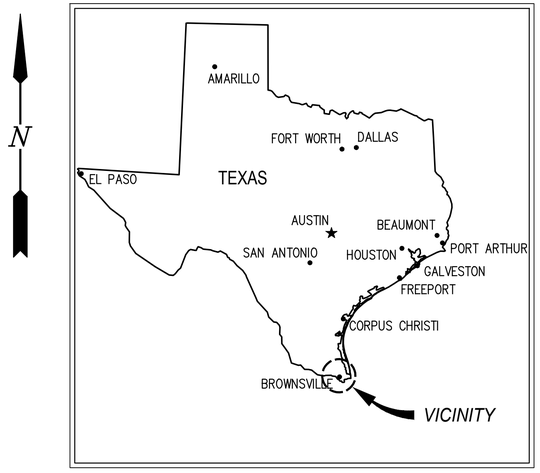
PORT OF BROWNSVILLE

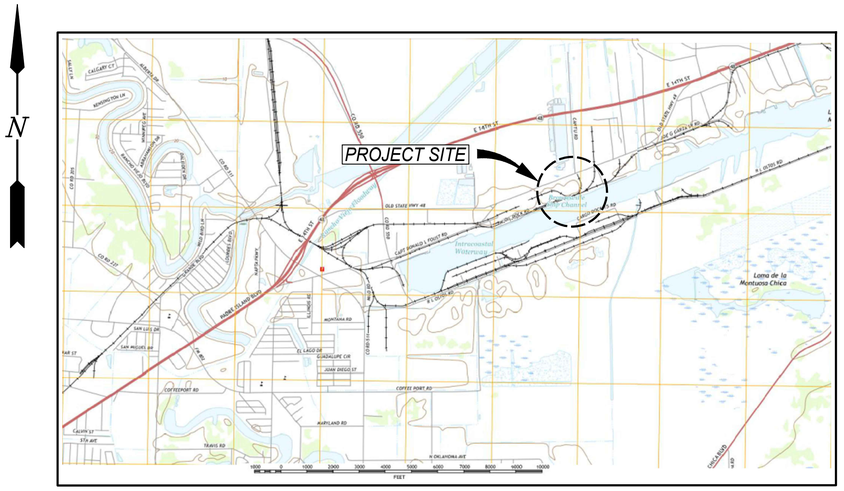
BROWNSVILLE, TX

OIL DOCK #6

EAST PIPE BRIDGE



AREA MAP



VICINITY MAP

LEGEND

A / GA2	SECTIONS USE LETTERS SHEET NUMBER ON WHICH SECTION IS FOUND
SECTION SCALE — A / GA1	SECTION CUT LETTER SHEET NUMBER FROM WHICH SECTION IS CUT
DETAIL — 1 / GA2	DETAILS USE NUMBERS SHEET NUMBER ON WHICH DETAIL IS FOUND
DETAIL SCALE — 1 / GA1	DETAIL NUMBER SHEET NUMBER FROM WHICH DETAIL IS TAKEN
*	SECTION OR DETAIL CALL-OUT
---	DASH INDICATES ON SAME SHEET AS CALL-OUT

DRAWING INDEX

DWG. NO.	REV.	DRAWING TITLE
CS1	A	TITLE SHEET, AREA MAP, VICINITY MAP, LEGEND & DRAWING INDEX
CS2	A	GENERAL NOTES
SP1	A	OVERALL EXISTING SITE PLAN
SP2	A	ENLARGED DEMO PLAN & ENLARGED NEW SITE PLAN
SP3	A	PILE PLAN & SCHEDULE
S1	A	PLANS & ELEVATION
S2	A	SECTIONS
S3	A	SECTIONS & DETAILS – SHT. 1
S4	A	SECTIONS & DETAILS – SHT. 2
S5	A	CONNECTION DETAILS
S6	A	TXDOT METAL BEAM GUARD FENCE

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DECEMBER 23, 2021

J:\10000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-CS1.DWG

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CONSULTING ENGINEERS
INCORPORATED
LA: EF-1120 TX: F-2981
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REV	DATE	BY	DESCRIPTION
*			
A	12/23/21	MEW	FOR BIDS ONLY

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DATE SEPT. '21
SHT SIZE 22"x34"
DESIGN ETW
DRAWN MEW
CHECK MDF
APPR'D DLK
JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6 - EAST PIPE BRIDGE
TITLE SHEET, AREA MAP, VICINITY MAP
LEGEND & DRAWING INDEX

SHEET NO.
CS1

GENERAL NOTES:

1. CONSTRUCTION SHALL COMPLY WITH THESE GENERAL NOTES, THE CONTRACT DRAWINGS, SPECIFICATIONS, AND ALL APPLICABLE STATE AND LOCAL CODES.
2. EXISTING CONSTRUCTION AND CONDITIONS SHOWN ARE SCHEMATIC. ACTUAL CONDITIONS MAY DIFFER. CONTRACTOR IS FULLY RESPONSIBLE FOR MAKING THEIR OWN SITE EXAMINATION AND DETERMINING ACTUAL NATURE AND EXTENT OF EXISTING CONDITIONS AS NEEDED PRIOR TO UNDERTAKING THE WORK.
3. ALL PERMITS, LICENSES AND NOTIFICATIONS NECESSARY FOR THE PROSECUTION OF WORK SHALL BE SECURED BY THE CONTRACTOR.
4. PORTIONS OF THE FACILITY WILL REMAIN IN OPERATION DURING WORK. CONTRACTOR SHALL COORDINATE WORK SCHEDULE WITH THE OWNER. CONTRACTOR SHALL NOT INTERFERE WITH ACTIVITIES AT THE FACILITY TO ALL EXTENTS POSSIBLE.
5. ANY DAMAGE, DISTURBANCE, OR OTHER IMPAIRMENT OF EXISTING FACILITIES SHALL BE PROMPTLY REPAIRED OR REPLACED BY THE CONTRACTOR AS APPROVED BY AND AT NO ADDITIONAL COST TO THE OWNER.
6. CONTRACTOR SHALL REMOVE CONSTRUCTION MATERIAL AND DEBRIS FROM WORK SITE DURING AND AT COMPLETION OF WORK.
7. STORAGE OF EQUIPMENT AND MATERIAL SHALL BE IN OWNER-DESIGNATED AREAS ONLY.
8. SITE ACCESS SHALL BE AS DIRECTED BY THE OWNER.
9. IT IS SOLELY THE CONTRACTOR'S RESPONSIBILITY TO FOLLOW ALL APPLICABLE SAFETY CODES, PERMIT RESTRICTIONS AND REGULATIONS DURING ALL PHASES OF CONSTRUCTION. CONTRACTOR IS RESPONSIBLE FOR SAFETY PRECAUTIONS, MEANS, METHODS, TECHNIQUES, SEQUENCES OR PROCEDURES REQUIRED FOR PERFORMANCE OF THE WORK INCLUDING, BUT NOT LIMITED TO, SHORING, SCAFFOLDING, UNDERPINNING AND ANY ERECTION METHODS.
10. ALL STRUCTURES ARE DESIGNED TO BE SELF-SUPPORTING AND STABLE AFTER ERECTION IS FULLY COMPLETED. IT IS SOLELY THE CONTRACTOR'S RESPONSIBILITY TO DETERMINE ERECTION PROCEDURE AND SEQUENCE AND TO ENSURE THE SAFETY OF THE STRUCTURE AND ITS COMPONENTS DURING ERECTION. THIS INCLUDES THE ADDITION OF WHATEVER SHORING, SHEETING, TEMPORARY BRACING, GUYS, OR TIE DOWNS WHICH MIGHT BE NECESSARY. SUCH MATERIAL SHALL REMAIN THE CONTRACTOR'S PROPERTY AFTER COMPLETION OF THE PROJECT.
11. CONTRACTOR WILL BE RESPONSIBLE FOR ALL LAYOUT AND SURVEYING REQUIRED FOR THE CONSTRUCTION AS SHOWN ON THE DRAWINGS.
12. CONTRACTOR SHALL LOCATE ALL UNDERGROUND PIPING, UTILITIES, AND OTHER OBSTRUCTIONS IN THE VICINITY OF WORK AREA PRIOR TO BEGINNING CONSTRUCTION.
13. ALL EXISTING DIMENSIONS AND ELEVATIONS SHOWN ON STRUCTURAL DRAWINGS SHALL BE VERIFIED BY THE CONTRACTOR PRIOR TO FABRICATION. CONTRACTOR SHALL NOTIFY THE ENGINEER OF ANY DISCREPANCIES.
14. SHOULD ANY OF THE DETAILED INSTRUCTIONS SHOWN ON THE PLANS CONFLICT WITH THE GENERAL STRUCTURAL NOTES, THE SPECIFICATIONS, OR WITH EACH OTHER, THE STRICTEST PROVISION SHALL GOVERN.
15. THE LATEST REVISION OF THE FOLLOWING CODES AND STANDARDS SHALL BE OBSERVED FOR ALL PROJECT RELATED ACTIVITIES:

    ASCE 7-16, UNLESS NOTED OTHERWISE.
    INTERNATIONAL BUILDING CODE-2018
    ACI 318-19 AND ACI 315R-18
    AWS D1.1-2020 AND AWS D1.4-2018
    AISC SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS 360-16
    AISC CODE OF STANDARD PRACTICE 303-16
    SPECIFICATIONS FOR STRUCTURAL JOINTS USING HIGH-STRENGTH BOLTS-2014
    PIP STC01015 STRUCTURAL DESIGN CRITERIA
16. CONTRACTOR SHALL NOTIFY THE USCG OF MARINE ACTIVITIES IN ACCORDANCE WITH USCG REGULATIONS.
17. CONTRACTOR TO DEVELOP AND SUBMIT A TRAFFIC CONTROL PLAN TO THE OWNER.
18. CONTRACTOR SHALL BE RESPONSIBLE FOR THE COST ASSOCIATED WITH ALL MATERIAL TESTING REQUIRED IN THE PROJECT DOCUMENTS, UNLESS NOTED OTHERWISE.

