality of a utility structure is increased through the use of high-quality ancillary components such as cable racking assemblies, pulling irons, conduit terminators and pipe supports.

Cable racking assemblies should be specified to match the characteristics of the type of cable to be supported. The assemblies and their hardware for attachment to the wall of the structure should be engineered to carry the anticipated weight of the supported cables.

Pulling irons should be structurally engineered to resist the anticipated cable pulling loads. Additionally, the pulling load placed upon the wall of the utility structure should be considered in the structural design calculations for the structure. Pulling irons should not be used for lifting and handling product.

Cable industry standards require a smooth or rolled edge for the cable to pass over as it leaves the conduit to enter the utility structure. End bells and conduit terminators that are cast into the wall of the precast concrete structure at the time of manufacture provide a quality labor-saving method to terminate conduit. These items should be sized and located on the wall of the structure to match the duct bank configuration.

Utility structures may be configured to accommodate the piping systems used for fluid conveyance. Integral concrete sleepers, thrust blocks and pipe support hardware may be cast into the structure. Boots and gaskets may be incorporated at pipe entrances to ensure watertightness and should be sized and located for the pipe being used.

Hardware should always meet specification requirements of the design engineer and the customer.

Access Risers and Manholes

All access risers and manholes must be structurally sound and watertight.

TRANSPORTATION AND INSTALLATION

Product Shipment

All vehicles used to transport products must be in good condition and capable of handling the product without causing damage. Utility structures should be adequately cured as specified prior to shipment to a job site or distant storage areas. All products must be properly secured with appropriate blockage and either nylon straps or chains with guards to avoid product damage during shipment. NPCA's publication "Cargo Securement for the Precast Concrete Industry" outlines proper methods for securing product. It is recommended that the final inspection include checking these items.

Site Conditions

The installation site must be accessible to large, heavy trucks or cranes weighing up to 80,000 pounds. The construction area should be free of trees, branches, overhead wires or parts of buildings that could interfere with the delivery and installation of the utility structure. Most trucks require access within 3-to-8-ft of the excavation to be unloaded.

Excavation

Prior to excavation, all buried utilities should be identified and located. OSHA regulations governing excavation work should be followed at all times; 29 CFR, Part 1926.650-652.

Excavations should be made with approximately 18 in. of clearance around the installed structure to allow room for adequate compaction. More space should be provided, as needed, if work other than installation is required. Excavations should be sloped to comply with all construction safety requirements.

Bedding

Proper use of bedding material is important to ensure correct installation of the utility structure. Engineered bedding material should be used as necessary to provide a uniform bearing surface. A good base will ensure that the structure will not be subjected to adverse settlement or unanticipated point loads. A minimum 4-in.-thick sand or granular bed overlaying a firm and uniform base is recommended unless otherwise specified. Utility structures should not bear on large boulders or massive rock edges.

Sites with silty soils, high water tables or other "poor" bearing characteristics must have specially designed bedding and bearing surfaces. In the presence of high water tables, structures should be properly designed to resist flotation.

Proper compaction of the underlying soil and bedding is critical to minimize differential settlement.

Installation

Proper installation is absolutely critical for maintaining the inherent quality of plant-manufactured concrete products and should be performed in accordance with ASTM C891, "Practice for Installation of Underground Precast Concrete Utility Structures." Many of the problems experienced with troublesome utility structures can be attributed to incorrect procedures during installation. In addition to damaging the structure, improper installation techniques can lead to safety hazards.

Placement

Prior to placement in the excavation, the structure's orientation should be confirmed. Inlet penetrations should be aligned in the proper direction, and the bedding material should be checked. After placement, check to ensure that the structure is level.

Photo courtesy of Wieser Concrete Products Inc.

Lifting Hardware

Lifting hardware such as lifting beams, chains, slings, shackles and hooks shall be verified for capacity, have an adequate factor of safety for lifting and handling products, and take into account the various forces acting on the lifting hardware.

All lifting hardware shall be capable of supporting at least five times the maximum applied load as required in OSHA 29 CFR 1926.704. Other applicable codes and standards are ANSI A10.9 and ASTM C857, C890 and C913.

Lifting hardware designed in the plant and not commercially manufactured must be load tested or evaluated by a professional engineer.

