Chapter 3 National Standard Material Specifications

Material Specification 511—Steel Piles

1. Scope
The specification covers the type and quality of steel piles.

2. Bearing piles
Steel bearing piles shall be structural steel H-piles conforming to the requirements of ASTM A 36.

The required length of pile may be fabricated by butt-welding shorter lengths of pile stock. Unless otherwise specified, the cross-section of each pile shall be constant throughout its length. The axis of the pile shall be straight, and the number of welded joints in the length of the pile shall be as few as practicable. Pieces below the top piece shall have a minimum length of 10 feet.

3. Sheet piles
Steel sheet piles shall conform to the requirements of ASTM A 328, A 572, or A 690.

Fabrication of piles from shorter lengths of pile stock is not permitted.

Material Specification 512—Wood Piles

1. Scope

This specification covers the quality of wood piles.

2. Quality of piles

The piles shall conform to the requirements of ASTM D 25 for the specified classes and sizes of piles.

3. Treatment

Piles shall be treated with the specified type and amount of preservative and in conformance with the requirements of Material Specification 585.

4. Marking

Each treated pile delivered to the job site shall be marked as specified in Material Specification 585.

Material Specification 513—Precast Concrete Piles

1. Scope

This specification covers the quality of precast concrete piles.

2. General requirements

The piles shall conform to the details shown on the drawings. The piles shall be cast of portland cement concrete mixed, placed, and cured by the methods specified in Construction Specification 31 except as amended in the specification. The finished piles shall be true to line with a smooth surface free from stone pockets, honeycomb, or other surface defects.

3. Classes of concrete

Unless otherwise specified, Class 4000 concrete applies.

4. Reinforcement

Reinforcement steel shall conform to the requirements of Construction Specification 34.

5. Forms

Forms shall be constructed of plywood, metal, or dressed lumber and shall have 1-inch chamfer strips at all corners. They shall be mortar tight, true to line, and adequately supported to prevent deformation or settlement during concrete placement. They shall be designed to be removable without damaging the completed piles.

6. Placing concrete

The concrete shall be placed in each pile in one continuous operation. The concrete shall be compacted and worked into the forms and around the reinforcement by procedures outlined in Construction Specification 31.

7. Curing

The piles shall be cured for a minimum of 14 days by a method specified in Construction Specification 31.

Test cylinders cast for the purpose of determining when the piles may be subjected to handling stresses shall be cured by the same method as the pile, at the same location, and under the same conditions as those applied to the piles.

The steam curing process may be used as an alternative to moist curing or membrane curing. The piles shall be cured inplace on the casting bed by the introduction of steam into a steam-tight housing that completely encloses the casting bed. The first application of steam shall be applied after the concrete has gained an initial set, but in no case sooner than 2 hours after the concrete is placed unless a set-retarding admixture is an ingredient of the approved concrete mix. When a set-retarding admixture is used, the first application of steam shall be applied no sooner than 4 hours after the concrete is placed. Moist curing methods shall be applied during the interval between the placement of the concrete and the application of the steam.

The steam shall be at 100 percent relative humidity and shall not be applied directly on the concrete. During application of the steam, the ambient air temperature within the housing shall be increased at a maximum rate of 40 degrees Fahrenheit per hour until the maximum temperature is reached. The temperature within the housing shall be maintained between 140 and 160 degrees Fahrenheit until the concrete has reached the specified strength. In discontinuing the application of the steam, the ambient air temperature within the housing shall be decreased at a maximum rate of 40 degrees Fahrenheit per hour until the temperature within the housing does not exceed than 20 degrees Fahrenheit above the ambient air temperature outside the housing.

The concrete shall not be exposed to temperatures below freezing for a minimum of 6 days after placement.

8. Removing forms

Side forms shall remain in place a minimum 24 hours.

9. Handling and storing piles

The contractor shall handle and store piles by methods that do not cause spalling, cracking, or other damage to the piles. The contractor shall furnish all bridles, slings, and other handling equipment as necessary.

Piles shall not be moved until the tests indicate a minimum compressive strength of 80 percent of the design 28-day compressive strength. Piles shall not be transported or driven until the field cure test cylinders indicate a minimum compressive strength equal to the design 28-day compressive strength.

Piles that are cracked, spalled, or otherwise damaged during handling will be rejected.

Material Specification 514—Cast-In-Place Concrete Piles With Shells

1. Scope

This specification outlines the quality of piles formed by driving shells to the required bearing, leaving the shells permanently in place, and placing concrete within the shells.

2. General requirements

The piles may have constant diameter or may be tapered. The diameter of the tapered pile shall increase uniformly from bottom to top. The pile may be stepped increasing in diameter from bottom to top with the diameter changes between steps to be gradual and uniform throughout the total pile length. Unless otherwise specified, the average diameter of each pile shall not be less than 11 inches. The minimum tip diameter of a tapered pile shall be 8 inches.

3. Shell

The shell shall be made of reinforced concrete or steel. It shall have sufficient strength and rigidity to prevent distortion during driving or after driving by soil or water pressures or pressures caused by the driving of adjacent piles. It shall be sufficiently watertight to exclude water during placement of concrete. Driven shells shall be clean and free of water before reinforcing steel and/or concrete is placed.

4. Reinforcement

When internal reinforcement is specified, it shall conform to the details on the drawings and to the requirements of Construction Specification 34.

5. Concrete

Concrete shall not be placed in any pile until the driven shell complete with reinforcement inplace has been inspected and approved by the engineer.

Unless otherwise specified, the concrete:

- shall conform to the requirements of Construction Specification 31 and shall be Class 4000
- shall be placed in each pile in one continuous operation
- shall be placed and consolidated into the shell in conformance with the requirements of Construction Specification 31

Material Specification 521—Aggregates for Drainfill and Filters

1. Scope

This specification covers the quality of mineral aggregates for the construction of drainfill and filters.

2. Quality

Drainfill and filter aggregates shall be sand, gravel, or crushed stone or mixtures thereof. Aggregates shall be composed of clean, hard, durable, mineral particles free from organic matter, clay balls, soft particles, or other substances that would interfere with the free-draining properties of the aggregates.

Coarse aggregate may be crushed limestone or other material that has limestone particles included. Aggregates from crushed limestone shall be thoroughly washed and screened to remove limestone dust, limestone fines, and fine soil particles. For coarse aggregate containing limestone, the total portion finer than the No. 4 sieve shall not contain more than 3 percent by weight of limestone. Limestone shall not be used for fine aggregates except in combination with other material, such that not more than 5 percent of the portion finer than the No. 4 sieve shall be limestone.

Aggregates shall be tested for soundness according to ASTM Method C 88 and shall have a weighted average loss in 5 cycles of not more than 12 percent when sodium sulfate is used or 18 percent when magnesium sulfate is used.

3. Grading

Drainfill and filter aggregates shall conform to the specified grading limits after being placed or after being compacted when compaction is specified. Grading shall be determined by ASTM Method C 136. The percentage of material finer than the No. 200 sieve shall be determined by the method in ASTM Designation C 117.

4. Storing and handling

Drainfill and filter aggregates shall be stored and handled by methods that prevent segregation of particle sizes or contamination by mixing with other material.

Material Specification 522—Aggregates for Portland Cement Concrete

1. Scope

This specification covers the quality of fine aggregate and coarse aggregate for use in the manufacture of portland cement concrete.

2. Quality

Aggregate shall conform to the requirements of ASTM Specification C 33 for the specified sizes. Aggregates that fail to meet any requirement may be accepted only when either:

a. The specified alternate conditions of acceptance can be proven before the aggregates are used on the job and within a period such that no work under the contract will be delayed by the requirements of such proof, or

b. The specification for concrete expressly contains a provision of special mix requirements to compensate for the effects of the deficiencies.

3. Reactivity with alkalies

The potential reactivity of aggregates with the alkalies in cement shall be evaluated by petrographic examination and, where applicable, the chemical method of test, ASTM Designation C 289, or by the results of previous tests or service records of concrete made from similar aggregates from the same source. The standards for evaluating potential reactivity shall be as described in ASTM Specification C 33, appendix A1.

Aggregates indicated by any of the above to be potentially reactive shall not be used except under one of the following conditions:

a. Applicable test results of mortar bar tests made according to ASTM Method C 227 are available which indicate an expansion of less than 0.10 percent at 6 months in mortar bars made with cement containing not less than 0.8 percent alkalies expressed as sodium oxide; or

b. Concrete made from similar aggregates from the same source has been demonstrated to be sound after 3 years or more of service under conditions of exposure to moisture and weather similar to those anticipated for the concrete under these specifications.

Aggregates indicated to be potentially reactive, but within acceptable limits as determined by mortar bar test results or service records, shall be used only with low alkali cement, containing less than 0.60 percent alkalies expressed as sodium oxide.

4. Storing and handling

Aggregates of each class and size shall be stored and handled by methods that prevent segregation of particles sizes or contamination by intermixing with other material.

Material Specification 523—Rock for Riprap

1. Scope

This specification covers the quality of rock to be used in the construction of rock riprap.

2. Quality

Individual rock fragments shall be dense, sound, and free from cracks, seams, and other defects conducive to accelerated weathering. Except as otherwise specified, the rock fragments shall be angular to subrounded. The least dimension of an individual rock fragment shall be not less than one-third the greatest dimension of the fragment. ASTM D 4992 provides guidance on selecting rock from a source.

Except as otherwise provided, the rock shall be tested and shall have the following properties:

Rock type 1

- ***Bulk specific gravity (saturated surface-dry basis)***—Not less than 2.5 when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Absorption***—Not more than 2 percent when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Soundness***—The weight loss in 5 cycles shall not be more than 10 percent when sodium sulfate is used or more than 15 percent when magnesium sulfate is used.

Rock type 2

- ***Bulk specific gravity (saturated surface-dry basis)***—Not less that 2.5 when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Absorption***—Not more than 2 percent when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Soundness***—The weight loss in 5 cycles shall be not more than 20 percent when sodium sulfate is used or more than 25 percent when magnesium sulfate is used.

Rock type 3

- ***Bulk specific gravity (saturated surface-dry basis)***—Not less than 2.3 when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Absorption***—Not more than 4 percent when tested in accordance with ASTM C 127 on samples prepared as described for soundness testing.
- ***Soundness***—The weight loss in 5 cycles shall be not more than 20 percent when sodium sulfate is used or more than 25 percent when magnesium sulfate is used.

3. Methods of soundness testing

Rock cube soundness—The sodium or magnesium sulfate soundness test for all rock types (1, 2, or 3) shall be performed on a test sample of 5,000 ± 300 grams of rock fragments, reasonably uniform in size and cubical in shape, and weighing, after sampling, about 100 grams each. They shall be obtained from rock samples that are representative of the total rock mass, as noted in ASTM D 4992, and that have been sawed into slabs as described in ASTM D 5121. The samples shall further be reduced in size by sawing the slabs into cubical blocks. The thickness of the slabs and the size of the sawed fragments shall be determined by the size of the available test apparatus and as necessary to provide, after sawing, the approximate 100-gram samples. The cubes shall undergo five cycles of soundness testing in accordance with ASTM C 88.

Internal defects may cause some of the cubes to break during the sawing process or during the initial soaking period. Do not test any of the

Material Specification 523 Rock for Riprap (continued)

cubes that break during this preparatory process. Such breakage, including an approximation of the percentage of cubes that break, shall be noted in the test report.

After the sample has been dried following completion of the final test cycle and washed to remove the sodium sulfate or magnesium sulfate, the loss of weight shall be determined by subtracting from the original weight of the sample the final weight of all fragments that have not broken into three or more fragments.

The test report shall show the percentage loss of the weight and the results of the qualitative examination.

Rock slab soundness—When specified, the rock shall also be tested in accordance with ASTM D 5240. Deterioration of more than 25 percent of the number of blocks shall be cause for rejection of rock from this source. Rock shall also meet the requirements for average percent weight loss stated below.

- For projects located north of the Number 20 Freeze-Thaw Severity Index Isoline (fig. 523–1). Unless otherwise specified, the average percent weight loss for Rock Type 1 shall not exceed 20 percent when sodium sulfate is used or 25 percent when magnesium sulfate is used. For Rock Types 2 and 3, the average percent weight loss shall not exceed 25 percent for sodium sulfate soundness or 30 percent for magnesium sulfate soundness.
- For projects located south of the Number 20 Freeze-Thaw Severity Index Isoline, unless otherwise specified, the average percent weight loss for Rock Type 1 shall not exceed 30 percent when sodium sulfate is used or 38 percent when magnesium sulfate is used.

Figure 523–1 Number 20 freeze-thaw severity index isoline (map approximates the map in ASTM D 5312)

For Rock Types 2 and 3, the average percent weight loss shall not exceed 38 percent for sodium sulfate soundness or 45 percent for magnesium sulfate soundness.

4. Field durability inspection

Rock that fails to meet the material requirements stated above (if specified), may be accepted only if similar rock from the same source has been demonstrated to be sound after 5 years or more of service under conditions of weather, wetting and drying, and erosive forces similar to those anticipated for the rock to be installed under this specification.

A rock source may be rejected if the rock from that source deteriorates in 3 to 5 years under similar use and exposure conditions expected for the rock to be installed under this specification, even though it meets the testing requirements stated above.

Deterioration is defined as the loss of more than one-quarter of the original rock volume, or severe cracking that would cause a block to split. Measurements of deterioration are taken from linear or surface area particle counts to determine the percentage of deteriorated blocks. Deterioration of more than 25 percent of the pieces shall be cause for rejection of rock from the source.

5. Grading

The rock shall conform to the specified grading limits after it has been placed within the matrix of the rock riprap. Grading tests shall be performed, as necessary, according to ASTM D 5519, Method A, B, or C, as applicable.

Material Specification 524—Aggregates for Roller Compacted Concrete

1. Scope

This specification covers the quality of aggregate for use in the manufacture of roller compacted concrete (RCC).