STRUCTURAL STEEL

1. ALL STRUCTURAL STEEL AND ASSOCIATED FABRICATION SHALL CONFORM WITH THE LATEST AISC EDITION MANUAL OF STEEL CONSTRUCTION FOR FABRICATION AND ERECTION OF STRUCTURAL STEEL AND PROJECT SPECIFICATIONS.
2. ALL STEEL WIDE FLANGES AND WT SECTIONS SHALL MEET ASTM A992; STEEL HP AND CHANNELS SHALL MEET ASTM A572 GRADE 50; STEEL ANGLES SHALL MEET ASTM A572 GRADE 50; STEEL PIPE (12" DIAMETER OR LESS) SHALL MEET ASTM A53 GRADE B; AND STEEL PIPE (EXCLUDING ROLLED MONOPILES) (GREATER THAN 12" DIAMETER) SHALL MEET ASTM A252 GRADE 2, UNLESS NOTED OTHERWISE. ALL STEEL PLATE SHALL MEET ASTM A572 GRADE 50.
3. ALL CONNECTIONS SHALL BE FULL PENETRATION WELDS AND DEVELOP FULL CAPACITY OF MEMBERS UNLESS OTHERWISE NOTED.
4. ALL BOLTED CONNECTIONS NOT DETAILED SHALL BE DESIGNED TO SUPPORT A MINIMUM OF ONE-HALF TOTAL UNIFORM LOAD CAPACITY OF A SIMPLE BEAM. ALL CONNECTIONS SHALL BE REINFORCED WITH 1/2" STIFFENER PLATES, UNLESS DETAILED OTHERWISE.
5. THERE SHALL BE A MINIMUM OF TWO (2) BOLTS PER CONNECTION AND BOLTS SHALL BE 1" DIA. MINIMUM.
6. ALL WELDS SHALL BE PERFORMED IN ACCORDANCE WITH AWS D1.1-2020 AND AWS D1.4-2018, LATEST EDITIONS, AND SHALL BE PERFORMED BY AWS QUALIFIED WELDERS. WELDING ELECTRODES TO BE E70XX.
7. ALL STRUCTURAL BOLTS SHALL BE A325 TYPE 1 AND HOT DIPPED GALVANIZED, UNLESS OTHERWISE NOTED.
8. ALL STRUCTURAL WELDS ARE SUBJECT TO NON-DESTRUCTIVE EXAMINATION BY ULTRASONIC TESTING (UT). EXAMINATION SHALL BE ACCOMPLISHED BY SELECTING SAMPLE GROUPS OF WELDS DURING VARIOUS STAGES OF FABRICATION. FIVE PERCENT (5%) OF THE WELDS WITHIN THE DEFINED SAMPLE GROUP SHALL BE TESTED. IF NO WELDS ARE PROVEN TO BE DEFECTIVE IN THE OPINION OF THE OWNER'S REPRESENTATIVE, NO FURTHER TESTING OF THE SAMPLE GROUP SHALL BE REQUIRED. IF TEN PERCENT (10%) OR MORE OF THE WELDS TESTED ARE PROVEN DEFECTIVE, THE NUMBER OF WELDS TO BE TESTED SHALL BE INCREASED FROM 5 TO 10 PERCENT (10%) OF THE SAMPLE GROUP. IF MORE THAN 10 PERCENT (10%) OF THE WELDS TO THIS TIME ARE PROVEN DEFECTIVE IN THE OPINION OF THE OWNER'S REPRESENTATIVE, THEN ALL OF THE WELDS IN THE SAMPLE GROUP SHALL BE TESTED.
9. OBTAIN APPROVAL OF ENGINEER PRIOR TO CUTTING AN OPENING IN ANY MEMBER.
10. ALL STEEL BEAMS SHALL BE FABRICATED WITH THE NATURAL CAMBER (WITHIN THE MILL TOLERANCE) LOCATED ABOVE THE HORIZONTAL CENTERLINE BETWEEN THE END CONNECTIONS.

COATING

1. ALL STEEL SHALL BE SURFACE BLASTED (NEAR WHITE) IN ACCORDANCE THE LATEST SSPC SPECIFICATIONS AND COATED PER SPECIFICATIONS UNLESS NOTED OTHERWISE. AFTER ERECTION, CONTRACTOR SHALL TOUCH-UP ALL DAMAGED COATING AREAS DUE TO HANDLING TO PROVIDE A FULLY COATED FINISHED PRODUCT.
2. ALL CONCRETE INSERTS, PENETRATIONS, AND OTHER STEEL ITEMS EMBEDDED IN CONCRETE SHALL BE HOT DIPPED GALVANIZED AFTER FABRICATION IN ACCORDANCE WITH ASTM 123.
3. ALL PILES SHALL BE COATED WITH A MINIMUM OF SIXTEEN (16) MILS DFT OF AN APPROVED COAL TAR EPOXY FROM THE TOP OF THE PILE FOR THE LENGTH NOTED IN THE DRAWINGS.
4. ALL STEEL FRAMING MEMBERS LOCATED ABOVE THE CONCRETE DECK SHALL BE GALVANIZED IN ACCORDANCE ASTM A123, UNLESS NOTED OTHERWISE.
5. TO MINIMIZE FIELD WELDING, POTENTIAL CORROSION, AND POSSIBLE COATING DAMAGE, CONTRACTOR SHALL COORDINATE WELDING OF STRUCTURAL MEMBERS TO THE MAXIMUM EXTENT POSSIBLE PRIOR TO SURFACE TREATMENT.

CONCRETE

1. CONCRETE COMPRESSIVE STRENGTH:
   ALL CONCRETE = 5,000 PSI AT TWENTY-EIGHT (28) DAYS, UNLESS OTHERWISE NOTED. CONCRETE SHALL CONFORM WITH THE "BUILDING CODE REQUIREMENTS FOR REINFORCING CONCRETE", ACI 318-19. CEMENT SHALL BE TYPE II.
2. CONCRETE WATER/CEMENT RATIO SHALL BE A MAXIMUM OF .40
3. CURING – CONCRETE SHALL BE KEPT IN MOIST CONDITION FOR AT LEAST SEVEN (7) DAYS AFTER PLACEMENT.
4. AT LEAST ONE SET OF SIX (6) TEST SPECIMENS SHALL BE COLLECTED. TWO (2) TEST SPECIMENS ARE TO BE TESTED AT SEVEN (7) DAYS, TWO (2) AT TWENTY-EIGHT (28) DAYS, AND THE OTHER TWO (2) HELD TO BE TESTED AS REQUIRED BY THE ENGINEER.
5. CONCRETE FOR STRUCTURES SHALL BE PLACED MONOLITHICALLY, UNLESS NOTED OTHERWISE.
6. CHAMFER ALL EXPOSED EXTERNAL CORNERS WITH A 3/4" 45° CHAMFER, UNLESS NOTED OTHERWISE.
7. ALL CONCRETE SHALL BE THOROUGHLY COMPACTED BY MECHANICALLY VIBRATING OR HAND POUNDING, AND SHALL BE THOROUGHLY WORKED AROUND THE REINFORCEMENT AND INTO ALL CORNERS OF THE FORMS.
8. GROUT SHALL BE FIVE STAR GROUT-HIGH PERFORMANCE NON-SHRINK GROUT, UNLESS NOTED OTHERWISE.

PILE DRIVING

1. ALL PILES SHALL BE DRIVEN THEIR ENTIRE LENGTH TO THE DESIGN "TIP OF PILE" ELEVATIONS INDICATED ON THE DRAWINGS.
2. THE LENGTH OF THE PILE SHOWN ON THE DRAWINGS IS THE TRUE LENGTH MEASURED ALONG THE CENTERLINE AXIS OF THE PILE AND IS THE LENGTH REQUIRED AFTER THE PILE IS DRIVEN AND CUTOFF (IF NECESSARY) IS ACCOMPLISHED.
3. CONTRACTOR WILL BE RESPONSIBLE FOR PROVIDING PILES OF SUFFICIENT LENGTH TO ACCOUNT FOR THE ADDED LENGTH REQUIRED FOR THE HAMMER IN USE AND FOR CUTOFF SUCH THAT THE FINAL, DRIVEN, CUTOFF PILE IS THE LENGTH SHOWN ON THE DRAWINGS.