Backfilling

Backfill should be placed in uniform, mechanically compacted layers less than 24 in. thick. This fill should be equally and uniformly placed around the structure. Backfill should be free of any large stones (greater than 3 in. in diameter) or other debris. Each layer should be adequately compacted.

REFERENCES

SPECIFICATIONS

American Concrete Institute (ACI)

ACI 116R, “Cement and Concrete Terminology”

ACI 211.1, “Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete”

ACI 211.3R, “Guide for Selecting Proportions for No-Slump Concrete”

ACI 212.3R, “Report on Chemical Admixtures for Concrete”

ACI 304R, “Guide for Measuring, Mixing, Transporting and Placing Concrete”

ACI 305R, “Guide to Hot Weather Concreting”

ACI 306R, “Guide to Cold Weather Concreting”

ACI 308R, “Guide to Curing Concrete”

ACI 318, “Building Code Requirements for Structural Concrete and Commentary”

ACI 544.5R, “Report on the Physical Properties and Durability of Fiber-Reinforced Concrete”

American National Standards Institute (ANSI)

ANSI A10.9, "Safety Requirements for Concrete and Masonry Work"

ASTM International

ASTM A36, "Specification for Carbon Structural Steel"

ASTM A496, “Specification for Steel Wire, Deformed, for Concrete Reinforcement”

ASTM A615, “Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement”

ASTM A706, “Specification for Low Alloy Steel Deformed and Plain Bars for Concrete Reinforcement”

ASTM A820, “Specification for Steel Fibers for Fiber-Reinforced Concrete”

ASTM A1064, “Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete”

ASTM C33, “Specification for Concrete Aggregates”

ASTM C94, “Specification for Ready-Mixed Concrete”

ASTM C125, “Terminology Relating to Concrete and Concrete Aggregates”

ASTM C150, “Specification for Portland Cement”

ASTM C171, “Specification for Sheet Materials for Curing Concrete”

ASTM C260, “Specification for Air-Entraining Admixtures for Concrete”

ASTM C494, “Specification for Chemical Admixtures for Concrete”

ASTM C595, “Specification for Blended Hydraulic Cements”

ASTM C618, “Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”

ASTM C857, “Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures”

ASTM C858, “Specification for Underground Precast Concrete Utility Structures”

ASTM C890, “Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures”

ASTM C891, “Practice for Installation of Underground Precast Concrete Utility Structures”

ASTM C913, “Specification for Precast Concrete Water and Wastewater Structures”

ASTM C989, “Specification for Slag Cement for Use in Concrete and Mortars”

ASTM C990, “Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants”

ASTM C1017, “Specification for Chemical Admixtures for Use in Producing Flowing Concrete”

ASTM C1037, “Practice for Inspection of Underground Precast Concrete Utility Structures”

ASTM C1116, “Specification for Fiber-Reinforced Concrete”

ASTM C1240, “Specification for Silica Fume Used in Cementitious Mixtures”

ASTM C1602, “Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete”

ASTM C1609, “Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)”

ASTM D7508, “Standard Specification for Polyolefin Chopped Strands for Use in Concrete”

American Welding Society (AWS)

AWS D1.4-Structural Welding Code – Reinforcing Steel

Occupational Safety and Health Administration (OSHA)

29 CFR 1910.184 (Slings)

29 CFR 1926.650-652 (Excavation)

29 CFR 1926.704 (c) (Lifting Inserts)

29 CFR 1926.704 (d) (Lifting Hardware)

European

EN 14651 Test Method for metallic fibre concrete – Measuring the flexural tensile strength (limit of proportionality (LOP), residual)

GLOSSARY

admixture – A material other than water, aggregates, cement or fiber reinforcement, used as an ingredient of concrete and added to the batch immediately before or during its mixing. Typically liquid in composition.

admixture, accelerating – An admixture that promotes early setting and early strength development of concrete.

admixture, air-entraining – An admixture that causes the development of a system of microscopic air bubbles in concrete, mortar or cement paste during mixing.

admixture, mineral – Finely divided, powdered or pulverized materials added to concrete to improve or alter the properties of the plastic or hardened concrete.

admixture, water-reducing – Admixture that either increases the slump of freshly mixed concrete without increasing the water content, or that maintains the slump with a reduced amount of water due to factors other than air entrainment.

aggregate – Granular material, such as sand, gravel, crushed stone or iron blast-furnace slag used with a cement medium to form hydraulic-cement concrete or mortar.