2. Quality

Aggregate shall conform to the quality requirements of ASTM Specification C 33.

3. Gradation

Aggregate gradation shall be within the limits provided below for the total aggregate weight in a unit volume of RCC. For the sieve sizes shown below that are larger than #4, no more than 20 percent of the total aggregate shall be retained on an individual sieve. For sieve sizes smaller than 3/8 inch, at least 3 percent of the total aggregate shall be retained on each sieve.

Sieve size	Percent passing
2"	100
1-1/2"	85–100
1"	70–100
3/4"	60–84
1/2"	50–70
3/8"	40–60
#4	32–50
#8	26–42
#16	20–35
#30	14–28
#50	8–22
#100	4–15
#200	0–7

Unless otherwise specified, the fines (material passing the #200 sieve) shall have a plasticity index less than four.

Particle shape—The amount of flat and elongated particles with a length-to-width or width-to-thickness ratio greater than 3:1, as determined by ASTM D 4791, shall not exceed 25 percent on any individual sieve size group nor a weighted average of 20 percent for all of the sieve sizes in the total gradation.

4. Reactivity with alkalies

The potential reactivity of aggregates with the alkalies in cement shall be evaluated by petrographic examination and, where applicable, the chemical method of test, ASTM C 289, or by the results of previous tests or service records of RCC or concrete made from similar aggregates from the same source. The standards for evaluating potential reactivity shall be as described in ASTM C 33, appendix A1.

Aggregates indicated by any of the above to be potentially reactive shall not be used except under one of the following conditions:

a. Applicable test results of mortar bar tests made according to ASTM Method C 227 are available and indicate an expansion of less than 0.10 percent at 6 months in mortar bars made with cement containing not less than 0.8 percent alkalies expressed as sodium oxide; or

b. RCC or concrete made from similar aggregates from the same source has been demonstrated to be sound after 3 years or more of service under conditions of exposure to moisture and weather similar to those anticipated for the RCC under these specifications.

Aggregates indicated to be potentially reactive, but within acceptable limits as determined by mortar bar test results or service records, shall be used only with low alkali cement, containing less than 0.60 percent alkalies expressed as sodium oxide.

5. Acceptance

Aggregates that fail to meet any requirement may be accepted only when the specification for RCC expressly contains either:

a. Special provisions for acceptance that can be proven before the aggregates are used on the job and within a period such that no work under the contract will be delayed by the requirements of such proof, or

b. Special provisions for specific mix requirements to compensate for the effects of the deficiencies.

6. Storing and handling

Aggregates shall be stored in stockpiles at specified storage areas. Separators, such as timbers, boards, or pre-cast concrete panels, shall be used between adjacent stockpiles to prevent the contamination and intermixing of dissimilar materials. The contractor shall be responsible for providing a system that reliably and consistently stockpiles the aggregates and allows the withdrawal of the aggregates from the stockpiles without contamination or segregation. Segregated or contaminated aggregates will not be allowed in production of RCC.

Material Specification 531—Portland Cement

1. Scope

This specification covers the quality of portland cement.

2. Quality

Portland cement shall conform to the requirements of ASTM Specification C 150 for the specific types of cement. When Type I portland cement is specified, Type IS portland blast-furnace slag cement or Type IP portland-pozzolan cement conforming to the requirements of ASTM Specification C 595 may be used unless prohibited by the specifications.

When air-entraining cement is required, the contractor shall furnish the manufacturer's written statement providing the source, amount, and brand name of the air-entraining component.

3. Storage at the construction site

Cement shall be stored and protected at all times from weather, dampness, or other destructive elements. Cement that is partly hydrated or otherwise damaged will not be accepted.

Material Specification 532—Mineral Admixtures for Concrete

1. Scope

This specification covers the quality of mineral admixtures for concrete.

2. Quality

Fly ash used as a partial substitution of portland cement shall conform to the requirements of ASTM C 618, Class C or F except the loss on ignition shall not exceed 3 percent, unless otherwise specified. Lot-to-lot variation in the loss on ignition shall not exceed 1 percent.

Blast-furnace slag used as a partial substitution of portland cement shall conform to ASTM Standard C 989 for ground granulated blast-furnace slag.

Material Specification 533—Chemical Admixtures for Concrete

1. Scope

This specification covers the quality of chemical admixtures for manufacturer of portland cement concrete.

2. Quality

Air-entraining admixtures shall conform to the requirements of ASTM Specification C 260.

Water-reducing and/or retarding admixtures shall conform to the requirements of ASTM Specification C 494, Types A, B, D, F, or G.

Plasticizing or plasticizing and retarding admixtures shall conform to ASTM C 494, Types F or G, or C 1017 as applicable.

Accelerating or water-reducing and accelerating admixtures shall be noncorrosive and conform to the requirements of ASTM Specification C 494, Types C and E. The manufacturer shall provide long-term test data results from an independent laboratory verifying that the product is noncorrosive when used in concrete exposed to continuously moist conditions.

Material Specification 534—Concrete Curing Compound

1. Scope

This specification covers the quality of liquid membrane-forming compounds suitable for spraying on concrete surfaces to retard the loss of water during the concrete curing process.

2. Quality

The curing compound shall meet the requirements of ASTM Specification C 309. Unless otherwise specified, the compound shall be type 2.

3. Delivery and storage

All curing compounds shall be delivered to the site of the work in the original container bearing the name of the manufacturer and the brand name. The compound shall be stored in a manner that prevents damage to the container and protects water-emulsion types from freezing.

Material Specification 535—Preformed Expansion Joint Filler

1. Scope

This specification covers the quality of preformed expansion joint fillers for concrete.

2. Quality

Preformed expansion joint filler shall conform to the requirements of ASTM Specification D 1752, Type I, Type II, or Type III, unless bituminous type is specified. Bituminous type preformed expansion joint filler shall conform to the requirements of ASTM Specification D 994, or D 1751.

Material Specification 536—Sealing Compound for Joints in Concrete and Concrete Pipe

1. Scope

This specification covers the quality of sealing compound for filling joints in concrete pipe and concrete structures.

2. Type

The compound shall be a cold-application material unless otherwise specified and shall be a single component or multiple component type.

3. Quality

The sealing compound shall conform to the requirements of one of the following specifications:

- ASTM Specification C 990—Joints for concrete pipe, manholes, and precast box sections using preformed flexible joint sealants.
- ASTM Specification C 877—External sealing bands for noncircular concrete sewer, storm drain, and culvert pipe.
- ASTM Specification D 1190—Concrete joint sealer, hot poured elastic type.
- ASTM Specification C 920—Elastomeric joint sealants for cold applied sealing and caulking of joints on mortar and concrete structures not subject to fuel spills. Use type S or M, grade NS for vertical joints; type S or M, grade P or NS for horizontal joints. For class 25, use M, quality materials shall be used for both vertical and horizontal joints unless otherwise specified.

The sealing compound if used with other joint material, such as fillers or gaskets, shall be compatible.

Material Specification 537—Nonmetallic Waterstops

1. Scope

This specification covers nonmetallic waterstops for use in joints of concrete structures.

2. Classification

Classes—Nonmetallic waterstops shall be of the following classes, as specified:

Class I shall be fabricated of either natural or synthetic rubber.

Class II shall be fabricated of vinyl chloride polymer or copolymer.

Types—Nonmetallic waterstops may be either split or solid and shall conform to the following types, as specified (see fig. 537–1):

Type A shall have ribbed anchor flanges and a smooth web. Flanges may be of uniform thickness or may have either a converging or a diverging taper toward the edges.

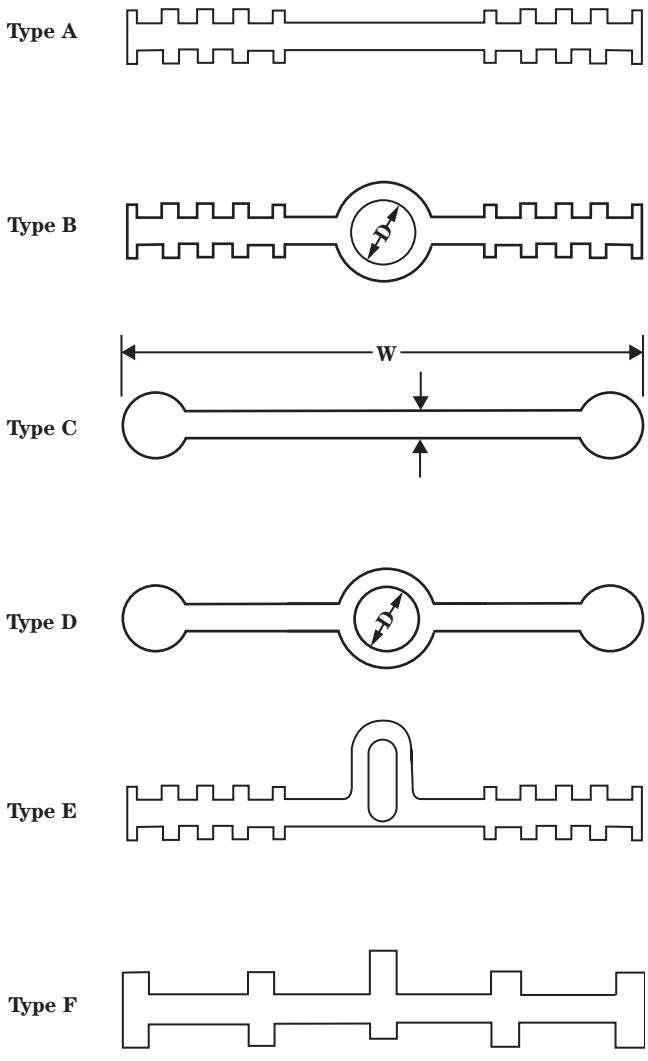
Type B shall have ribbed anchor flanges and a smooth web containing a hollow tubular center bulb having a wall thickness equal to at least one-half the web thickness, and the inside diameter (D) specified in the specifications or shown on the drawings. Flanges may be of uniform thickness or may have either a converging or a diverging taper toward the edges.

Type C shall have a single, circular bulb-type anchor flange at each edge and a smooth web.

Type D shall have a single, circular bulb-type anchor flange at each edge and a smooth web containing a hollow tubular center bulb having a wall thickness equal to a least one-half the thickness of the web, and the inside diameter (D) specified in the contract.

Type E shall have ribbed anchor flanges and a web molded or extruded in the form of a round or U-shaped bulb of the dimensions specified in the contract or shown on the drawings. The web bulb shall be connected at the open-end of the U by a thin membrane having a minimum thickness of 1/64 inch and a maximum thickness of 1/5 of the web thickness and design to prevent infiltration of wet

Figure 537–1 Types of nonmetallic waterstops



concrete into the bulb and to tear when expansion of the joint occurs. Flanges may be of uniform thickness or may have either a converging or a diverging taper toward the edges. Auxiliary positioning or nailing flanges may be provided as long as the functioning of the web bulb is not altered.

Type F shall have ribbed anchor flanges with at least two extra heavy ribs designed to resist displacement of the waterstop during concrete placement on each flange, and a smooth web having a positioning or nailing flange attached at the center.

Type G shall be of special design conforming to the details shown on the drawings.

Sizes—Waterstops of types A through F shall be of the sizes specified in the specifications or shown on the drawings and listed in table 537–1 of this specification. Type G waterstops shall have the dimensions shown on the drawings.

3. Physical requirements

The extruded or molded material shall exhibit the properties specified herein when tested by the methods specified in section 4 of this specification.

Class I waterstops

- Hardness as determined by the Shore A durometer method shall be a minimum of 60.
- Specific gravity shall be a maximum of 1.2.
- Tensile strength shall be a minimum of 2,500 pounds per square inch.
- Ultimate elongation shall be a minimum of 450 percent.
- Compression set shall be a maximum of 30 percent.
- Water absorption in weight measurements shall not exceed 5 percent.
- Decrease in tensile strength and ultimate elongation after aging shall not exceed 20 percent.
- There shall be no sign of failure due to brittleness at a temperature of minus 35 degrees Fahrenheit.

Class II waterstops

- Hardness as determined by the Shore A durometer method shall be a minimum of 60.
- Specific gravity shall be a maximum of 1.4.
- Tensile strength shall be a minimum of 1,400 pounds per square inch.
- Ultimate elongation of the web shall be a minimum of 280 percent, and the flanges shall be a minimum of 200 percent.

Table 537–1 Sizes of waterstops

Size designation	Web thickness (T) (inches)	Width (W) (inches)
1	1/16	5 1/4
2	3/32	3 3/4
3	3/32	4
4	3/32	5 1/4
5	3/32	6
6	1/8	4
7	1/8	5 1/4
8	1/8	6
9	5/32	4
10	5/32	4 1/2
11	5/32	9
12	3/16	4
13	3/16	5
14	3/16	6
15	3/16	9
16	1/4	6
17	1/4	9
18	3/8	5
19	3/8	6
20	3/8	9
21	1/2	6
22	1/2	9
23	1/2	12

- There shall be no sign of failure due to flange brittleness at a temperature of 0 degrees Fahrenheit nor of web brittleness at a temperature of minus 35 degrees Fahrenheit.
- Decrease in either tensile strength or ultimate elongation after accelerated extraction shall not exceed 15 percent.
- Results of alkali exposure:
  a. After immersion for 7 days, the sample shall exhibit no loss of weight and a maximum weight gain of 0.25 percent, and the hardness measured by the Shore A durometer method shall not vary more than 5 points either plus or minus from the untreated sample.
  b. After immersion for 30 days, the sample shall exhibit no loss of weight and a maximum weight gain of 0.40 percent, and the dimensions of the treated sample shall not vary by more than 1 percent from the untreated sample.