REINFORCING STEEL AND ANCHOR BOLTS

1. REINFORCING BARS SHALL BE NEW DEFORMED BILLET STEEL CONFORMING TO ASTM A615 GRADE 60 OR ASTM A706 GRADE 60. REINFORCING BARS TO BE WELDED SHALL BE ASTM A706 GRADE 60.
2. ALL REBAR SPLICES SHALL COMPLY WITH THE PROVISIONS OF ACI 318-19 AND HAVE A MINIMUM OVERLAP OF FORTY (40) BAR DIAMETERS.
3. BAR SUPPORTS AND SPACERS SHALL COMPLY WITH REQUIREMENTS OF ACI 315R-18.
4. FABRICATION OF BARS, INCLUDING BENDS AND HOOKS, SHALL CONFORM TO ACI 315R-18. ALL BENDS SHALL BE MADE COLD UNLESS NOTED OTHERWISE.
5. BARS SHALL BE SECURELY TIED IN PLACE WITH 16-GAGE BLACK ANNEALED TIE WIRE AND SUPPORTED ON APPROVED STEEL CHAIRS OR PRECAST CONCRETE SADDLES.
6. ANCHOR BOLTS SHALL CONFORM TO ASTM F1554 GRADE 55 AND GALVANIZED, UNLESS NOTED OTHERWISE ON THE DRAWINGS.
7. ADHESIVE FOR POST INSTALLED EPOXY ANCHORS SHALL BE HILTI HIT-HY200. ANCHOR RODS SHALL BE HILTI HAS-E-55 (ASTM F1554, GR. 55), CARBON STEEL (GALV.), OR APPROVED ALTERNATE. HOLES IN EXISTING CONCRETE FOR ANCHORS SHALL EITHER BE DRILLED VIA THE HILTI SAFESET INSTALLATION METHOD, HAMMER-DRILLED AND THOROUGHLY CLEANED PER MANUFACTURER'S SPECIFICATIONS, OR ANOTHER APPROVED METHOD. HOLE DIAMETERS SHALL BE IN ACCORDANCE WITH MANUFACTURER'S SPECIFICATIONS.

SHOP DRAWINGS.

1. SHOP DRAWINGS MUST BE PROVIDED AND REVIEWED BY ENGINEER PRIOR TO FABRICATION.

SURVEY NOTES

1. SURVEY INFORMATION PROVIDED BY PORT OF BROWNSVILLE DATED AUGUST 2021. ALL LAYOUT INFORMATION, ELEVATIONS, AND DIMENSIONS TO EXISTING STRUCTURES ARE BASED ON THE PROVIDED SURVEY AND SHALL BE FIELD VERIFIED BY CONTRACTOR PRIOR TO FABRICATION AND CONSTRUCTION.
2. ALL ELEVATIONS SHOWN ARE REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988 (NAVD88)

SITE SPECIFIC NOTES

1. OIL DOCK #6 IS A RESTRICTED AREA. ANY PERSONNEL WORKING INSIDE THE FENCE MUST POSSESS AND CARRY A TRANSPORTATION WORKERS IDENTIFICATION CREDENTIAL (TWIC) CARD OR BE ESCORTED BY A CERTIFIED TWIC ESCORT. TWIC ESCORT CERTIFICATION IS AVAILABLE BY BROWNSVILLE NAVIGATION DISTRICT (B.N.D.) SECURITY AT NO COST TO THE CONTRACTOR.
2. ANY WORK INSIDE OR IN PROXIMITY OF OIL DOCK #6 SHALL BE COORDINATED WITH THE B.N.D. HARBORMASTER'S OFFICE FOR SCHEDULING AND WITH B.N.D. SECURITY FOR ACCESS TO THE DOCK.
3. NO HOT WORK (WELDING OR SIMILAR) SHALL BE PERMITTED ON OR IN PROXIMITY OF OIL DOCK #6 WHEN THERE IS A BARGE OR VESSEL BERTHED AT THE DOCK AND/OR WHEN THE DOCK IS IN USE BY A PORT TENANT.

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INCORPORATED
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SHT SIZE 22"x34"
DESIGN ETW
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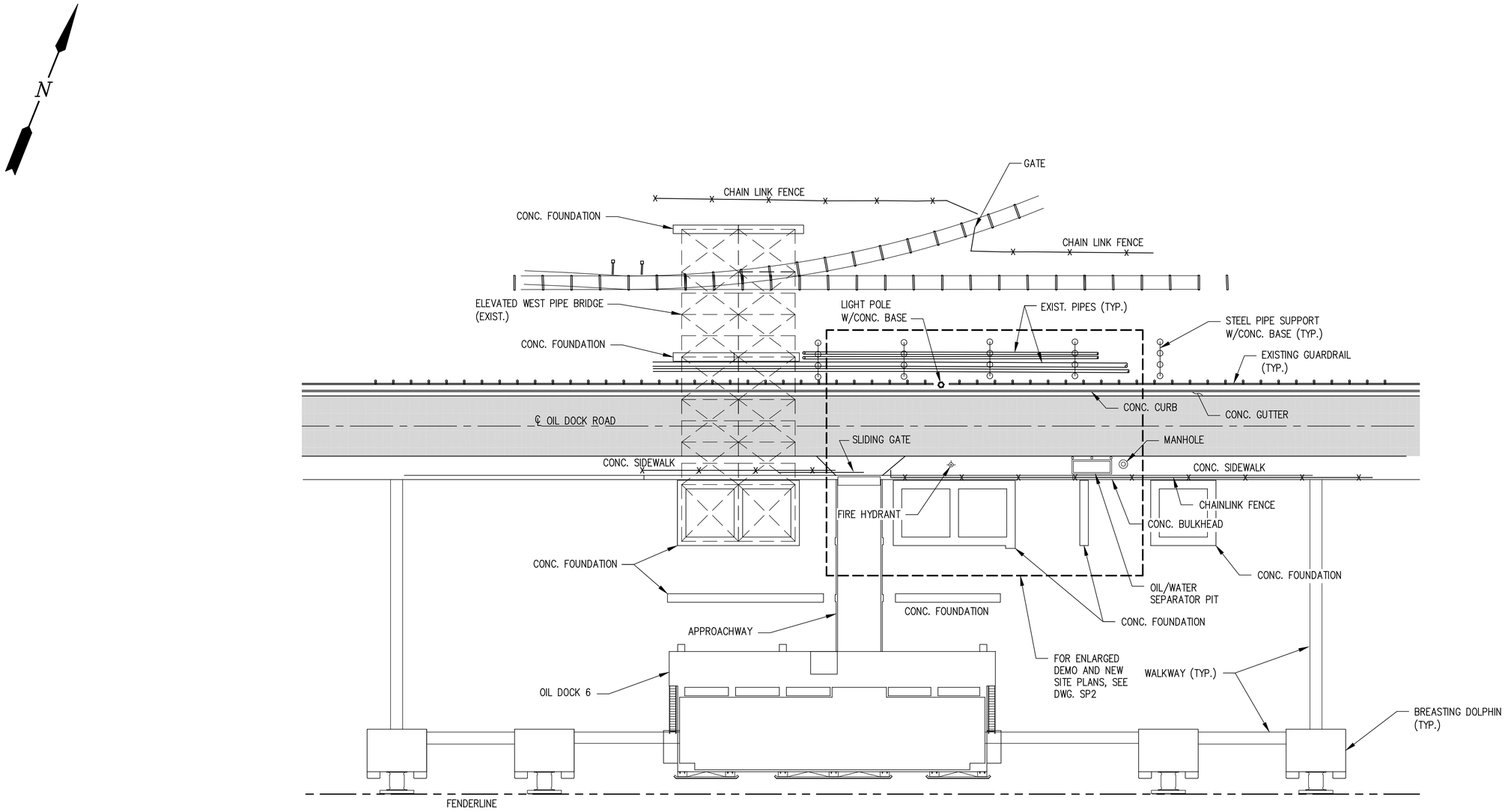
CHECK MDF
APPR'D DLK
JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
GENERAL NOTES

SHEET NO.
CS2



OVERALL EXISTING SITE PLAN

SCALE: 1" = 20'-0"

20 0 10 20 40

(IN FEET)