aggregate, coarse – Generally pea-sized to 2 in.; aggregate of sufficient size is to be predominately retained on a No. 4 sieve (0.187 in. or 4.75 mm).

aggregate, fine – Generally coarse sand to very fine; aggregate passing the ⅜ in. sieve (9.5 mm) and almost entirely passing a No. 4 sieve (0.187 in. or 4.75 mm) and predominately retained on the No. 200 sieve (0.0029 in. or 0.074 mm).

air content – The volume of air voids in cement paste, mortar or concrete, exclusive of pore space in aggregate particles, usually expressed as a percentage of total volume of the paste, mortar or concrete.

air void – A space in cement paste, mortar or concrete filled with air; an entrapped air void is characteristically 0.0394 in. (1 mm) or more in width and irregular in shape; an entrained air void is typically between 0.000394 in. (10 µm) and 0.0394 in. (1,000 µm) in diameter and spherical in shape.

alkali-aggregate reactivity (AAR) – A chemical reaction that occurs between the alkalis (sodium and potassium) from portland cement or other sources and certain constituents of some aggregates; under certain conditions resulting in deleterious expansion of concrete or mortar; often known as alkali-silica reaction (ASR). Cement manufacturers often test aggregates for AAR as a service to their customers.

ASTM – ASTM International is a not-for-profit organization that provides a forum for producers, users, ultimate consumers and those having a general interest (government and academia) to meet and write standards for materials, products, systems and services.

bedding material – Gravel, soil , sand or other material that serves as a bearing surface on which a structure rests and which carries the load transmitted to it.

bleeding – The separation of mixing water or its emergence from the surface of newly placed concrete, caused by the settlement of the solid materials.

bonding agent – A substance applied to a suitable substrate to create a bond between it and a succeeding layer, such as between a layer of hardened concrete and a layer of fresh concrete.

cement, hydraulic – A cement that sets and hardens by chemical interaction with water and is capable of doing so under water.

cementitious material – An inorganic material or mixture of inorganic materials that set and develop strength by chemical reaction with water by formation of hydrates.

concrete – A composite material that consists essentially of a binding medium within which are embedded particles of fragments of aggregate, usually a combination of fine aggregate and coarse aggregate; in portland-cement concrete, the binder is a mixture of portland cement and water.

concrete, fresh – Concrete that possesses enough of its original workability so that it can be placed and consolidated by the intended methods.

compressive strength – Measured maximum resistance of a concrete or mortar specimen to axial compressive loading; expressed as a force per unit cross-sectional area; or the specified resistance used in design calculations.

consistency – The relative mobility or ability of freshly mixed concrete to flow; it is usually measured by the slump test.

consolidation – The process of inducing a closer arrangement of the solid particles in freshly mixed concrete during placement by the reduction of voids, usually accomplished by vibration, centrifugation, rodding, tamping or some combination of these actions. Consolidation facilitates the release of entrapped air; as concrete subsides, large air voids between coarse aggregate particles are filled with mortar.

curing – Action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration and (if applicable) pozzolanic reactions to occur so that the potential properties of the mixture may devlop.

curing compound – A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water or to reflect heat so as to provide an opportunity for the concrete to develop its properties in a favorable temperature and moisture environment.

dead load – A constant load that in structures is due to the mass of the members, the supported structure, and permanent attachments or accessories.

delayed ettringite formation (DEF) – Occurs at later ages (months to years) and the related heterogeneous expansion in hardened concrete that can produce cracking and spalling. DEF is related to environmental or internal sulfate attack.

deleterious substances – Materials present within or on aggregates that are harmful to hardened concrete, often in a subtle or unexpected way. More specifically, this may refer to one or more of the following: materials that may be detrimentally reactive with the alkalis in the cement (see alkali aggregate reactivity); clay lumps and friable particles; coal and lignite; etc.

dry-cast (no-slump concrete) – Concrete of stiff or extremely dry consistency showing no measurable slump after removal of the slump cone.

differential settlement – The uneven sinking of material (usually gravel or sand) after placement.

elongated aggregate – A particle of aggregate where its length is significantly greater than its width.

entrained air – See air void; microscopic air bubbles intentionally incorporated in mortar or concrete during mixing, typically between 0.000394 in. (10 μm) and 0.0394 in. (1000 μm) diameter and spherical or nearly so.