4. Test methods

Testing shall be conducted by the methods cited herein. All cited test methods are included in ASTM as follows:

a. Hardness shall be determined by ASTM D 2240.

b. Specific gravity shall be determined by ASTM D 792.

c. Tensile strength shall be determined by ASTM D 412 for Class I waterstops and ASTM D 638 for Class II waterstops.

d. Ultimate elongation shall be determined by ASTM D 412 for Class I waterstops and ASTM D 638 for Class II waterstops.

e. Compression set shall be determined by ASTM D 395.

f. Water absorption shall be determined by ASTM D 570.

g. Tensile strength and ultimate elongation after aging shall be determined by ASTM D 412 for Class I waterstops and ASTM D 638 for Class II waterstops.

h. Brittleness shall be determined by ASTM D 746 for Class II waterstops.

i. Accelerated extraction shall be accomplished by procedures outlined by United States Army Corps of Engineers (USACE), Concrete Research Division (CRD) C 572 under the following conditions:
   (1) Samples shall not be less than 1/16 inch nor more than 1/8 inch in thickness.
   (2) The immersion medium shall be a solution prepared by dissolving 5 grams of chemically pure sodium hydroxide and 5 grams of chemically pure potassium hydroxide in 1 liter of water.
   (3) The samples shall be immersed in the medium for 14 days at a temperature of 145 degrees Fahrenheit, plus or minus 5 degrees Fahrenheit.
   (4) During the period of immersion, air shall be gently bubbled through the medium from a 0.25-inch diameter glass tube at an approximate rate of one bubble per second.
   (5) Fresh medium shall be provided each day.
   (6) Samples need not be dipped in acetone.

j. The effects of alkalies shall be determined by USACE CRD C 572 under the following conditions:
   (1) Sample shall have a maximum thickness of 0.25 inch.
   (2) The immersion medium shall be as described for accelerated extraction above.
   (3) Fresh medium shall be provided every 7 days.
   (4) The samples shall be immersed in the medium for 30 days.
   (5) Samples need not be dipped in acetone.

5. Condition

Waterstops shall be extruded or molded in such a manner that the material is dense and homogeneous throughout and free from voids, tears, thins, indentations, or other imperfections. Unless otherwise specified, waterstops shall be symmetrical in shape and uniform in dimensions and shall be furnished in continuous strips a minimum length of 50 feet. Factory splices shall have a minimum tensile strength of 50 percent of the unspliced section.

6. Packaging and storing

Waterstops shall be packaged and stored by methods that provide protection from prolonged exposure to direct sunlight and/or excessive heat.

Material Specification 538—Metal Waterstops

1. Scope

This specification covers the quality of material for metal waterstops as specified for reinforced concrete installation.

2. Material

Metal waterstops shall be made of copper or galvanized steel as specified. Waterstops that require forming of the metal involving sharp bends shall be made of copper, which shall be soft and pliable so bending to an inside radius equal to its thickness without cracking will occur at temperatures less than 180 degrees Fahrenheit.

3. Quality

Metal for waterstops shall conform to the requirements of the applicable ASTM Standard:

- **Copper—**ASTM Specification B 152
- **Zinc-coated (galvanized) steel—**ASTM Specification A 653

Material Specification 539—Steel Reinforcement (for concrete)

1. Scope

This specification covers the quality of steel reinforcement for reinforced concrete.

2. Quality

All reinforcement shall be free from loose or flaky rust, soil, oil, grease, paint, or other deleterious matter.

Steel bars for concrete reinforcement shall be grade 40, 50, or 60 deformed bars conforming to one of the following specifications:

- Deformed and plain billet-steel bars for concrete reinforcement—ASTM A 615
- Rail-steel deformed bars for concrete reinforcement—ASTM A 996
- Axle-steel deformed bars for concrete reinforcement—ASTM A 996

Dowels shall be plain round bars conforming to the same specifications listed above for steel bars.

Fabricated deformed steel bar mats for concrete reinforcement shall conform to the requirements of ASTM A 184.

Plain steel welded wire fabric for concrete reinforcement shall conform to the requirements of ASTM A 185.

Deformed steel welded wire fabric for concrete reinforcement shall conform to the requirements of ASTM A 497.

Epoxy-coated steel bars for concrete reinforcement shall conform to the requirements of ASTM A 775.

3. Dimensions of welded wire fabric

Gauges, diameters, spacing, and arrangement of wires for welded steel wire fabric shall be as defined for the specified style designations.

4. Storage

Steel reinforcement inventories at the site of the work shall be stored above the ground surface on platforms, skids, or other supports and shall be kept clean and protected from mechanical injury and corrosion.

Material Specification 541—Reinforced Concrete Pressure Pipe

1. Scope

This specification covers the quality of reinforced concrete pressure pipe and fittings.

2. Manufacture and fabrication

The pipe, the material used in its manufacture, and the methods of fabrication shall conform to the requirements of the following specifications applicable to the specified type of pipe.

***Steel cylinder type, pre-stressed*—**AWWA Standard C301 for Pre-stressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids.

***Steel cylinder type, not pre-stressed*—**AWWA Standard C300 for Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids.

***Noncylinder type, not pre-stressed*—**AWWA Standard C302 for Reinforced Concrete Pressure Pipe, Non-Cylinder Type, for Water and Other Liquids.

***Steel cylinder type, pre-tensioned*—**AWWA Standard C303 for Concrete Pressure Pipe, Bar-Wrapped, Steel Cylinder Type for Water and Other Liquids.

***Low head pressure pipe*—**ASTM Specification C 361.

The following specification sections shall not apply:

- AWWA C300 and C301, sections 1.5 and 1.6.
- AWWA C302 and C303, sections 4.2 and 4.3.

3. Design

The actual pipe and fittings shall be designed by the manufacturer to withstand the specified external loads and internal pressures. Designs shall be by either of the following methods as applicable to the type of pipe specified:

***Indirect design*—**ASTM C497 for Standard Test Method for Concrete Pipe, Manhole Sections, or Tile. Pipe design shall be based on the results of external crushing strength tests on a minimum 2-foot length of pipe or a specimen of equivalent size, design, and material. The test shall demonstrate the following bearing loads:

- For pipe manufactured according to ASTM C361, AWWA C300, or AWWA C302, the load required to produce a 0.01-inch crack 1 foot long.
- For pipe manufactured according to AWWA C301, the load required to produce a 0.001-inch crack 1 foot long or the load 10 percent greater than the specified three-edge bearing strength, whichever occurs first.

In lieu of actual testing for this contract, pipe design may be based on design curve previously approved and published by the Natural Resources Conservation Service.

***Direct design*—**AWWA C304 for Design of Pre-Stressed Concrete Cylinder Pipe or AWWA Manual M9 for Concrete Pressure Pipe. Pipe design shall be based on structural analysis and design calculations.

***Standard design*—**ASTM C361 for Reinforced Concrete Low Head Pressure Pipe. Pipe design shall be as published in the standard.

4. Steel reinforcement

The steel reinforcements shall conform to the requirements of the specifications cited in section 2 for the specified type of pipe except that elliptical reinforcing cages or other reinforcements that require special orientation of the pipe during placement are not allowed.

5. Joints

The pipe joints shall conform to the requirements of the applicable specification for the pipe. They shall be bell-and-spigot type or double-spigot-and-sleeve type and shall have a positive groove in the spigot to contain the rubber gasket. The size and shape of the groove shall be such that it prevents displacement of the gasket by either internal or external water pressure when the joint is in any position within the required range of movement capability. Joint sleeves, also referred to as collars or coupling bands, shall conform to the requirements for bell rings in the applicable pipe specification.

The joints shall be constructed to permit relative movement of the adjoining pipe sections with no reduction of watertightness. The *joint length* and the *limiting angle* defining the required capability of relative movement at each joint shall be no less than specified.

Joint length refers to the permissible axial movement in the joint. It is defined as the maximum distance through which the spigot can move, relative to the bell or sleeve, from the fully engaged to the fully extended condition of the joint when the adjoining pipe sections are in parallel, concentric alignment. The joint is considered to be fully engaged when the spigot is inserted as far as it will go into the bell or sleeve and is fully extended when it is inserted the least amount that will ensure full confinement of the gasket and complete watertightness.

Joint length specified for double-spigot joints refers to the permissible movement in each of the spigot-to-sleeve connections, not the sum of the two.

The *limiting angle* of the joint is defined as the maximum deflection angle between adjoining pipe sections the joint will permit before the outer surface of the spigot comes into direct contact with inside of the mating bell or sleeve. If both spigot-to-sleeve connections of a double-spigot joint permit angular movement, the limiting angle of the joint is the sum of the two deflection angles permitted by the two connections.

6. Gaskets

The pipe joint gaskets shall conform to the requirements of the specifications cited in section 2 of this specification. They shall be endless rubber gaskets having circular cross section. The cross-sectional diameter of the gaskets shall conform to the pipe manufacturer's recommendation for the type and size of pipe furnished.

7. Marking

All pipe sections and special fittings shall be marked by the manufacturer with the manufacturer's name or trademark, the date of manufacture, the nominal size, design head, design external load, and the structure site for which it was designed and manufactured.

8. Certification

All component material and actual pipe fabrication shall be tested, inspected, and documented as prescribed in the manufacturing specifications for the type of pipe specified. All documentation as noted in the manufacturing specifications shall be submitted to the engineer. Documentation shall include current test reports on steel and steel wire reinforcing and compression tests of concrete used in the manufacture of the furnished pipe. Current tests are those that have been conducted within the last year.

For pipe design based on actual external crushing strength tests, the engineer shall witness the actual test.

For pipe design based on published design curves, a copy of the appropriate design curve marked to show the resultant concrete core

stress and corresponding three-edge bearing load and a specification sheet showing all data and dimensions necessary to calculate the resultant core stress for the pipe furnished shall be submitted to the engineer.

For pipe design based on structural analysis and calculations, such analysis and calculations shall be submitted to the engineer. Printouts of such calculations by computer programs shall be sufficiently detailed to enable comparison with standardized procedures and methods.

Drawings, details, and descriptions of the pipe joints as necessary to show that the joint conforms to the specified requirements shall also be submitted.

Material Specification 542—Concrete Culvert Pipe

1. Scope

This specification covers the quality of nonreinforced and reinforced concrete culvert pipe.

2. Nonreinforced pipe

Nonreinforced concrete culvert pipe shall conform to the requirements of ASTM Specification C 14 for the class of pipe specified.

3. Reinforced pipe

Round pipe—Round reinforced concrete culvert pipe shall conform to the requirements of ASTM Specification C 76 or ASTM C 655 for the class of pipe specified.

Arch pipe—Reinforced concrete arch culvert pipe shall conform to the requirements of ASTM Specifications C 506 for the class of pipe specified.

Elliptical pipe—Reinforced concrete elliptical culvert pipe shall conform to the requirements of ASTM Specification C 507 for the class of pipe specified.

4. Reinforced box sections

Reinforced concrete box sections shall be manufactured meeting the requirements of ASTM Specification C 1433.

5. Rubber gasket joints

When rubber gasket joints are specified, the joints and gaskets shall conform to the requirements of ASTM Specification C 443.

Material Specification 543—Nonreinforced Concrete Pipe

1. Scope
This specification covers the quality of nonreinforced concrete irrigation pipe, drainage pipe, and drain tile.

2. Irrigation pipe
Unless rubber gasket joints are specified, nonreinforced concrete irrigation pipe shall conform to the requirements of ASTM Specification C 118 for Standard Concrete Irrigation Pipe.

3. Irrigation pipe with rubber gasket joints
Nonreinforced concrete irrigation pipe with rubber gasket joints shall conform to the requirements of ASTM Specification C 505.

4. Drainage pipe
Nonreinforced concrete drainage pipe shall conform to the requirements of ASTM Specification C 118 for the class of pipe specified.

5. Perforated pipe
Perforated nonreinforced concrete pipe shall conform to the requirements of ASTM Specification C 444 for the class of pipe specified.

6. Drain tile
Concrete drain tile shall conform to the requirements of ASTM Specification C 412 for the class of tile specified.

Material Specification 544—Clay Pipe and Drain Tile

1. Scope
This specification covers the quality of clay pipe and drain tile.

2. Pipe
Standard strength clay pipe and extra strength clay pipe shall conform to the requirements of ASTM Specification C 700 for the specified class of pipe.

3. Perforated pipe
Perforated clay pipe shall conform to the requirements of ASTM Specification C 700 for the specified class of pipe.

4. Drain tile
Clay drain tile shall conform to the requirements of ASTM Specification C 4 for the specified class of tile. Perforated drain tile shall conform to the requirements of ASTM Specification C 4 for the specified class.

5. Compression joint material
Compression joints using material having resilient properties shall conform to the requirements of ASTM Specification C 425

Material Specification 547—Plastic Pipe

1. Scope

This specification covers the quality of Poly Vinyl Chloride (PVC), Polyethylene (PE), High Density Polyethylene (HDPE), and Acrylonitrile-Butadiene-Styrene (ABS) plastic pipe, fittings, and joint materials.

2. Material

***Pipe*—**The pipe shall be as uniform as commercially practicable in color, opaqueness, density, and other specified physical properties. It shall be free from visible cracks, holes, foreign inclusions, or other defects. The dimensions of the pipe shall be measured as prescribed in ASTM D 2122.

Unless otherwise specified, the pipe shall conform to the requirements listed in this specification and the applicable reference specifications in table 547–2, the requirements specified in Construction Specification 45, Plastic Pipe, and the requirements shown on the drawings.

***Fittings and joints*—**Fittings and joints shall be of a schedule, SDR or DR, pressure class, external load carrying capacity, or pipe stiffness that equals or exceeds that of the plastic pipe. The dimensions of fittings and joints shall be compatible with the pipe and measured in accordance with ASTM D 2122. Joint and fitting material shall be compatible with the pipe material. The joints and fittings shall be as uniform as commercially practicable in color, opaqueness, density, and other specified physical properties. It shall be free from visible cracks, holes, foreign inclusions, or other defects.