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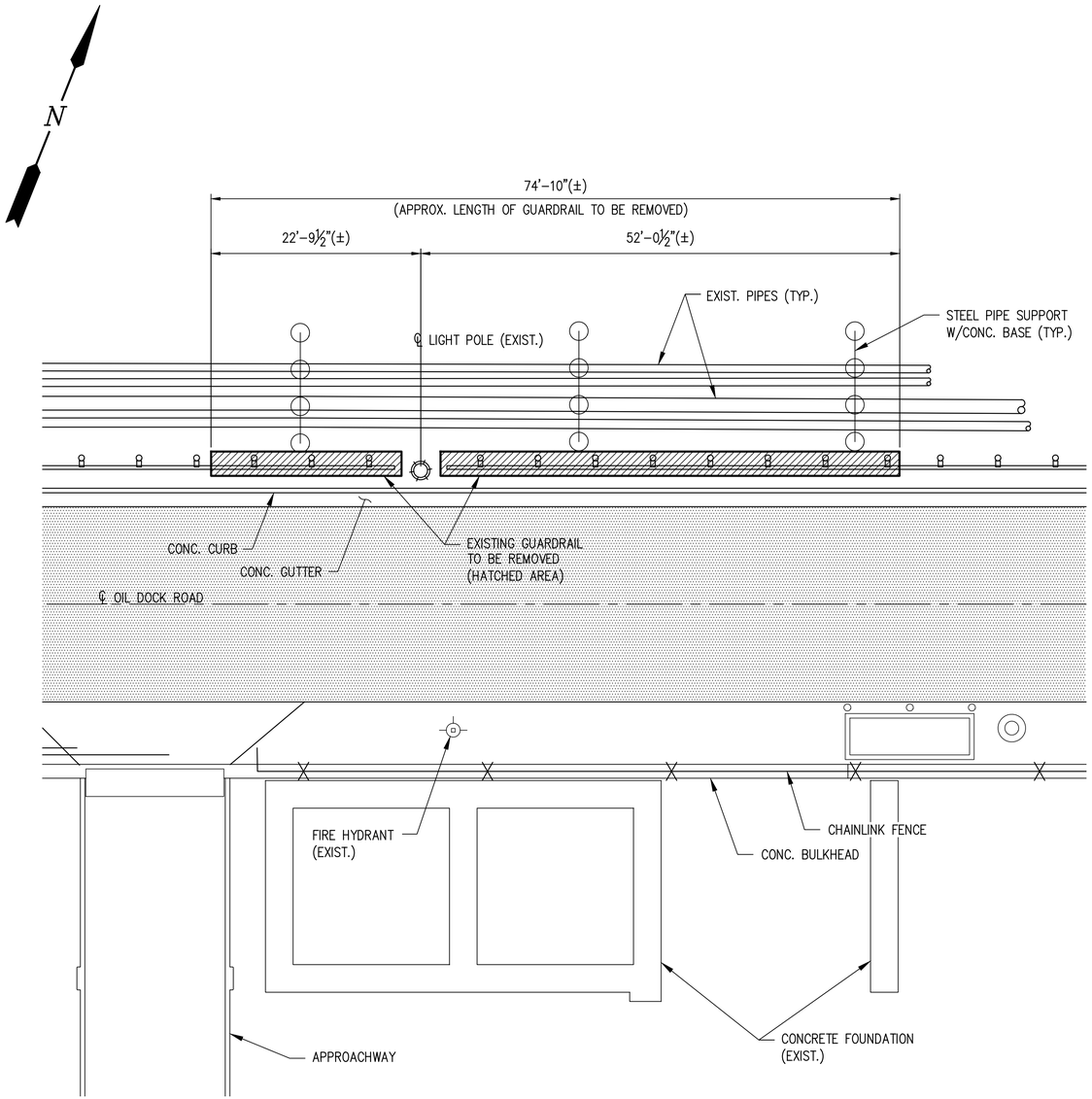
PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
OVERALL EXISTING SITE PLAN

SHEET NO.
SP1

NOTES:

1. SEE TXDOT REFERENCE DRAWING AT END OF PACKAGE FOR CONSTRUCTION DETAILS FOR NEW GUARDRAIL SECTIONS.

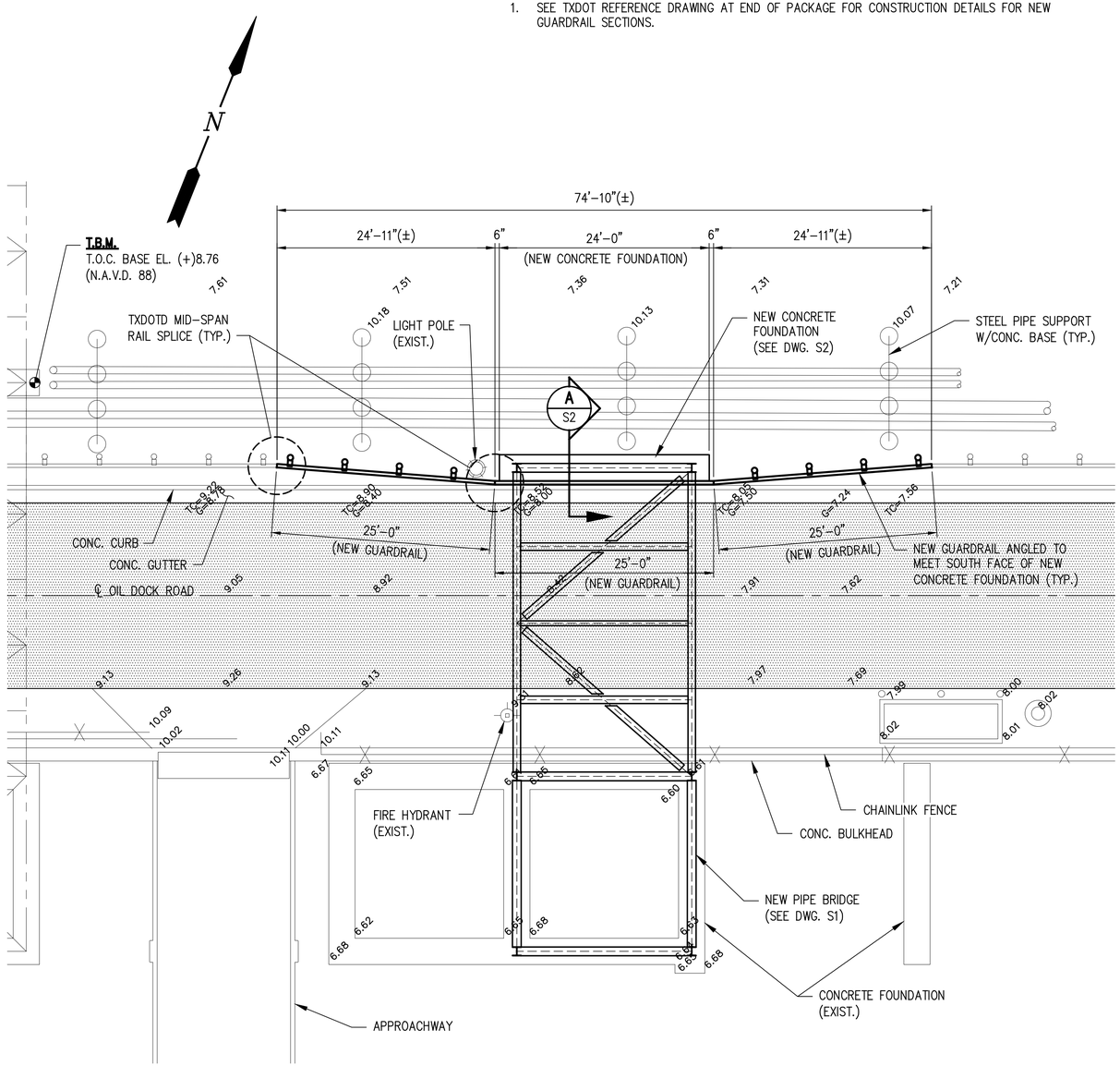


ENLARGED DEMO PLAN

SCALE: 1/8" = 1'-0"

8 0 4 8 16

(IN FEET)



ENLARGED NEW SITE PLAN

SCALE: 1/8" = 1'-0"

8 0 4 8 16

(IN FEET)

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PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
ENLARGED DEMO PLAN & ENLARGED NEW SITE PLAN