entrapped air – See air void; air voids in concrete that are not purposely entrained and that are larger, mainly irregular in shape, and less useful than those of entrained air; typically greater than 0.0394 in. (1 mm) in diameter.

ettringite – A mineral, high-sulfate calcium sulfoaluminate occurring in nature or formed by sulfate attack on mortar and concrete.

float – A tool, usually of wood, aluminum or magnesium, used in finishing operations to impart a relatively even but still open texture to an unformed fresh concrete surface.

floating – The operation of finishing a fresh concrete or mortar surface by use of a float, preceding troweling when that is to be the final finish.

fly ash – The finely divided residue transported by flue gases from the combustion of ground or powdered coal; often used as a supplementary cementitious material in concrete.

forms (molds) – A structure for the support of concrete while it is setting and gaining sufficient strength to be self-supporting.

friable – Easily crumbled or pulverized, as it refers to aggregates.

gap grading – Aggregate graded so that certain intermediate sizes are substantially absent (i.e., aggregate containing large and small particles with medium-size particles missing).

gradation – The particle-size distribution as determined by a sieve analysis (i.e., ASTM C136); usually expressed in terms of cumulative percentages larger or smaller than each of a series of sizes (sieve openings) or the percentages between certain ranges of sizes (sieve openings).

hydration – Formation of a compound by the combining of water with some other substance; in concrete, the chemical process between hydraulic cement and water.

infiltration – To permeate something (as a liquid) by penetrating pores or interstices.

initial set – A degree of stiffening of a mixture of cement and water less than final set, generally stated as an empirical value indicating the time in hours and minutes required for cement paste to stiffen sufficiently to resist to an established degree, the penetration of a weighted test needle; often performed on a sample of mortar sieved from a concrete sample.

live load – Any load that is not permanently applied to a structure, including transitory loading such as water, vehicles and people.

organic impurities (re: aggregate) – Extraneous and unwanted organic materials (twigs, soil, leaves and other debris) that are mixed in aggregates; these materials may have detrimental effects on concrete produced from such aggregates.

OSHA – Occupational Safety and Health Administration, U.S. Department of Labor.

plastic concrete – See concrete, fresh.

portland cement – A hydraulic cement produced by pulverizing portland-cement clinker, usually in combination with calcium sulfate.

portland cement clinker – A partially fused ceramic material consisting primarily of hydraulic calcium silicates and calcium aluminates.

pozzolan – A siliceous or siliceous and aluminous material that in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

psf – Pounds per square foot.

psi – Pounds per square in.

secondary pour – A situation when a succeeding layer of concrete is placed on previously placed hardened concrete.

segregation – The unintentional separation of the constituents of concrete or particles of an aggregate, resulting in nonuniform proportions in the mass.

set – The condition reached by a cement paste, mortar or concrete when it has lost plasticity to an arbitrary degree, usually measured in terms of resistance to penetration or deformation; initial set refers to first stiffening; final set refers to attainment of significant rigidity.

silica fume – Very fine non-crystalline silica produced in electric arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon; also known as condensed silica fume and micro-silica. It is often used as an additive to concrete and can greatly increase the strength of a concrete mix.

slump – A measurement indicative of the consistency of fresh concrete. A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete is allowed to subside. The distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength. (ASTM C143)

specification – An explicit set of requirements to be satisfied by a material, product, system or service that also indicates the procedures for determining whether each of the requirements is satisfied.

spread – The distance of lateral flow of concrete during the slump-flow test. (ASTM C1611)

standard – As defined by ASTM International, a document that has been developed and established within the consensus principles of the Society.

superplasticizer – See admixture, water-reducing. Superplasticizers are also known as high-range water-reducing admixtures.

surcharge – A surface load applied to the structure, transferred through the surrounding soil.

trowelling – Smoothing and compacting the unformed surface of fresh concrete by strokes of a trowel.

water-to-cementitious materials ratio (w/c) – The ratio of the mass of water, exclusive only of that absorbed by the aggregates, to the mass of portland cement in concrete, mortar or grout; stated as a decimal and abbreviated as w/c.

waterstop – A thin sheet of metal, rubber, plastic or other material inserted across a joint to obstruct the seepage of water through the joint.

water table – The upper limit of the portion of the ground wholly saturated with water.

workability of concrete – The property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated and finished to a homogenous condition.

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