Fittings and joints shall conform to the requirements listed in this specification, the requirements of the applicable specification referenced in the ASTM or AWWA specification for the pipe, the requirements specified in Construction Specification 45, and the requirements shown on the drawings.

***Solvents*—**Solvents for solvent welded pipe joints shall be compatible with the plastic pipe used and shall conform to the requirements of the applicable specification referenced in the ASTM or AWWA specification for the pipe, fitting, or joint.

***Gaskets*—**Rubber gaskets for pipe joints shall conform to the requirements of ASTM F 477, Elastomeric Seals (Gaskets) for Jointing Plastic Pipe.

3. Perforations

When perforated pipe is specified, perforations shall conform to the following requirements unless otherwise specified in Construction Specification 45 or shown on the drawings:

a. Perforations shall be either circular or slots.

b. Circular perforations shall be 1/4 ± 1/16-inch diameter holes arranged in rows parallel to the axis of the pipe. Perforations shall be evenly spaced along each row such that the center-to-center distance between perforations is not less than eight times the perforation diameter. Perforations may appear at the ends of short and random lengths. The minimum perforation opening per foot of pipe shall be as shown in table 547–1.

Table 547–1 Perforations

Nominal pipe size (inches)	Minimum number of rows		Minimum opening/foot (square inches)
	circular	slot	
4	2	2	0.22
6	4	2	0.44
8	4	2	0.44
10	4	2	0.44
12	6	2	0.66

Rows shall be arranged in two equal groups at equal distance from the bottom on each side of the vertical centerline of the pipe. The lowermost rows of perforations shall be separated by an arc of not less than 60 degrees or more than 125 degrees. The uppermost rows of perforations shall be separated by an arc not to exceed 166 degrees. The spacing of rows between these limits shall be uniform. The minimum number of rows shall be as shown in table 547–1.

c. Slot perforations shall be symmetrically located in two rows, one on each side of the pipe centerline. Slot perforations shall be located within the lower quadrants of the pipe with slots no wider than 1/8 inch and spaced not to exceed 11 times the perforation width. Minimum perforation opening per lineal foot of pipe shall be as shown in table 547–1.

d. On both the inside and outside of the pipe, perforations shall be free of cuttings or frayed edges and of any material that would reduce the effective opening.

Table 547–2 Pipe specification

Pipe	Specification
Poly vinyl chloride (PVC) pipe	
Plastic pipe - Schedules 40, 80, 120	ASTM D 1785 ASTM D 2466
Pressure rated pipe - SDR Series	AWWA C 900 ASTM D 2241
Plastic drain, waste, and vent pipe and fittings	ASTM D 2665
Joints for IPS PVC pipe using solvent weld cement	ASTM D 2672
Composite sewer pipe	ASTM D 2680
Type PSM PVC sewer pipe and fittings	ASTM D 3034
Large-diameter gravity sewer pipe and fittings	ASTM F 679
Smooth-Wall Underdrain Systems for Highway, Airport, and Similar Drainage	ASTM F 758
Type PS-46 gravity flow sewer pipe and fittings	ASTM F 789
Profile gravity sewer pipe and fittings based on controlled inside diameter	ASTM F 794
Corrugated sewer pipe with a smooth interior and fittings	ASTM F 949
Pressure pipe, 4-inch through 12-inch for water distribution	AWWA C 900
Water transmission pipe, nominal diameters 14-inch through 36-inch	AWWA C 905
Polyethylene (PE) plastic pipe	
Schedule 40	ASTM D 2104
SIDR-PR based on controlled inside diameter	ASTM D 2239
Schedules 40 and 80 Based on outside diameter	ASTM D 2447
SDR-PR based on controlled outside diameter	ASTM D 3035
High density polyethylene (HDPE) plastic pipe	
Plastic pipe and fittings	ASTM D 3350
SDR-PR based on controlled outside diameter	ASTM F 714
Plastic moldings and extrusion compounds	ASTM D 1248
Heat joining polyolefin pipe and fittings	ASTM D 2657
Acrylonitrile-butadiene-styrene (ABS) pipe	
Plastic pipe, schedules 40 and 80	ASTM D 1527
Plastic pipe, SDR-PR	ASTM D 2282
Schedule 40 plastic drain, waste, and vent pipe	ASTM D 2661
Composite sewer pipe	ASTM D 2680
Sewer pipe and fittings	ASTM D 2751

Material Specification 548—Corrugated Polyethylene Tubing

1. Scope

The specification covers the quality of corrugated polyethylene tubing and fittings.

2. Tubing

Corrugated polyethylene tubing shall conform to the requirements of ASTM F 405, ASTM F 667, ASTM F 894, AASHTO M 252, or AASHTO M 294 for the appropriate tubing sizes and fittings.

3. Fittings

ASTM F 405	3-6 inch diameter pipe and fittings
ASTM F 667	8-, 10-, 12-, 15-, 18-, and 24-inch diameter pipe and fittings
ASTM F 894	18- to 120-inch diameter pipe and fittings
AASHTO M 252	3- to 10-inch diameter N12 pipe and fittings
AASHTO M 294	12- to 36-inch diameter N12 pipe and fittings

Material Specification 551—Coated Corrugated Steel Pipe

1. Scope

This specification covers the quality of zinc-coated, aluminum-coated, aluminum-zinc alloy-coated, and polymer-coated corrugated steel pipe and fittings.

2. Pipe

All pipe shall be metallic zinc-coated, aluminum-coated, or aluminum-zinc alloy-coated corrugated steel pipe and fittings conforming to the requirements of ASTM A 742, A 760, A 761, A 762, A 849, A 875, A 885, and A 929 for the specified type, class, fabrication of pipe and coating, and to the following additional requirements:

a. When closed riveted pipe is specified:

(1) Pipe shall be fabricated with circumferential seam rivet spacing that does not exceed 3 inches except that 12 rivets are sufficient to secure the circumferential seams in 12-inch pipe.

(2) Longitudinal seams that will be within the coverage area of a coupling band, the rivets shall have flat heads or the rivets and holes shall be omitted and the seams shall be connected by welding to provide a minimum of obstruction to the seating of the coupling bands.

b. Double riveting or double spot welding for pipe less than 42 inches in diameter may be required. When double riveting or double spot welding is specified, the riveting or welding shall be performed in a manner specified for pipe 42 inches or greater in diameter.

3. Coatings

Coatings described herein, unless otherwise specified, equally refer to the inside and outside pipe surfaces.

When coatings in addition to metallic coatings are specified, they shall conform to the requirements of ASTM A 742, A 760, A 761, A 762, A 849, A 875, A 885, and A 929 for the specified type.

Polymer-coated pipe, unless otherwise specified on the drawings or in the construction specifications, shall be coated on each side with a minimum thickness of 0.01 inches (10 mils), designated as grade 10/10 in ASTM A 762.

4. Coupling bands

Coupling bands are to be provided for each section of pipe. The hardware for fastening the coupling band tightly to the connecting pipe shall be fabricated to permit tightening sufficiently to provide the required joint tensile strength and, if required, watertightness without failure of its fastening.

Gaskets, if specified, are to be provided for each coupling band. The fabrication of coupling bands and fastening hardware, in addition to the above, shall be sufficient to provide the required gasket seating without warping, twisting, or bending.

5. Fittings

Fittings shall be fabricated from steel conforming to ASTM A 742, A 849, A 875, A 885, and A 929. The coating of fittings shall be the same as that specified for the contiguous corrugated coated pipe.

Welded surfaces and adjacent surfaces damaged during welding shall be treated by removing all flux residue and weld splatter. The affected surfaces shall be cleaned to bright metal by sand blasting, power disk sanding, or wire brushing. The cleaned area shall extend at least 0.5 inch into the undamaged section of the coated area. Repair and coating application of damaged and uncoated pipe surface areas shall be in accordance with ASTM A 780.

Material Specification 552—Aluminum Corrugated Pipe

1. Scope

This specification covers the quality of aluminum corrugated pipe and fittings.

2. Pipe

Aluminum corrugated pipe and fittings shall conform to the requirements of ASTM B 745, B 746, or B 790 for the specified pipe sheet thickness, shape type, fabrication methods, and the following additional requirements:

a. When close-riveted pipe is specified:

(1) Pipe shall be fabricated with circumferential seam rivet spacing that does not exceed 3 inches except that 12 rivets are sufficient to secure the circumferential seams in 12-inch pipe.

(2) Longitudinal seams that will be within the coverage area of a coupling band, the rivets shall have flat heads or the rivets and holes shall be omitted and the seams shall be connected by welding to provide a minimum of obstruction to the seating of the coupling bands.

3. Coatings

Bituminous coatings, when specified, shall conform to the requirements of ASTM A 849.

4. Coupling bands

Coupling bands are to be provided for each section of pipe. The hardware for fastening the coupling band tightly to the connecting pipe shall be fabricated to permit tightening sufficiently to provide the required joint tensile strength and, if required, watertightness without failure of its fastening.

Gaskets, if specified, are to be provided for each coupling band. The fabrication shall also be sufficient to provide the required gasket seating without warping, twisting, or bending.

Gaskets provided with connecting bands meeting requirements for special joints in erodible soil conditions shall be as specified in ASTM A 762.

5. Fittings

Fittings shall be fabricated from sheet aluminum meeting the requirements contained in ASTM B 744. The coating for fittings shall be the same as that specified for the contiguous corrugated aluminum pipe.

Fittings that are welded during fabrication shall be accomplished in a good workmanshiplike manner resulting in a continuous smooth surface finish. Aluminum welding electrodes used shall conform to the requirements of American Welding Society (AWS) specification AWS A5.10, "Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes." Welded surfaces and adjacent surfaces damaged during welding shall be treated by removing all weld splatter. The affected surface shall be cleaned to bright metal by sand blasting, power disk sanding, or wire brushing. The cleaned area shall extend at least 0.5 inch into the undamaged section of coated area. Within 24 hours of completion of surface preparation all treated surfaces shall be painted with two coats of a chromate rich primer and allowed to fully dry before exposure to weathering conditions.

Aluminum surfaces fabricated that will have contact with steel, iron, or other metals shall be coated with a zinc-chromate primer and allowed to fully dry before final installation.

Material Specification 553—Ductile-Iron Pipe

1. Scope
This specification covers the quality of ductile-iron pipe and fittings.

2. Pipe
Ductile-iron pipe shall conform to the requirements of ANSI/AWWA C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids, and ANSI/AWWA C115/A21.15, Flanged Ductile-Iron Pipe with Threaded Flanges.

3. Fittings
Ductile-iron pipe fittings shall conform to the requirements of ANSI/AWWA C110/A21.10, Ductile-Iron and Gray-Iron Fittings, 3-inch through 48-inch, for Water and Other Liquids, and ANSI/AWWA C153/A21.53, Ductile-Iron Compact Fittings, 3-inch through 12-inch, for Water and Other Liquids.

4. Joints
Rubber-gasket joints for ductile-iron pipe and fittings where either mechanical or push-on joints are used shall conform to the requirements of ANSI/AWWA C111/A21.11, Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings.

5. Lining
Interior lining for ductile-iron pipe and fittings shall conform to the requirements of ANSI/AWWA C104/A21.4, Cement Mortar Lining for Ductile-Iron Pipe and Fittings for Water.

6. Encasement
Encasement for ductile-iron pipe and fittings shall conform to the requirements of ANSI/AWWA C105/A21.5-88, Polyethylene Encasement for Ductile-Iron Pipe for Water and Other Liquids.

Material Specification 554—Steel Pipe

1. Scope

This specification covers the quality of steel pipe and fittings.

2. Pipe

Steel pipe shall conform to the requirements of the applicable specification listed below for the kind of pipe and the type, weight, grade, and finish specified:

Pipe	ASTM specification
Steel, black and hot-dipped, zinc-coated welded and seamless	A 53
Steel, electric-fusion (ARC)-welded (sizes NPS 16 and over)	A 134
Electric-resistance-welded steel	A 135
Electric-fusion (ARC)-welded steel (NPS 4 and over)	A 139
	AWWA standard
Steel water pipe, 6 inches and larger	C 200

3. Fittings

Fittings shall conform to the requirements for the types and kinds specified.

Fittings	ASTM specification
Heat-treated carbon steel fittings for low-temperature and corrosive service	A 858
Threaded couplings, steel, black or zinc-coated (galvanized) welded or seamless, for use in steel pipe joints	A 865

Material Specification 571—Slide Gates

1. Scope

This specification covers the quality of metal slide gates for water control.

2. Class and type of gate

The class of gate is expressed as a numerical symbol composed of the seating head and unseating head. The two numbers are separated by a hyphen with the seating head listed first. For this purpose, the heads shall be expressed in terms of feet of water. Gates shall be of the specified types as defined:

Light duty

Type MLS-1 Cast iron with cast iron seat facings

Type MLS-2 Fabricated metal

Moderate duty

Type MMS-1 Cast iron with bronze seat facings, cast iron or galvanized structural steel guides, and galvanized steel, bronze, or stainless steel fasteners.

Type MMS-2 Cast iron with bronze seat facings, cost iron or stainless steel guides, and bronze or stainless steel fasteners. Guides and fasteners are stainless steel, when specified.

Heavy duty

Type MHS-1 Have gray cast iron slides, frames, guides, and yokes, and are fitted with bronze seat facings, bronze wedges and wedge blocks or wedge seat facings, and bronze stem blocks or thrust nuts; bronze or stainless steel fasteners; and cold rolled steel stems except where stainless steel stems are specified.

Type MHS-2 Have gray cast iron slides, frame, guides, and yokes, and are fitted with stainless steel seat facings, wedges, wedge seat facings, stems and fasteners; and austenitic cast iron stem blocks or thrust nuts.

Type MHS-3 Have austenitic gray cast iron slides, frames, guides, and yokes, and are fitted with nickel-copper alloy seat facings, wedges, wedge seat facings, stems and fasteners; and austenitic cast iron stem blocks or thrust nuts.