SHEET NO.
SP2

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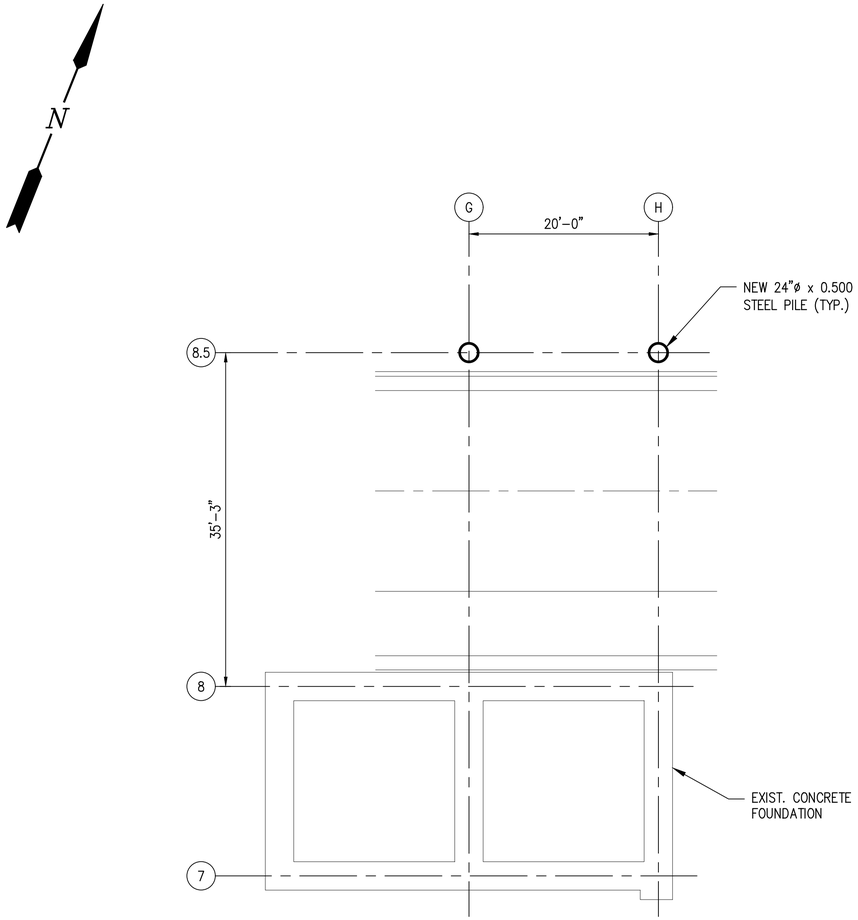

PILE PLAN
SCALE: 1/8" = 1'-0"

8 0 4 8 16
(IN FEET)

PILE SCHEDULE					
PILE DESIGNATION	MATERIAL	PILE SIZE	CUTOFF ELEVATION (NAVD 88)	TIP ELEVATION (NAVD 88)	COATING LENGTH
G–8.5	STEEL	24"øx0.500"	(+)7'–8"	(–)32'–4"	15'–0"
H–8.5	STEEL	24"øx0.500"	(+)7'–8"	(–)32'–4"	15'–0"

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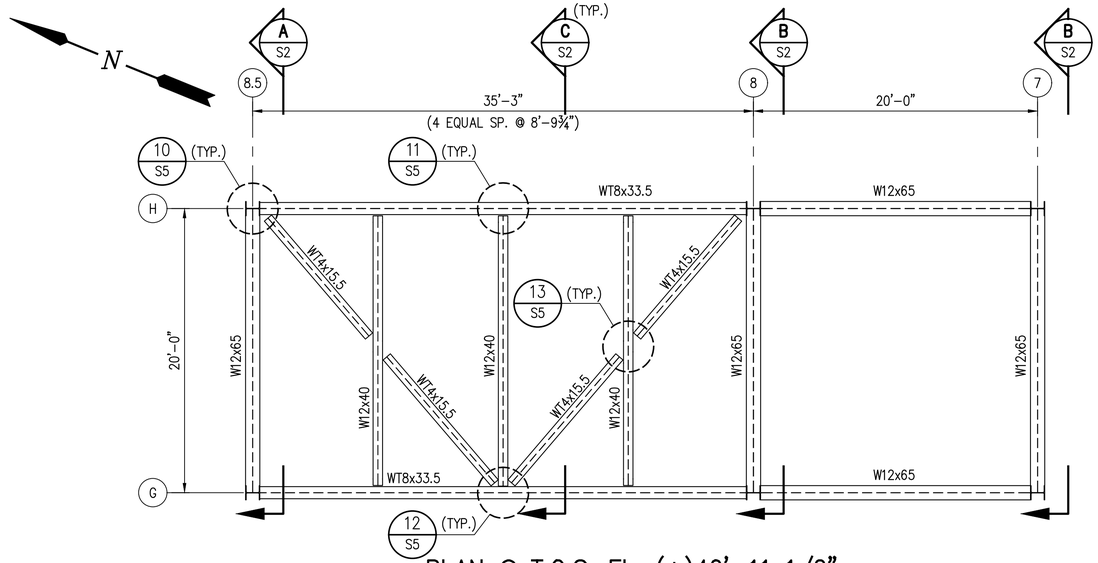
PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
PILE PLAN & SCHEDULE

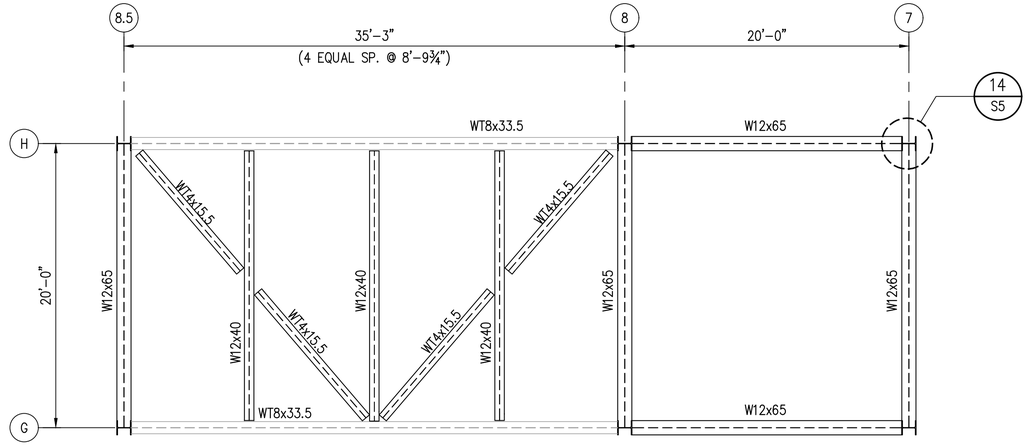
SHEET NO.
SP3

J:\11000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-SP3.DWG



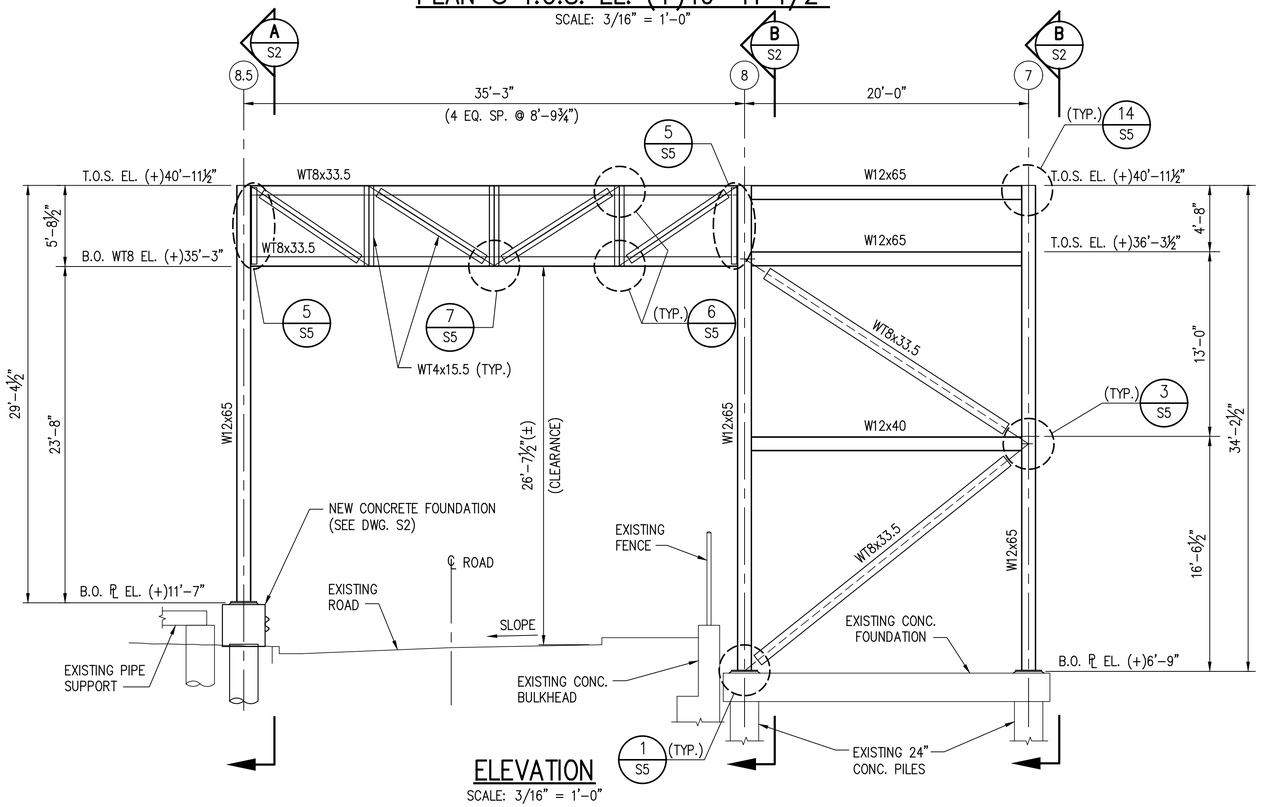
PLAN @ T.O.S. EL. (+)40'-11 1/2"