3. Quality of material

Material for slide gates and appurtenances shall conform to the requirements of the applicable specifications listed below for the alloy, grade, type, or class of material and the condition and finish appropriate to the structural and operational requirements.

Material	ASTM specification
Cast iron and gray cast iron	A 48, Class 30 A 126, Class B
Austenitic cast iron	A 436
Structural steel shapes, plates, and bars	A 36
Cold rolled steel	A 108
Carbon steel bars	A 108 or A 575
Stainless steel	A 167, A 276, A 582; Type 302, 303, 304, or 304L
Castings, nickel and nickel alloy	A 494
Carbon steel sheets and strips	A 1011
Zinc-coated carbon steel sheets	A 653 or A 924
Bronze bar, rods, shapes	B 21 or B 98
Naval bronze	B 21
Phosphor bronze	B 103 or B 139
Manganese bronze	B 138 or B 584
Silicon bronze	B 98 or B 584
Cast bronze	B 584
Nickel-copper alloy plate, sheet, strip	B 127
Nickel-copper alloy rod or bar	B 164
Rubber for gaskets and seals	D 2000

Galvanizing (zinc coating) shall conform to the requirements of Material Specification 582.

4. Fabricated metal gates (light duty gates)

Fabricated metal gates shall be built to withstand the seating head expressed by the gate class designation. Unless otherwise specified, the gates shall be galvanized steel with flat-back frames.

5. Cast iron gates (light duty gates)

The frame shall be cast iron of the specified type. The front face shall be machined to receive the gate guides.

The gate slide shall be cast iron and shall be fabricated to withstand the seating and unseating heads expressed by the gate class designation as defined in section 2 of this specification.

Grooves shall be cast on the vertical sides of the slide to match the guide angles.

The gates guides shall be galvanized structural steel and shall be fabricated to withstand the total thrust of the gate slide from water pressure and wedge action under maximum operating conditions.

Wedges and wedge seats shall have smooth bearing surfaces. Wedges may be cast as integral parts of the slide. Removable wedges and wedge seats shall be fastened to the slide, frame, or guides by means of suitable studs, screws, or bolts and shall be firmly locked in place after final adjustment. Each interacting set of wedge and wedge seat shall be adjustable as needed to ensure accurate and effective contact. Adjusting bolts or screws shall be bronze or galvanized steel.

Seat facings shall be machined to a smooth finish to ensure proper watertight contact.

6. Frame or seat (moderate and heavy duty gates)

The frame shall be cast iron and of the specified type. The front face shall be machined to receive the gates guides, and the rear face shall be machined as required to match the specified attaching means. For heavy duty gates, a dovetailed groove shall be machined on the perimeter of the front face to receive the seat facing.

7. Gate slide (moderate and heavy duty gates)

The gate slide shall be cast iron, rectangular in shape, and shall have horizontal and vertical stiffening ribs of sufficient section to withstand the seating and unseating heads expressed by the gate class designation as defined in section 2 of this specification. For heavy duty gates, a dovetailed groove shall be machined on the perimeter of the slide face to receive the seat facing.

Tongues shall be machined on the vertical sides of the slide along its entire height to match the guide grooves and angles with a maximum clearance of 1/16 inch for gates smaller than 54 inches by 54 inches, and 1/8 inch for larger gates.

A nut pocket with reinforcing ribs shall be integrally cast on the vertical centerline and above the horizontal centerline of the slide. The pocket shall be of a shape adequate to receive a flat-backed thrust nut or stem block and shall be built to withstand the opening and closing thrust of the stem.

8. Gate guides (moderate and heavy duty gates)

The gate guides shall be built to withstand the total thrust of the gate slide from water pressure and wedge action. The gate guides shall be cast iron for heavy duty gates.

Grooves shall be machine-in cast iron guides to receive the tongue on the gate slide throughout the entire length of the guide.

The guides shall be of adequate length to retain a minimum of one-half the height of the gate slide when the gate is fully opened.

9. Wedges and wedge seats (moderate and heavy duty gates)

Pads for supporting wedges, wedge seats (or blocks), and wedge loops (or stirrups) shall be cast as integral parts of the gate frame, slide, or guides and shall be accurately machined to receive those parts.

Wedges and wedge seats shall have smooth bearing surfaces for moderate duty gates and shall have machine finish bearing surfaces for heavy duty gates. Removable wedges may be cast as integral part of the slide for moderate duty gates. Wedges shall be fastened to the gate slide, frame, or guides with suitable studs, screws, or bolts and shall be firmly locked in place after final adjustment. Each interacting set of wedge and wedge seat shall be adjustable as needed to ensure accurate and effective contact.

10. Seat facing

***Moderate duty gates*—**Seat facings shall be machined to a smooth finish to ensure proper watertight contact. Bronze facings shall be securely attached by welding or other approved methods.

***Heavy duty gates*—**Seat facings shall be pressed or impacted into the machined dovetailed grooves on the gate slide and frame and machined to a smooth finish to ensure proper watertight contact.

11. Yoke

When a self-contained gate is specified, the yoke shall be of such design as to withstand the loads resulting from normal operation of the gate. For moderate and heavy duty gates, cast iron yokes shall be provided with machined pads for connecting to the ends of gate guides and to receive the stem thrust cap or handwheel lift.

12. Flush bottom seal (heavy duty gate)

When a flush bottom sealing gates is specified, a solid, square-corner type rubber seal shall be provided at the bottom of the gate opening. It shall be securely attached either to the bottom of the slide or to the frame. Metal surfaces bearing on the rubber seal shall be smooth and rounded as necessary to prevent cutting of the seal during gate operation.

13. Gate stem and lift (or hoist)

The gate stem and lift/hoist shall be of the specified type, size, and capacity and, if hand operated, shall be capable of moving the gate slide under normal conditions, following unseating from the wedging device, with a pull on the handwheel or crank of not more than 25 pounds with the specified seating and/or unseating head of water against the gate.

Unless otherwise specified, the stem shall be carbon steel and shall be furnished in sections as necessary to permit reasonable ease in installation. Couplings shall be bolted, pinned, or keyed to the stem. The stem shall be furnished with rolled or machine-cut 29 degree Acme threads of sufficient length to completely open the gate. The threads shall be smooth and of uniform lead and cross-section, such that the nut can travel the full length without binding or excessive friction. For moderate and heavy duty gates, the stem shall be threaded for connection to the stem block or thrust nut on the gate slide.

The lift shall be compatible with the type of stem furnished. Unless otherwise specified, the lift nut shall be cast bronze for light and moderate duty gates and cast manganese bronze for heavy duty gates and shall be fitted with ball or roller thrust bearings designed to withstand the normal thrust developed during opening and closing of the gate at the maximum operating heads. All gears, sprockets, and pinions shall be machine-cut, with ratios and strength adequate to withstand expected operating loads. Sufficient grease fittings shall be provided to allow lubrication of all moving parts. An arrow and the word "open" shall be cast on the rim of the handwheel or on the lift housing to indicate the direction of gate opening. Unless otherwise specified, the lift for the nonrising-stem gate shall be provided with an indicator capable of showing both when the gate

is fully open and when it is fully closed for the moderate and heavy duty gates.

Provisions shall be made to prevent stem rotation within the stem block or thrust nut or at the connection of the gate slide.

Stop collars shall be provided to prevent overtravel in opening and closing the gate.

14. Stem guides

Unless otherwise specified, stem guides shall be cast iron for light duty gates and cast iron with bronze bushed collars for moderate and heavy duty gates. They shall be fully adjustable in two directions.

15. Wall thimble (moderate and heavy duty gates)

When a wall thimble is specified, it shall be of the same cast iron used in the gate frame and of the section, type, and depth specified. The front flange shall be machined to match the gate frame and drilled and tapped to accurately receive the gate attachment studs.

Gaskets or mastic to be installed between the thimble and the gate frame shall conform to the recommendations of the gate manufacturer and shall be furnished with the thimble.

16. Fasteners

Unless otherwise specified, all anchor bolts and other fasteners shall be galvanized steel or bronze for light duty gates; galvanized steel or stainless steel or bronze for moderate duty gates; and, of the quality and size as recommended by the gate manufacturer for heavy duty gates. All anchor bolts, assembly bolts, screws, nuts, and other fasteners shall be of ample section to withstand the forces created by operation of the gate while subjected to the specified seating and unseating heads. Anchor bolts shall be furnished with two nuts to facilitate installation.

17. Installation instructions

Before installation, the contractor shall provide the engineer with the manufacturer's complete installation data, instructions for adjustments, and drawings or templates showing the location of all anchor bolts for each gate.

18. Painting

When specified, gates and accessories shall be painted by the designated paint system.

19. Certification

The supporting data submitted to the engineer shall include the name of the manufacturer, the manufacturer's model number (for standard catalogue items), or the seating and unseating heads for which the gate is designed together with such drawings and specifications as may be necessary to show that the gate conforms to the requirements of this specification.

Material Specification 572—Flap Gates, Metal

1. Scope

This specification covers the quality of metal flap gates for water control.

2. Class and type of gate

The class of gate is expressed as the numerical value of the seating head that the gate must be built to withstand. For this purpose, the head shall be expressed in terms of feet of water measured to the center of the gate. Gates shall be of the specified type as defined below:

Light duty

Type MLF-1—Cast iron or cast steel fitted with unbushed linkage systems and galvanized steel fasteners, or with bronze bushed linkage systems and bronze or stainless steel fasteners.

Moderate duty

Type MMF-1—Cast iron or cast steel fitted with bronze seat facings, bronze bushed linkage systems, and bronze or stainless steel fasteners.

Heavy duty

Type MHF-1—Have gray cast iron frames and flaps and are fitted with naval bronze seat facings, gray cast iron or high-strength bronze hinge arms, bronze bushings, bronze hinge pins, and bronze fasteners.

Type MHF-1R—The same as Type MHF-1 gates except that the frame is fitted with a rubber seat facing instead of a metal seat facing.

Type MHF-2—Have gray cast iron frames and flaps and are fitted with stainless steel seat facings, gray cast iron or stainless steel hinge arms, and stainless steel bushings, hinge pins, and fasteners.

Type MHF-2R—The same as Type MHF-2 gates except that the frame is fitted with a rubber seat facing instead of a metal seat facing.

Type MHF-3—Have austenitic gray cast iron frames, flaps and hinge arms and are fitted with nickel-copper alloy seat facings, bushings, hinge pins, and fasteners.

Type MHF-3R—The same as Type MHF-3 except that the frame is fitted with a rubber seat facing instead of a metal seat facing.

3. Quality of material

Material in flap gates and appurtenances shall conform to the requirements of the applicable specifications listed below for the alloy, grade, type, or class of material and the condition and finish appropriate to the structural and operational requirements:

Material	ASTM specifications
Cast iron and gray cast iron	A 48, Class 30, or A 126, Class B
Cast steel	A 27 or A 148
Structural steel shapes, plates, and bars	A 36
Carbon steel bars	A 108 or A 575
Stainless steel	A 167, A 276, or A 582; Type 302, 303, 304, or 304L
Austenitic gray cast iron	A 436
Castings, nickel and nickel-alloy	A 494
Carbon steel sheets and strips	A 1011
Bronze bar, rods, shapes, and naval bronze	B 21 or B 98
Red brass	B 43
Silicon bronze	B 98 or B 584
Phosphor bronze	B 103 or B 139
Manganese bronze	B 138 or B 584
Nickel-copper alloy plate, sheet, strip	B 127
Nickel-copper alloy rod, bar	B 164
Cast bronze	B 584
Rubber gaskets and seals	D 2000

4. Frame

The frame shall be cast iron or cast steel for light and moderate duty gates and as specified for heavy duty gates, and of the specified type. For moderate and heavy duty gates, the rear face shall be machined as required to match the specified attaching means. For the heavy duty gate, a groove shall be matched on the perimeter of the front face to receive the seat facing.

5. Flap

For light and moderate duty gates, the flap shall be cast iron or cast steel and shall be built to withstand the seating head expressed by the gate class designation as defined in section 2 of this specification.

For heavy duty gates, the flap shall be built to withstand the seating head expressed by the gate class designation as defined in section 2 of this specification. A groove shall be machined on the perimeter of the face to receive the seat facing.

6. Linkage system

The linkage system by which the flap is mounted onto the frame shall be double-pivoted type for gates more than 8 inches in diameter. It shall be designed to prevent the flap from folding inside of the seat and wedging in the open position. For the moderate heavy duty gates, the top pivot shall be so designed as to allow adjustment of gate alignment and sensitivity.

7. Seat facings

***Light duty gates*—**All facings shall be machined to a smooth finish to insure proper contact.

***Moderate duty gates*—**Seat facings shall be securely attached by welding or other approved means and machined to a smooth finish to ensure proper contact.

***Heavy duty gates*—**Metal facings shall be pressed or impacted into machined dovetailed grooves on the flap and frame (or securely attached in the seat grooves by means of studs, set screws, or other approved means) and machined to a smooth finish to ensure proper contact. Rubber facings shall be pressed into a dovetailed groove in the frame.

8. Wall thimble

Where a wall thimble is specified for moderate and heavy duty gates, it shall be of the same cast iron used in the gate frame and of the section, type, and depth specified. The front flange shall be machined to match the gate frame and drilled and tapped to accurately receive the gate attachment studs.

Gaskets or mastic to be installed between the thimble and the gate frame shall conform to the recommendations of the gate manufacturer and shall be furnished with the thimble.

9. Galvanizing

Unless otherwise specified, cast steel and fabricated steel parts shall be galvanized in accordance with Material Specification 582.

10. Painting

When specified, gates and accessories shall be painted by the designated paint system.

11. Installation instructions

The contractor shall provide the engineer with the manufacturer's complete installation data, instructions for adjustments, and drawings or templates showing the location of anchor bolts for each gate.

12. Certification

The supporting data submitted to the engineer shall include the name of the manufacturer, the manufacturer's model number (for standard catalogue items), or the seating head for which the gate is designed together with such drawings and specifications as may be necessary to show that the gate conforms to the requirements of this specification.

Material Specification 573—Radial Gates

1. Scope

This specification covers the quality of radial (Tainter) gates for water control.

2. Quality of material

Material in radial gates and appurtenances shall conform to the requirements of the applicable specifications listed below for the alloy, grade, type, or class of material and the condition and finish appropriate to the structural and operational requirements:

Material	ASTM specifications
Cast iron	A 48, Class 30, or A 126, Class B
Cast steel	A 27 or A 148
Structural steel shapes, plates and bars	A 36
Carbon steel bars	A 108 or A 575
Stainless steel	A 167, A 276, or A 582; Type 302, 303, 304, or 304L
Zinc-coated steel sheets	A 653 or A 924
Bronze bar, rods, shapes	B 21 or B 98
Cast bronze	B 584

Galvanizing (zinc coating) shall conform to the requirements of Material Specification 582.

3. Gates

Unless otherwise specified, the gates shall be fabricated from structural steel with skin plates made of smooth or corrugated iron or steel sheets. They shall conform to the dimensions shown on the drawings and shall be built to withstand the specified head. The curvature of the skin plate shall be concentric with the pivot pins or trunnions. Gates shall be supplied with pin bearings, pins, hoist, galvanized hoisting cable, and all anchor bolts. Unless otherwise specified, the pin bearings shall be cast iron and of the embedded type.

4. Hoist

Hoists shall be of the worm-gear type and shall be equipped with hand crank or be power operated as specified on the drawings. Hoists shall be furnished complete with all lubricants, anchor bolts, and other appurtenances necessary for their installation and operation.

5. Rubber seals

Each gate shall be fitted with rubber seals along the side and bottom edges of the gate face. The seals shall be of the belt type or J type, as specified, and shall be designed to bear on the walls and bottom of the structure or on rubbing plates and sills to ensure a watertight fit when the gate is closed. When specified, a rubber seal shall also be provided at the top edge of the gate.

6. Installation instructions

Before gate installation, the contractor shall provide the engineer with the manufacturer's complete installation data, instructions for adjustments and drawings, or templates showing the location of anchor bolts and pin bearings for each gate.

7. Painting

Gates and accessories shall be galvanized or painted with the specified paint system.

8. Certification

The supporting data submitted to the engineer shall include the manufacturer's name and the hydraulic head for which the gate is designed together with such drawings and specifications as may be necessary to show that the gate conforms to the requirements of this specification.

Material Specification 581—Metal

1. Scope
This specification covers the quality of steel and aluminum alloys.

2. Structural steel
- Structural steel shall conform to the requirements of ASTM A 36.
- High-strength low-alloy structural steel shall conform to ASTM A 242 or A 588.
- Carbon steel plates of structural quality to be bent, formed, or shaped cold shall conform the ASTM A 283, Grade C.
- Carbon steel sheets of structural quality shall conform to ASTM Standard A 1011, Grade 40, or A 1008, Grade 40.
- Carbon steel strip of structural quality shall conform to ASTM Standard A 1011, Grade 36.

3. Commercial or merchant quality steel
Commercial or merchant quality steel shall conform to the requirements of the applicable ASTM listed below:

Product	ASTM standards
Carbon steel bars	A 575, Grade M 1015 to Grade M 1031
Carbon steel sheets	A 1011
Carbon steel strips	A 1011
Zinc-coated carbon steel sheets	A 653 or A 924

4. Aluminum alloy
Aluminum alloy products shall conform to the requirements of the applicable ASTM standard listed below. Unless otherwise specified, alloy 6061-T6 shall be used.

Product	ASTM standard
Standard structural shape	B 308
Extruded structural pipe and tube	B 429
Extruded bars, rods, shapes, and tubes	B 221
Drawn seamless tubes	B 210
Rolled or cold-finished bars, rods, and wire	B 211
Sheet and plate	B 209

5. Bolts
Steel bolts shall conform to the requirements of ASTM Standard A 307. If high-strength bolts are specified, they shall conform to the requirements of ASTM A 325.

When galvanized or zinc-coated bolts are specified, the zinc coating shall conform to the requirements of ASTM Standard A 153 except that bolts 0.5 inch or less in diameter may be coated with electro-deposited zinc or cadmium coating conforming to the requirements of ASTM Standard B 633, Service Condition SC 3, or ASTM B 766, unless otherwise specified.

6. Rivets
Unless otherwise specified, steel rivets shall conform to the requirements of ASTM Specification A 31, Grade B. Unless otherwise specified, aluminum alloy rivets shall be Alloy 6061 conforming to the requirements of ASTM Standard B 316.

7. Welding electrodes
Steel welding electrodes shall conform to the requirements of American Welding Society Specification AWS A5.1, "Specification for Mild Steel Covered Arc-Welding Electrodes," except that they shall be uniformly and heavily coated (not washed) and shall be of such a nature that the coating does not chip or peel while being used with the maximum amperage specified by the manufacturer.

Aluminum welding electrodes shall conform to the requirements of American Welding Society Specification AWS A5.10, "Specification for Aluminum and Aluminum-Alloy Welding Rods and Bare Electrodes."

Material Specification 582—Galvanizing

1. Scope

This specification covers the quality of zinc coatings applied to iron and steel productions.

2. Quality

Zinc coatings shall conform to the requirements of ASTM A 123 for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products or as otherwise specified in the items of work and construction details of the Construction Specification.

ASTM A 123 covers both fabricated and nonfabricated products; e.g., assembled steel products, structural steel fabrications, large tubes already bent or welded before galvanizing, and wire work fabricated from noncoated steel wire. It also covers steel forgings and iron castings incorporated into pieces fabricated before galvanizing or which are too large to be centrifuged (or otherwise handled to remove excess galvanizing bath metal).

Items to be centrifuged or otherwise handled to remove excess zinc shall meet the requirements of ASTM A 153, except bolts, screws, and other fasteners 0.5 inch or less in diameter may be coated with electro-deposited zinc or cadmium coating conforming to the requirements of ASTM B 766, coating thickness Class 5, Type III, or ASTM B 633, Service Condition SC-3, unless otherwise specified.

Material Specification 583—Coal Tar-Epoxy Paint

1. Scope

This specification covers the quality of a coal tar polyamide epoxy paint suitable for use on structural steel or concrete. Paint supplied meeting Paint Specification No. 16, Type 1, Class II, of the Steel Structures Painting Council will meet the requirements of this specification.

2. Composition and processing

***Composition*—**The paint shall be a two-component system that has the pitch, filler, and catalyst in one component and the resin in another. Each component of this paint based on the specified ingredients shall be uniform, stable in storage, and free from grit and coarse particles. The components shall contain the followings types and proportions of ingredients:

Ingredient	Component A percent by weight min.	max.	Component A and B typical composition percent by weight
Coal tar pitch	33.0	36.0	28.2
Polyamide	11.0	12.0	9.5
Magnesium silicate	30.0	33.0	25.8
Xylene	18.0	21.0	15.4
Gelling agent and activator	2.5	2.6	2.0
Catalyst (accelerator)	1.2	1.3	1.1
Subtotal			82.0
	Component B		
Epoxy resin (100% nonvolatile)	100	---	18.0
Total			100.0

***Processing*—**Magnesium silicate and gelling agent shall be thoroughly dispersed in component A by means of grinding equipment capable of developing substantial shear values. Gellant shall be mixed with an equal weight of magnesium silicate and then dampened by stirring-in all of the alcohol; the resultant mixture shall be added to and thoroughly dispersed into component A. (The viscosity of component A is markedly influenced by the degree of dispersion of gellant and magnesium silicate.)

***Quality of ingredients*—**Ingredient material shall exhibit the following properties:

Coal tar pitch. Coal tar pitch is a product obtained from the distillation of high temperature crude coke oven tar, which in itself is a product obtained during the destructive distillation of coal in slot ovens operated at a temperature above 700 degrees Celsius. Coal tar pitch shall have the following characteristics:

	Min.	Max.
Softening point, in water, °C (ASTM D 36)	70	75
Ash, percent by weight (ASTM D 2415)	--	0.5
Insolubles in carbon disulfide, percent by weight (ASTM D 4)	--	20
Volatiles, percent by weight		
Under 250 °C	--	0.0
Under 300 °C	--	5.0

Gellant. The gellant or thixotropic-producing additive shall be an organic derivative of magnesium montmorillonite or hydrogenated castor oil. It shall be a creamy white powder having a bulking value of 15 ± 0.2 pounds per gallon and water content of 3 percent maximum.

Activator. The activator, if used, shall be methanol, ethanol, or propylene carbonate.

Catalyst. The catalyst (accelerator) shall be 2,4,6-tri (dimethylamino methyl) phenol.

Epoxy resin. Epoxy resin shall be a di-epoxide condensation product of bisphenol-A and epichlorohydrin with terminal epoxide group. It shall be clear, tree of turbidity, crystals, and particulate matter with the following properties:

Property	Requirements min.	max.
Nonvolatile content (1 to 2 grams after 1 hour at 105 ± 2 °C), % by weight	99	--
Epoxide equivalent (ASTM D 1652)	180	200
Color, Gardner (ASTM D 1544)	--	5.0
Specific gravity (ASTM D 1475)	1.15	1.18
Viscosity, Brookfield, poises at 25 °C	100	160

Polyamide resin. Polyamide resin shall be a condensation product of a dimerized fatty acid in polyamides. It shall be clear, free of turbidity and particulate matter, with the following characteristics:

Characteristics	Requirements min.	max.
Amine value 1/	330	360
Color, Gardner (ASTM D 1544)	--	9
Specific gravity (ASTM D 1475)	0.96	0.98
Viscosity, Brookfield, poises at 25 °C	7	9
Nonvolatile content (1-2 grams after 1 hr at 105 ± 2 °C), % by weight	97	--

1/ The amine value is defined as the milligrams of potassium hydroxide equivalent to the amine alkalinity potentiometric titration with standard perchloric acid according to the following method:

a. Weigh the approximate amount of well mixed resin to give a titration in the range of 12 to 18 milliliters (mL) into a tared 200 mL berzelius tall form beaker on an analytical balance. Cover the beaker with aluminum foil to minimize contact with air.
b. From a graduated cylinder, carefully add 90 mL of solvent (suitable solvents are nitrobenzene, propylene carbonate, or acetonitrile), insert a stirring bar, cover the beaker with aluminum foil, and stir on a magnetic stirrer to dissolve the sample. Add the solvent immediately after weighing the sample. A fume hood should be used for all operations.
c. From a graduated cylinder, add 20 mL of glacial acetic acid to the sample solution and stir for several minutes.
d. Immerse the electrodes into the sample solution, stir for 2 minutes, and titrate potentiometrically with 0.1 N perchloric acid using the millivolt scale. Record the millivolt reading every 0.1 mL. Plot a graph showing the millivolts against the titration. The endpoint is the midpoint of the inflection on the titration curve.
e. Conduct a blank determination on 90 mL of the solvent and 20 mL of acetic acid. The blank need only be determined once for each lot of solvent used. On the majority of lots used, the blank has been found to be zero.
f. Calculate the amine value using the following formula:

Amine value = (sample titration-solvent blank) x normality x 56.1 weight of sample

Magnesium silicate. Magnesium silicate shall conform to ASTM Standard D 605 "Magnesium Silicate Pigment (Talc)." When a dark red coating is specified, a dark red coating shall be furnished in 50 percent or more (by volume) of the magnesium silicate is replaced by synthetic red iron conforming to ASTM Standard D 3721. The red coating shall meet all of the test requirements prescribed for the black coating except that the nonvolatile content of component A shall be an amount reflecting the greater specific gravity of the iron oxide pigment.

3. Physical requirements

When tested by the methods described in section 4, component A shall exhibit the following properties:

- Viscosity, Brookfield, at 25 degrees Celsius poises 160 maximum
- Nonvolatile residue, percent by weight 77 minimum

The mixed paint shall exhibit the following properties:

- Sag, 14 mil wet film—None
- Pot life at 24 to 27 °C, hours—4 minimum

The cured film shall exhibit the following properties:

- Penetration, 200 grams, 5 seconds, 25 °C, hundredth centimeter units—3 maximum
- Odor after 48 hours curing—Pass test
- Flexibility on 0.5-inch mandrel—Pass test
- Adhesion—No delamination

4. Test methods

Viscosity of component A—Fill a container having a minimum diameter of 3 inches, a minimum height of 3.75 inches, and a minimum depth of 3 inches with a representative sample of component A. Set up a Model RVT or RVF-100 Brookfield Synochro-Electric Viscometer with a No. 7 spindle and with guard removed. Bring the sample to (and thereafter maintain) a temperature of 25 degrees Celsius and stir vigorously for 2 minutes with a stiff spatula. Immediately after stirring, lower the viscometer, immersing the spindle until half of the neck mark on the spindle is covered. Run the viscometer at 100 rpm for 1 minute and record the pointer position on the dial. If the dial reading is 40 or less, the viscosity shall be considered to be 160 poises or less. If the reading is over 40, immediately start the motor and take additional readings at 1-minute intervals. If one or more readings of 40 or less are obtained out of 10 readings, taken at 1-minute intervals, the viscosity of the material shall be considered to be within specification limits.

Nonvolatile content of component A—Place a stirrer (e.g., short length of stiff wire, such as a partly-straightened paper clip) into a small disposable aluminum dish of about 2 inches in diameter and weigh to the nearest 0.1 milligram. As rapidly as possible, place between 2 and 3 grams of component A into the dish and weigh immediately to the nearest 0.1 milligram. After weighing, spread the material over the bottom of the dish. Heat the dish, wire, and contents in a well-ventilated, convection-type oven maintained at 105 degrees Celsius plus or minus 2 degrees Celsius for 3 hours. After the material has been in the oven for a few minutes, and periodically thereafter, stir the material. Cool in a desiccator, weigh to the nearest 0.1 milligram, and calculate the percentage of nonvolatile on a weight basis.