SCALE: 3/16" = 1'-0"



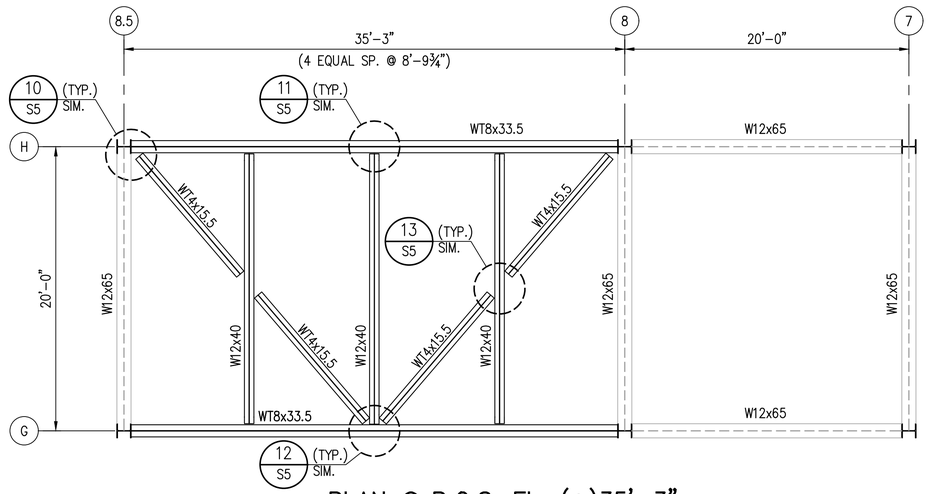
PLAN @ T.O.S. EL. (+)36'-3 1/2"

SCALE: 3/16" = 1'-0"



ELEVATION

SCALE: 3/16" = 1'-0"



PLAN @ B.O.S. EL. (+)35'-3"

SCALE: 3/16" = 1'-0"

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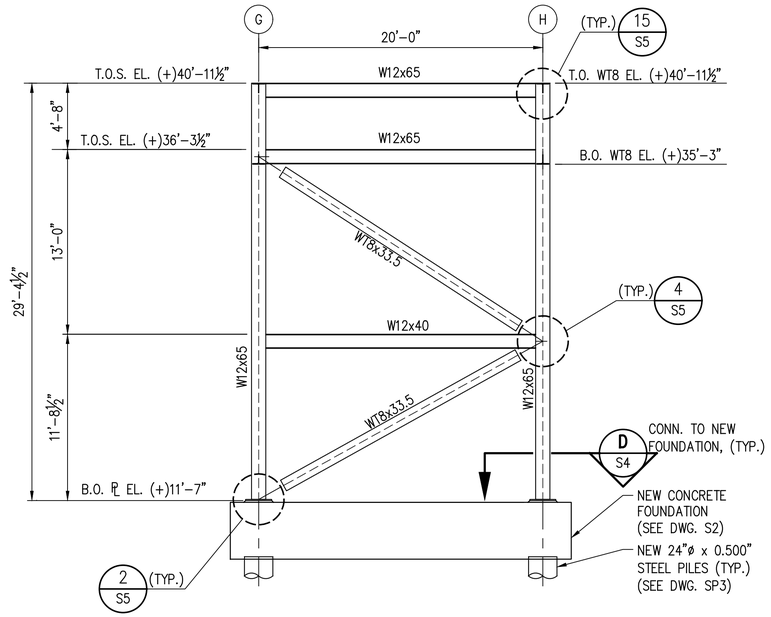
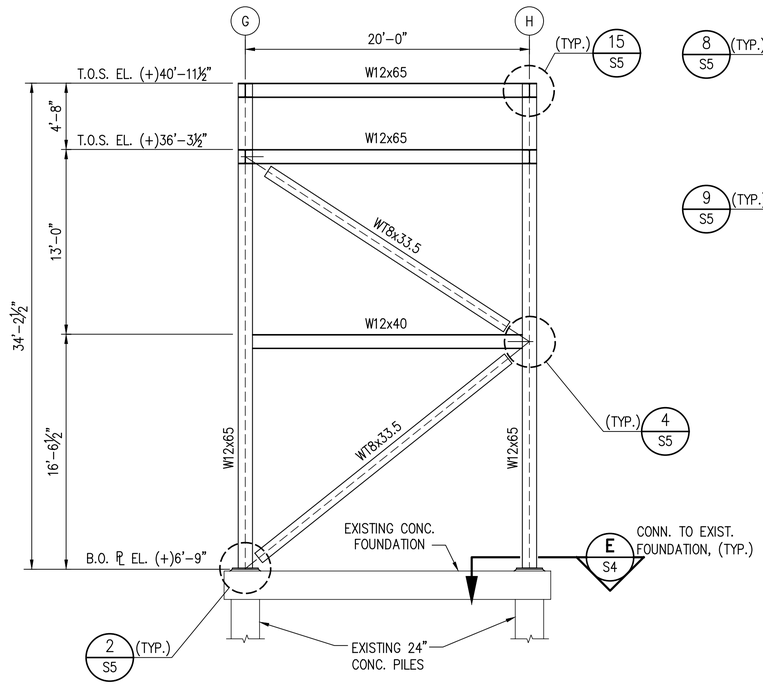
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
PLANS & ELEVATION

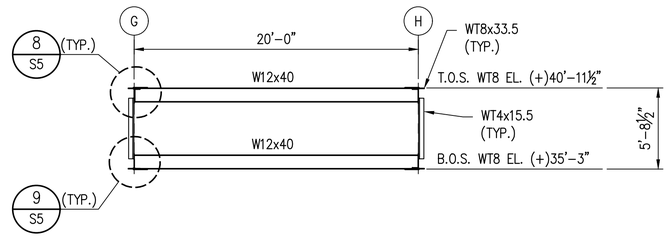
SHEET NO.
S1



SECTION A
SCALE: 3/16" = 1'-0"



SECTION B
SCALE: 3/16" = 1'-0"



SECTION C
SCALE: 3/16" = 1'-0"

PRELIMINARY
FOR BIDS ONLY
DECEMBER 23, 2021

J:\11000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-S02.DWG

LANIER & ASSOCIATES
CONSULTING ENGINEERS
INCORPORATED
LA: EF-1120 TX: F-2981
NEW ORLEANS • BEAUMONT • CORPUS CHRISTI • HOUSTON

REV	DATE	BY	DESCRIPTION
*			
A	12/23/21	MEW	FOR BIDS ONLY

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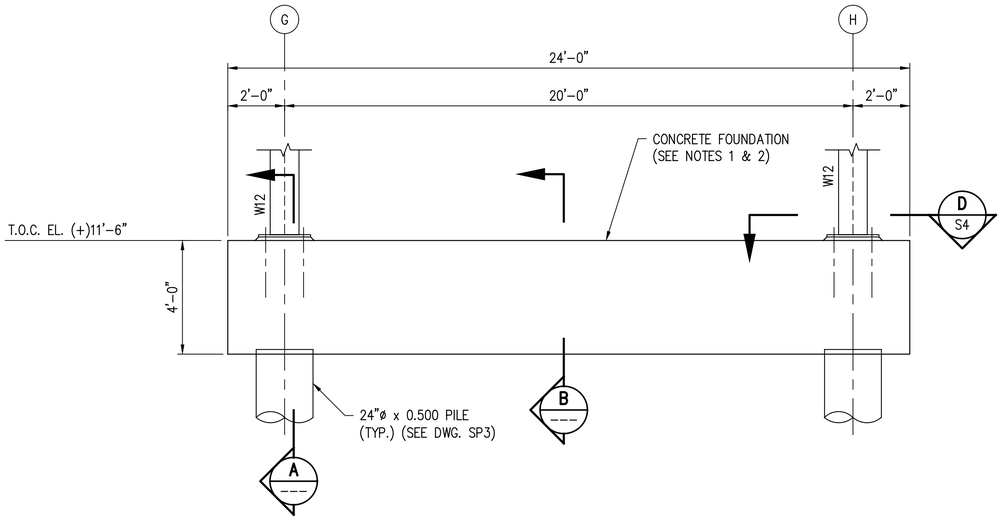
DATE SEPT. '21
SHT SIZE 22"x34"
DESIGN ETW
DRAWN MEW
CHECK MDF
APPR'D DLK
JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