Sag test of coal tar-epoxy paint—Prepare about 500 mL of the material by thoroughly mixing 100 mL of component B into 400 mL of component A. Determine its viscosity immediately after mixing using the same procedure as those for component A, but employing a No. 5 spindle. If all of five readings recorded at 1-minute intervals are above 50, reduce the viscosity by adding xylene in small increments until a reading not greater than 50 is obtained. Press a strip of 1-inch masking tape across the full width of a solvent-cleaned 3-inch by 6-inch cold-rolled steel panel. The tape should be parallel to and centered on the shorter axis of the panel. Within 5 minutes after making the final check of viscosity, apply the material to the panel to a wet film thickness at least 14 mils as determined by an Interchemical wet film doctor blade having a gap of about 25 mils, or by brush. Immediately after applying the material, carefully remove the masking tape and stand the panel in a vertical position (with the bare strip horizontal) in a draft-free, 24 to 27 degree Celsius location. Examine the panel after 4 hours. Sagging or running of the coating into the bare area shall constitute failure of the material to pass the sag test.

Pot life test of coal tar-epoxy paint—Mix 100 mL of compound B into 400 mL of component A with both components having a temperature of 24 to 27 degrees Celsius before mixing. Pour the material at once into a pint metal can, seal tightly, and maintain at 24 to 27 degrees Celsius. Examine the material 4 hours after it was mixed. For its pot life to be considered satisfactory, the mixed material must remain in a fluid condition and, when thinned with no more than 100 mL of xylene, shall be lump-free and brushable.

Penetration test on coal tar-epoxy film—Select and solvent spray-clean two 3-inch by 6-inch cold-rolled steel panels in accordance with ASTM D 609. Draw down in accordance with a

coat of the paint prepared as described in section 4 for the sag test. Allow the film to dry 18 to 24 hours in a horizontal position at 24 to 27 degrees Celsius and at a relative humidity of not over 60 percent. Apply a second coat over and at right angles to the first coat, using freshly mixed paint prepared identically to that used for the first coat. The draw down applicator(s) shall be such as to provide a total dry-film thickness for the two coats of 20 to 25 mils, and the coats shall be of approximately equal thickness. Allow the second coat to dry in a horizontal position for 120 hours at 24 to 27 degrees Celsius. After 120 hours of curing, and daily thereafter, clamp the panel into the table of a penetrometer (ASTM D 5) so that the needle is over an area that is within the prescribed thickness range (as measured by ASTM D 1186). Determine the penetration using a total load of 200 grams applied for 5 seconds at 25 degrees Celsius. The average of the three lowest out of five penetration readings, all taken within a 1 centimeter square, shall not exceed 0.03 of a centimeter after 120 hours of curing.

Odor of dried coal tar-epoxy film—Examine the paint film on one of the flexibility panels for odor after it has cured for 48 hours. The film shall be free of any odor except for a faint odor of xylene.

Flexibility of coal tar-epoxy film—Sand blast three steel panels (similar to those used in the penetration test) at low pressure with a clean, 30 to 50 mesh, nonmetallic abrasive until a uniform, gray-white surface with well developed anchor pattern, is achieved. (Note: It may be necessary to blast both sides of panel, in stages, to avoid warping.) Blow off any dust with a clean air blast. Apply two coats of paint as described in section 4 for the penetration test. Allow the film to cure in the period equal to that required to reach a penetration of 0.03 centimeter on the penetration test panel, whichever occurs first. With the film side up, and in a time interval of about 1 second, bend each of the flexibility panels double over a 0.5-inch diameter mandrel. Cracks in any of the panels visible to the naked eye shall constitute failure except that edge cracks extending no further than 0.5 inch or small local fissures emanating from air bubbles, craters, and similar imperfections shall be disregarded.

Adhesion of coal tar-epoxy film—Test the adhesion of the coating on an unbroken area of the flexibility panel with a sharp knife after the coating has cured for 120 hours. It shall strongly resist being removed from the metal. Also use a knife to test the intercoat adhesion of the film on a penetration panel after 120 hours curing. Any delamination of the two coats shall constitute failure.

Material Specification 584—Structural Timber and Lumber

1. Scope

The specification covers the quality of structural timber, lumber, and plywood.

2. Grading

Structural timber and lumber shall be graded in accordance with the grading rules and standards, applicable to the specified species adopted by a lumber grading or inspection bureau or agency recognized as being competent and that conform to the basic principles of ASTM Standard D 245. The material supplied according to the commercial grading rules shall be of equal or greater stress value than the specified stress-grade.

3. Quality of material

All material shall be sound wood free from decay and disease damage. Boxed heart pieces of Douglas fir or redwood shall not be used in stringers, floor beams, caps, posts, sills, or other principal structural members. Boxed heart pieces are defined as timber so sawed that at any section in the length of a sawed piece the pith lies entirely inside the four faces.

4. Heartwood requirements

All timber and lumber specified for use without preservative treatment shall contain a minimum of 75 percent heartwood on any diameter or on any side or edge, measured at the point where the greatest amount of sapwood occurs. This requirement shall not apply to timber and lumber for which pressure treatment with wood preservative is specified.

5. Sizes

The sizes specified are nominal sizes. Unless otherwise specified, the material shall be furnished in American Standard dressed sizes.

6. Marking

Each piece of timber and lumber shall be legibly stamped or branded with an official grade identification. Plywood shall be legibly stamped with an official mark designating the grade, type, and surface finish as described in the cited Product Standard.

Material Specification 585—Wood Preservatives and Treatment

1. Scope

This specification covers the quality of wood preservatives and methods of treatment of wood products.

2. Treating practices

Treating practices and sampling, inspection, and test procedures shall conform to the requirements of ASTM D 1760, "Standard Specification for Pressure Treatment of Timber Products."

3. Preservatives

The wood shall be treated with the specified type of preservative. Wood preservatives shall conform to the requirements of the applicable specifications list in ASTM D 1760.

4. Quality of treated material

Treated lumber, timber, piles, poles, or posts shall be free from heat checks, water bursts, excessive checking, results of chafing, or from any other damage or defects that would impair their usefulness or durability for the purpose intended. The use of s-irons is not permitted. Holes bored for tests shall be filled with tight fitting, treated wood plugs.

5. Marking

Each treated wood item delivered to the job site shall be marked as specified in ASTM D 1760, unless otherwise specified.

Material Specification 591—Field Fencing Material

1. Scope
This specification provides the minimum quality requirements for the material used in the construction of field fences.

2. Wire gauge
When the size of steel wire is designated by gage number, the diameter shall be as defined for U.S. Steel Wire Gauge.

3. Fencing
Fencing material shall conform to the requirements of ASTM A 121 for barbed wire, ASTM A 116 for woven wire, ASTM A 390 for poultry fence or netting, and ASTM A 854 for high-tensile wire. Barbed wire and woven wire shall be class 3 zinc coated unless otherwise specified. High-tensile wire shall have type I zinc coating unless otherwise specified.

4. Stays, fasteners, and tension wire
Stays and fasteners shall conform to the requirements of the appropriate ASTM for the fencing material specified unless otherwise specified. Tension wires shall have a tensile strength not less than 58,000 pounds per square inch. Stays, fasteners and tension wire shall have class 3 zinc coating as specified in ASTM A 641.

5. Wood fence posts and braces
Unless otherwise specified, wood posts shall be of black locust, red cedar, osageorange (Bois d'Arc), redwood, pressure treated pine, or other wood of equal life and strength. At least half the diameter or diagonal dimension of red cedar or redwood posts shall be in heartwood. Pressure treatment shall conform to Material Specification 585, Wood Preservatives and Treatment. The posts shall be sound, new, free from decay, with all limbs trimmed substantially flush with the body. All posts shall be substantially straight throughout their full length.

Wood braces shall be of wood material equal to or better than construction grade Douglas fir. Wood braces shall be pressure treated in conformance with Material Specification 585.

6. Steel fence posts and braces
Steel fence posts and braces shall conform to the requirements of ASTM A 702 for steel fence posts and ASTM A 53 for bracing pipes. Posts with punched tabs for fastening the wires shall not be installed.

7. Concrete fence posts
Concrete fence posts shall be manufactured to the specified requirements of size, shape, and strength.

8. Panel gates
Panel gates shall be the specified types, sizes, and quality and shall include the necessary fittings required for installation. The fittings shall consist of not less than two hinges and one latch or galvanized chain for fastening. Latches shall be of such design that a padlock may be used for locking. All fittings shall not be of lesser quality than the gate manufacturer's standard.

9. Wire gates
Wire gates shall be the type shown on the drawings, constructed in accordance with specifications, at the locations, and to the dimensions shown on the drawings. The material shall conform to the kinds, grades, and sizes specified for new fence, and shall include the necessary fittings and stays.

10. Staples
Staples required to secure the fence wire to wood posts shall be 9-gauge galvanized wire with a minimum length of 1.5 inches for soft woods and a minimum length of 1 inch for close-grain hardwoods.

11. Galvanizing

All iron and steel fencing material, except as otherwise specified, shall be zinc coated by the hot dip process meeting the requirements of Material Specification 582. Clips, bolts, and other small hardware may be protected by electro-deposited zinc or cadmium coating.

Material Specification 592—Geotextile

1. Scope

This specification covers the quality of geotextiles.

2. General requirements

Fibers (threads and yarns) used in the manufacture of geotextile shall consist of synthetic polymers composed of a minimum of 85 percent by weight polypropylenes, polyesters, polyamides, polyethylene, polyolefins, or polyvinylidene-chlorides. They shall be formed into a stable network of filaments or yarns retaining dimensional stability relative to each other. The geotextile shall be free of defects and conform to the physical requirements in tables 592–1 and 592–2. The geotextile shall be free of any chemical treatment or coating that significantly reduces its porosity. Fibers shall contain stabilizers and/or inhibitors to enhance resistance to ultraviolet light.

Thread used for factory or field sewing shall be of contrasting color to the fabric and made of high strength polypropylene, polyester, or polyamide thread. Thread shall be as resistant to ultraviolet light as the geotextile being sewn.

3. Classification

Geotextiles shall be classified based on the method used to place the threads or yarns forming the fabric. The geotextiles will be grouped into woven and nonwoven types.

***Woven*—**Fabrics formed by the uniform and regular interweaving of the threads or yarns in two directions. Woven fabrics shall be manufactured from monofilament yarn formed into a uniform pattern with distinct and measurable openings, retaining their position relative to each other. The edges of fabric shall be selvedged or otherwise finished to prevent the outer yarn from unraveling.

***Nonwoven*—**Fabrics formed by a random placement of threads in a mat and bonded by heat-bonding, resin-bonding, or needle punching. Nonwoven fabrics shall be manufactured from individual fibers formed into a random pattern with distinct, but variable small openings, retaining their position relative to each other when bonded by needle punching, heat, or resin bonding. The use of nonwovens other than the needle punched geotextiles is somewhat restricted (see note 3 of table 592–2).

4. Sampling and testing

The geotextile shall meet the specified requirements (table 592–1 or 592–2) for the product style shown on the label. Product properties as listed in the latest edition of the "Specifiers Guide," Geotechnical Fabrics Report, (Industrial Fabrics Association International, 1801 County Road BW, Roseville, MN 55113-4061) and that represent minimum average roll values, are acceptable documentation that the product style meets the requirements of these specifications.

For products that do not appear in the above directory or do not have minimum average roll values listed, typical test data from the identified production run of the geotextile will be required for each of the specified tests (tables 592–1 or 592–2) as covered under clause AGAR 452.236-76.

5. Shipping and storage

The geotextile shall be shipped/transported in rolls wrapped with a cover for protection from moisture, dust, dirt, debris, and ultraviolet light. The cover shall be maintained undisturbed to the maximum extend possible before placement.

Each roll of geotextile shall be labeled or tagged to clearly identify the brand, class, and the individual production run in accordance with ASTM D 4873.

Table 592–1 Requirements for woven geotextiles

Property	Test method	Class I	Class II & III	Class IV
Tensile strength (pounds) 1/	ASTM D 4632 grab test	200 minimum in any principal direction	120 minimum in any principal direction	180 minimum in any principal direction
Elongation at failure (percent) 1/	ASTM D 4632 grab test	<50	<50	<50
Puncture (pounds) 1/	ASTM D 4833	90 minimum	60 minimum	60 minimum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minimum	70 minimum	70 minimum
Apparent opening size (AOS)	ASTM D 4751	As specified, but no smaller than 0.212 mm (#70) 2/	As specified, but no smaller than 0.212 mm (#70) 2/	As specified, but no smaller than 0.212 mm (#70) 2/
Percent open area (percent)	CWO-02215-86	4.0 minimum	4.0 minimum	1.0 minimum
Permitivity sec^{-1}	ASTM D 4491	0.10 minimum	0.10 minimum	0.10 minimum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
Note: CWO is a USACE reference.

Table 592–2 Requirements for nonwoven geotextiles

Property	Test method	Class I	Class II	Class III	Class IV 3/
Tensile strength (lb) 1/	ASTM D 4632 grab test	180 minumum	120 minumum	90 minumum	115 minumum
Elongation at failure(%) 1/	ASTM D 4632	≥50	≥ 50	≥ 50	≥ 50
Puncture (pounds)	ASTM D 4833	80 minumum	60 minumum	40 minumum	40 minumum
Ultraviolet light (% residual tensile strength)	ASTM D 4355 150-hr exposure	70 minumum	70 minumum	70 minumum	70 minumum
Apparent opening size (AOS)	ASTM D 4751	As specified max. #40 2/	As specified max. #40 2/	As specified max. #40 2/	As specified max. #40 2/
Permittivity sec^{-1}	ASTM D 4491	0.70 minumum	0.70 minumum	0.70 minumum	0.10 minumum

1/ Minimum average roll value (weakest principal direction).
2/ U.S. standard sieve size.
3/ Heat-bonded or resin-bonded geotextile may be used for classes III and IV. They are particularly well suited to class IV. Needle-punched geotextiles are required for all other classes.

Material Specification 593—Lime

1. Scope

This material specification covers the quality of hydrated lime used in the treatment of clayey soils.

2. Quality

Hydrated lime—Hydrated lime shall meet the following requirements when tested in accordance with ASTM C 25 or AASHTO T 219:

- Minimum available lime, reported as $Ca(OH)_2$ = 90 percent.
- Maximum carbon dioxide (as-received basis) = 7 percent.

The physical gradation of hydrated lime when tested in accordance with ASTM C 110 shall meet the requirements of ASTM C 977.

Material Specification 594—Flexible Membrane Liner

1. Scope

This specification covers the quality of High Density Polyethylene (HDPE), Linear Low Density Polyethylene (LLDPE), Ethylene Propylene Diene Monomer (EPDM), Poly Vinyl Chloride (PVC), and Polypropylene (PP) flexible liner, seams, gaskets, metal battens, bolts, embed channels, clamps, and sealant.

2. Material

***Liner*—**The liner shall have a nominal thickness as specified. The liner shall be manufactured to be suitable for use in the specified exposed or buried conditions. It shall conform to the requirements of this specification, Construction Specification 97, and the requirements shown on the drawings.

***Gaskets, metal battens, clamps, bolts, embed channels, welding rod, adhesive, and sealant*—**Gasket material shall be neoprene, closed-cell medium, 0.25 inch thick, with adhesive on one side, or other gasket material as approved by the liner manufacturer. Metal battens shall be 0.25-inch-thick by 2-inch-wide stainless steel. Clamps shall be 0.5-inch-wide stainless steel. Bolts shall be stainless steel. The embed channel and welding rod shall have the same properties as the liner. Adhesive shall be approved by the manufacturer and shall consist of material with a life expectancy similar to the liner material. Sealant shall be as recommended by the manufacturer. Silicone sealant shall not be used with PVC liner materials.

***Vents and pipe boots*—**Vents and pipe boots shall be made of the same material as the liner.

3. Liner properties

The liner shall be uniform in color, thickness, and surface texture. The liner shall be resistant to fungal or bacterial attack and free of cuts, abrasions, holes, blisters, contaminants, and other imperfections.

***HDPE and LLDPE*—**The HDPE or LLDPE liner shall be manufactured from virgin polymer material and shall meet the property values specified in tables 594–1 through 594–4 as applicable.

***EPDM*—**The EPDM liner shall be formulated from virgin compounding materials and shall meet the property values specified in tables 594–5 and 594–6 as applicable. Regrind, reworked, or trim materials shall be from the same manufacturer and the same formulation as the liner. Recycled materials shall not be allowed.

***PVC*—**The PVC liner shall be manufactured from virgin polymers and other compounding materials and shall meet the property values specified in table 594–7 as applicable. Regrind, reworked, or trim materials shall be from the same manufacturer and the same formulation as the liner. No more than 10 percent regrind, reworked, or trim materials shall be used to manufacture the liner. Recycled materials shall not be allowed.

The PVC compound shall consist of 50- to 70-percent PVC resin, by weight. Liquid plasticizers shall be mixed until completely absorbed by the resin powder. Other additives shall be thoroughly mixed into the resin.

***PP*—**The PP liner shall be manufactured from virgin polymer material and shall meet the property values specified in tables 594–8 and 594–9 as applicable.

A reinforced PP liner shall consist of one ply of reinforcing polyester (scrim) between two sheets of PP. The polyester scrim shall be of an open weave that permits strike-through of the PP.

Table 594–1 Requirements for smooth HPDE liner

Property	Test methods	Requirements* nominal thickness 30 mil	40 mil	60 mil
Density, g/cc	ASTM D 1505	0.940	0.940	0.940
Tensile properties	ASTM D 638			
yield stress, lb/in	(type IV at 2 in/min)	63	84	126
break stress, lb/in		114	152	228
yield elongation, %		12	12	12
break elongation, %		700	700	700
Tear resistance, lb	ASTM D 1004	21	28	42
Puncture resistance, lb	ASTM D 4833	54	72	108
Carbon black content, %	ASTM D 1603	2-3	2-3	2–3
Carbon black dispersion	ASTM D 5596	Cat 1–2	Cat 1–2	Cat 1–2
Seam properties	ASTM D 6392			
shear strength, lb/in		60	80	120
peel strength, lb/in**		39/FTB	52/FTB	78/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.
** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Table 594–2 Requirements for textured HDPE liner

Property	Test methods	Requirements* nominal thickness 30 mil	40 mil	60 mil
Density, g/cc	ASTM D 1505	0.940	0.940	0.940
Tensile properties	ASTM D 638			
yield stress, lb/in	(type IV at 2 in/min)	63	84	126
break stress, lb/in		45	60	90
yield elongation, %		12	12	12
break elongation, %		100	100	100
Tear resistance, lb	ASTM D 1004	21	28	42
Puncture resistance, lb	ASTM D 4833	45	60	90
Carbon black content, %	ASTM D 1603	2 - 3	2 - 3	2 – 3
Carbon black dispersion	ASTM D 5596	Cat 1–2	Cat 1–2	Cat 1–2
Seam properties	ASTM D 6392			
shear strength, lb/in		60	80	120
peel strength, lb/in**		39/FTB	52/FTB	78/FTB

* All values, unless specified otherwise, are minimum average roll values as reported by the specified test method.
** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Table 594–3 Requirements for smooth LLDPE liner

Property	Test methods	Requirements* nominal thickness 30 mil	40 mil	60 mil
Density, g/cc	ASTM D 1505	0.915	0.915	0.915
Tensile properties	ASTM D 638			
break stress, lb/in	(type IV at 2 in/min)	114	150	228
break elongation, %		800	800	800
Tear resistance, lb	ASTM D 1004	16	22	33
Puncture resistance, lb	ASTM D 4833	42	56	84
Carbon black content, %	ASTM D 1603	2–3	2–3	2–3
Carbon black dispersion, %	ASTM D 5596	Cat 1–2	Cat 1–2	Cat 1–2
Seam properties	ASTM D 6392			
shear strength, lb/in		44	58	90
peel strength, lb/in**		37/FTB	50/FTB	75/FTB

* All values, unless otherwise specified, are minimum average roll values as reported for each test method.
** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Table 594–4 Requirements for textured LLDPE liner

Property	Test methods	Requirements* nominal thickness 30 mil	40 mil	60 mil
Density, g/cc	ASTM D 1505	0.915	0.915	0.915
Tensile properties	ASTM D 638			
break stress, lb/in	(type IV at 2 in/min)	60	80	120
break elongation, %		350	350	350
Tear resistance, lb	ASTM D 1004	17	22	33
Puncture resistance, lb	ASTM D 4833	33	44	66
Carbon black content, %	ASTM D 1603	2–3	2–3	2–3
Carbon black dispersion, %	ASTM D 5596	Cat 1–2	Cat 1–2	Cat 1–2
Seam properties	ASTM D 4437			
shear strength, lb/in	(1 in wide at 2 in/min)	40	53	79
peel strength, lb/in**		33/FTB	44/FTB	66/FTB

* All values, unless otherwise specified, are minimum average roll values as reported for each test method.
** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Table 594–5 Requirements for nonreinforced EPDM liner

Property	Test methods	Requirements* - - nominal thickness - - 45 mil	60 mil
Specific gravity	ASTM D 792	1.1	1.1
Tensile properties	ASTM D 882		
break stress, lb/in	(Type IV at 20 in/min)	50	50
break elongation, %		400	400
Tear resistance, lb	ASTM D 1004	9	11
Puncture resistance, lb	ASTM D 4833	35	60
Low temperature brittleness, °F	ASTM D 1790	<-45	<-45
Seam properties	ASTM D413/D4437		
shear strength, lb/in**	(NSF modified 20 in/min strain rate)	35	35
peel strength, lb/in***		14	14

* All values, unless specified otherwise, are minimum average **roll values** as reported for the test method.
** At 200 percent strain.
*** Cohesive bond mode.

Table 594–6 Requirements for reinforced EPDM liner

Property	Test methods	Requirements* nominal thickness 45 mil
Specific gravity	ASTM D 792	1.1
Tensile properties	ASTM D 751 Method A	125
Tear resistance, lb	ASTM D 5884 Method B	130
Puncture resistance, lb	FTMS 101C Method 2031	45
Ply adhesion, lb/in	ASTM D 413 Machine method	7
Low temperature brittleness, °F	ASTM D 1790	< –45
Seam properties		
shear strength, lb/in**	ASTM D 751	35
peel strength, lb/in***	ASTM D 413	14

* All values, unless specified otherwise, are minimum average **roll values** as reported for the test method.
** At 200 percent strain.
*** Cohesive bond mode.

Table 594–7 Requirements for PVC liner

Property	Test methods	Requirements* - - nominal thickness - - 30 mil	40 mil
Specific gravity	ASTM D 792	1.2	1.2
Tensile properties	ASTM D 882		
break strength, lb/in	(MD and XD)	73	97
elongation at break, %		350	400
Tear resistance, lb	ASTM D 1004	8.5	10.5
Low temperature brittleness, °C	ASTM D 1790	< –29	< –29
Dimensional stability, % (maximum)	ASTM D 1204	3	3
Hydrostatic resistance, lb/in^2	ASTM D 751 Method A	100	120
Seam properties	ASTM D 6392/D 6214/D 4437 **		
shear strength, lb/in		58	77
peel strength, lb/in		15	15

* All values, unless specified otherwise, are minimum average **roll values** as reported for the test method.
MD Machine direction
XD Cross-machine direction
** ASTM D 6392 shall be used for thermally welded seams, D 6214 for chemically welded seams, and D 4437 for all other types.

Table 594–8 Requirements for unreinforced PP liner

Property	Test methods	Requirements* nominal thickness 30 mil	40 mil	60 mil
Specific gravity	ASTM D 792	0.90	0.90	0.90
Tensile Properties	ASTM D 638			
break stress, lb/in	(Type IV at 20 in/min)	60	72	130
break elongation, %		600	600	600
Tear resistance, lb	ASTM D 1004	9	11	16
Puncture resistance, lb	ASTM D 4833	28	35	65
Carbon black content, %	ASTM D 1603	2–4	2–4	2–4
Carbon black dispersion	ASTM D 5596	Cat 1–2	Cat 1–2	Cat 1–2
Low temperature brittleness, °C	ASTM D 1790	<–40	<–40	<–40
Seam properties	ASTM D 6392/D6214/D 4437 ***			
shear strength, lb/in		35	45	55
peel strength, lb/in***		20/FTB	30/FTB	40/FTB

* All values, unless specified otherwise, are minimum average **roll values** as reported for the test method.
** ASTM D 6392 shall be used for thermally welded seams, D 6214 for chemically welded seams, and D 4437 for all other types.
*** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Table 594–9 Requirements for reinforced PP liner

Property	Test methods	Requirements* - - - nominal thickness - - - 36 mil	45 mil
Specific gravity	ASTM D 792	0.90	0.90
Tensile properties	ASTM D 751 Method A	225	225
Tear resistance, lb	ASTM D 5884 Method B	55	75
Puncture resistance, lb	FTMS 101C Method 2031	200	250
Ply adhesion, lb/in	ASTM D 413 Machine Method	20	20
Carbon black content, %	ASTM D 1603	2–4	2–4
Carbon black dispersion	ASTM D 5596	Cat 1–2	Cat 1–2
Low temperature brittleness, °C	ASTM D 2136	< –40	< –40
Seam properties			
shear strength, lb/in	ASTM D 751	160	200
peel strength, lb/in**	ASTM D 413	20/FTB	20/FTB

* All values, unless specified otherwise, are minimum average **roll values** as reported for the test method.
** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

Material Specification 595—Geosynthetic Clay Liner

1. Scope

This specification covers the quality of geosynthetic clay liner (GCL) material and workmanship.

2. General requirements

The GCL is composed of a layer of high shrink-swell sodium bentonite sandwiched between two geosynthetics. The GCL material shall be manufactured by one of the following processes:

- Needle punched process by which the bentonite is encapsulated between the geotextile layers by a mechanical bonding process without the use of any chemical binders or adhesive, or
- Lock stitched to provide internal shear strength and the integrity and consistency to the thickness and unit weight of the material.

The bentonite shall have the following base properties:

- A minimum of 0.75 pound per square foot of high shrink/swell sodium bentonite at 12 percent moisture. If the liner material is manufactured at higher moisture content, it shall still meet the above requirements when adjusted to the 12 percent moisture level.
- Swell index—minimum 24 ml per 2 grams.
- Fluid loss—maximum 18 ml

The GCL shall have an index flux value no larger than 1×10^{-8} m/s or 1×10^{-9} m/s at 2 pounds per square inch (4.6 feet of head) as specified.

3. Packaging and labeling

All material shall be packaged in individual rolls of a minimum of 3.65 meters wide and with at least 22.5 meters in length on the roll. All rolls shall be labeled and in a wrapping that is resistant to UV light deterioration. The labels on each roll shall identify the length and width of the roll, the manufacturer, the product, lot number, and the roll number.

4. Testing and quality control

The following tests shall be performed and the results certified by the manufacturer:

Swell index	ASTM D 5890
Fluid loss	ASTM D 5891
Bentonite mass/unit area	ASTM D 5993
Index flux	ASTM D 5887
Hydraulic conductivity	ASTM D 5887

5. Inspection and acceptance

No liner material shall be accepted for placement in the permanent works that has not been certified by the manufacturer as meeting all specified requirements. No liner material shall be accepted that exhibits any visible defects. The liner material shall be subject to quality assurance testing at any time before and during installation.