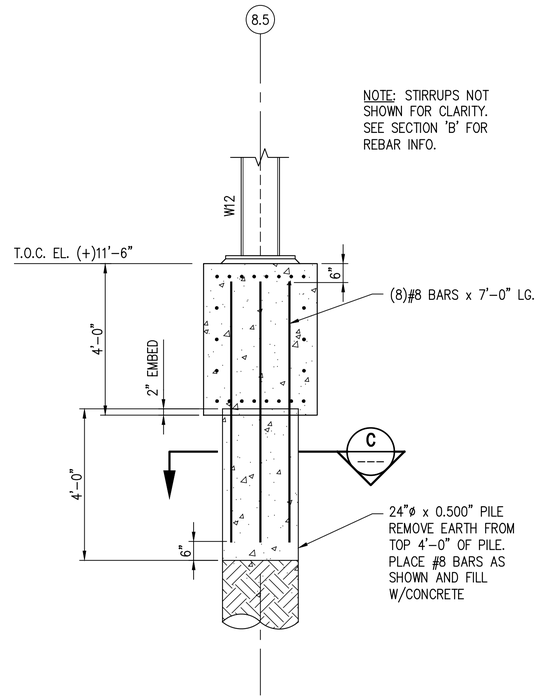
OIL DOCK #6
EAST PIPE BRIDGE
SECTIONS

SHEET NO.
S2



NEW CONCRETE FOUNDATION – ELEVATION

SCALE: 3/8" = 1'–0"

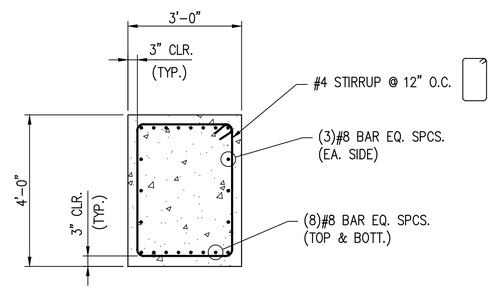


SECTION A

SCALE: 1/2" = 1'–0"

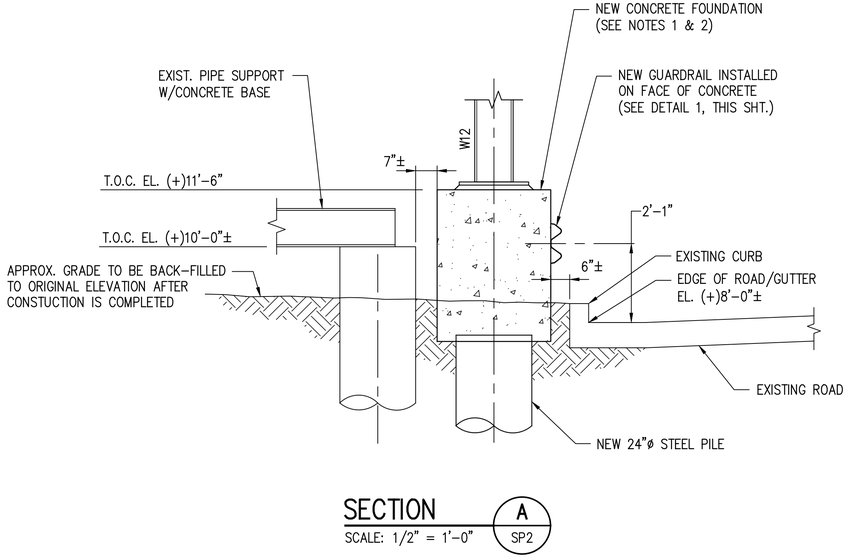
NOTES:

1. EAST, WEST AND SOUTH FACES OF CONCRETE FOUNDATION TO BE PAINTED SAFETY YELLOW.
2. NORTH/SOUTH LOCATION OF NEW CONCRETE FOUNDATION TO BE FIELD VERIFIED AND POSITIONED IN BETWEEN EXISTING ROADWAY AND PIPE SUPPORT FOUNDATION SO AS TO DISTURB BOTH STRUCTURES AS LITTLE AS POSSIBLE.



SECTION B

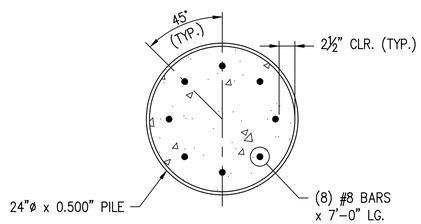
SCALE: 1/2" = 1'–0"



SECTION A

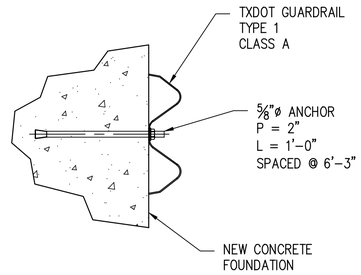
SCALE: 1/2" = 1'–0"

SP2



SECTION C

SCALE: 1" = 1'–0"



DETAIL 1

SCALE: 1 1/2" = 1'–0"

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DECEMBER 23, 2021

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DATE SEPT. '21
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JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

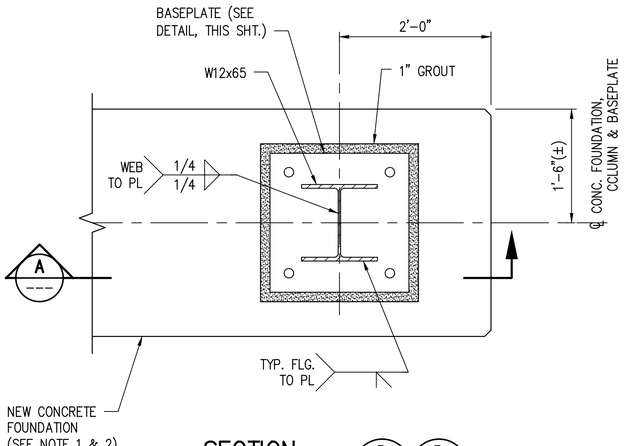
OIL DOCK #6
EAST PIPE BRIDGE
SECTIONS & DETAILS - SHT. 1

SHEET NO.
S3

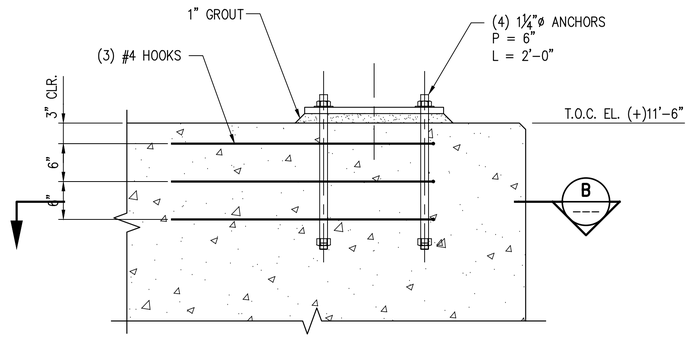
J:\11000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-S03.DWG

NOTES:

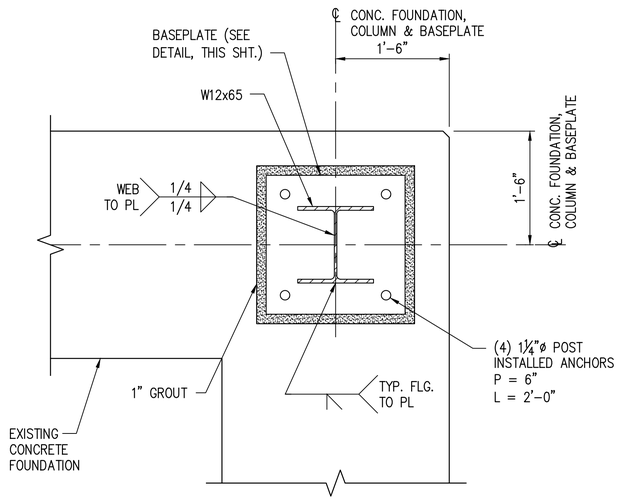
1. EAST, WEST AND SOUTH FACES OF CONCRETE FOUNDATION TO BE PAINTED SAFETY YELLOW.
2. NORTH/SOUTH LOCATION OF NEW CONCRETE FOUNDATION TO BE FIELD VERIFIED AND POSITIONED IN BETWEEN EXISTING ROADWAY AND PIPE SUPPORT FOUNDATION SO AS TO DISTURB BOTH STRUCTURES AS LITTLE AS POSSIBLE.



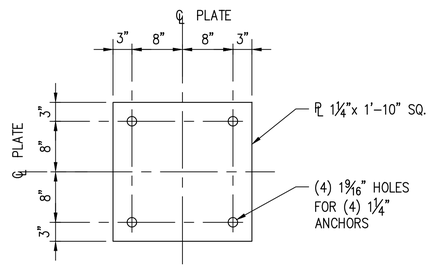
SECTION D D
SCALE: 1" = 1'-0" S2 S3



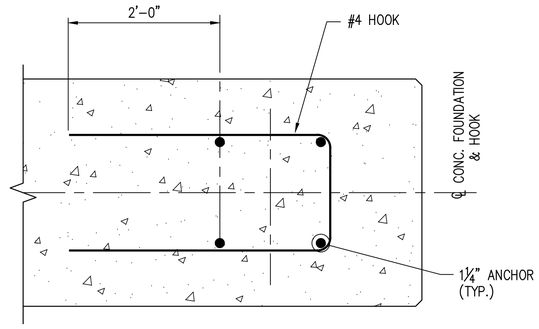
SECTION A
SCALE: 1" = 1'-0" ---



SECTION E
SCALE: 1" = 1'-0" S2



BASEPLATE DETAIL
SCALE: 1" = 1'-0"



SECTION B
SCALE: 1" = 1'-0" ---

PRELIMINARY
FOR BIDS ONLY
DECEMBER 23, 2021

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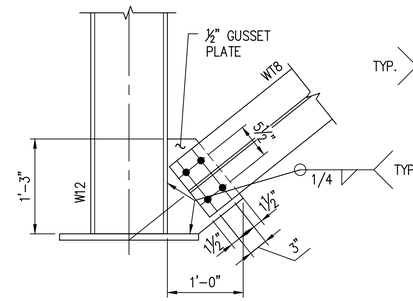
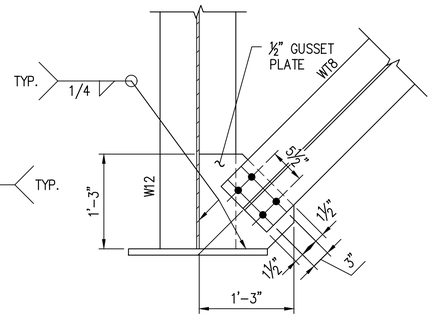
PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
SECTIONS AND DETAILS - SHT. 2

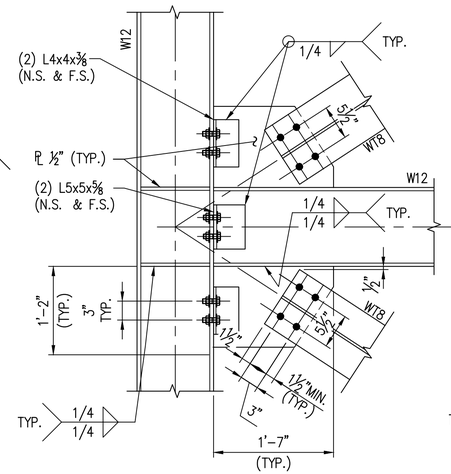
SHEET NO.
S4



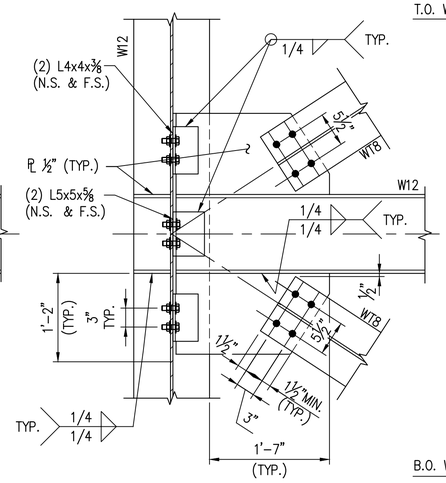
DETAIL 1
SCALE: 1"=1'-0" S1



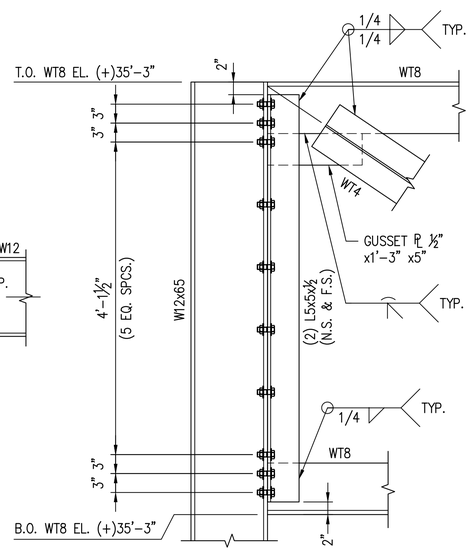
DETAIL 2
SCALE: 1"=1'-0" S2



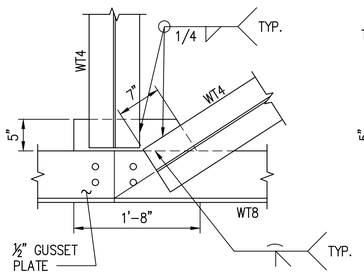
DETAIL 3
SCALE: 1"=1'-0" S1



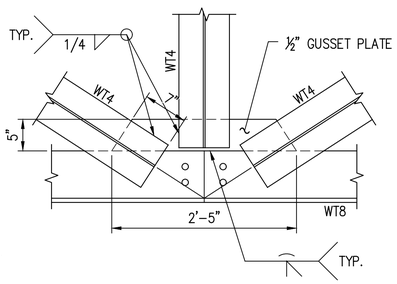
DETAIL 4
SCALE: 1"=1'-0" S2



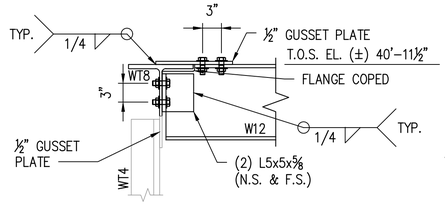
DETAIL 5
SCALE: 1"=1'-0" S1



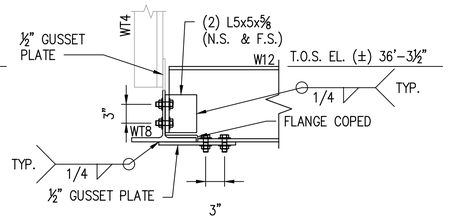
DETAIL 6
SCALE: 1"=1'-0" S1



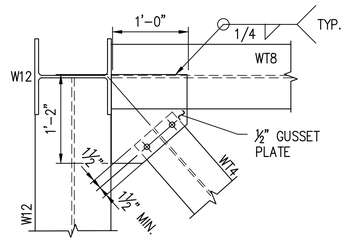
DETAIL 7
SCALE: 1"=1'-0" S1



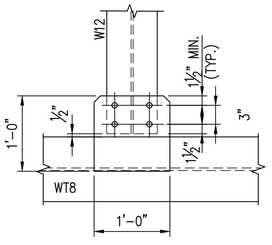
DETAIL 8
SCALE: 1"=1'-0" S2



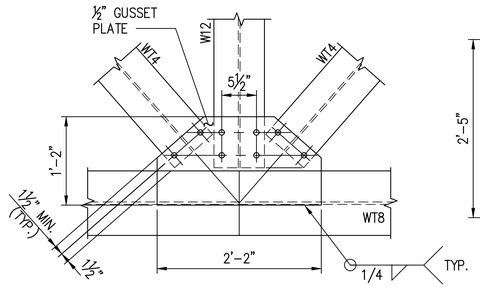
DETAIL 9
SCALE: 1"=1'-0" S2



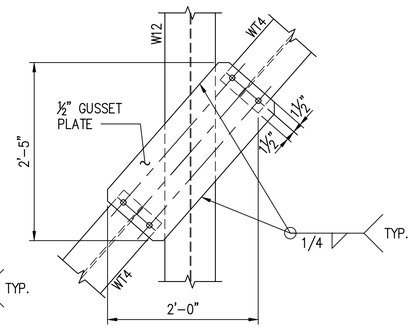
DETAIL 10
SCALE: 1"=1'-0" S1



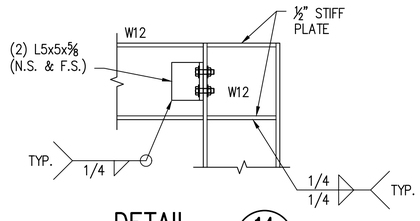
DETAIL 11
SCALE: 1"=1'-0" S1



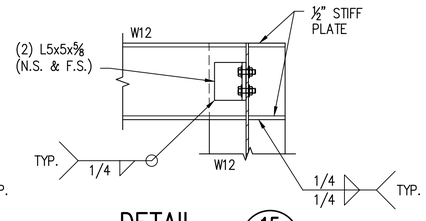
DETAIL 12
SCALE: 1"=1'-0" S1



DETAIL 13
SCALE: 1"=1'-0" S1



DETAIL 14
SCALE: 1"=1'-0" S1



DETAIL 15
SCALE: 1"=1'-0" S2

PRELIMINARY FOR BIDS ONLY
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NOTES:

1. ALL BOLTS TO BE 1"ø, UNLESS NOTED OTHERWISE. ALL BOLT HOLES TO BE 1⅛"ø, UNLESS NOTED OTHERWISE.

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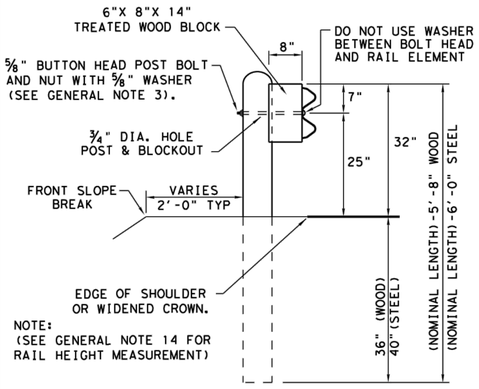
JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

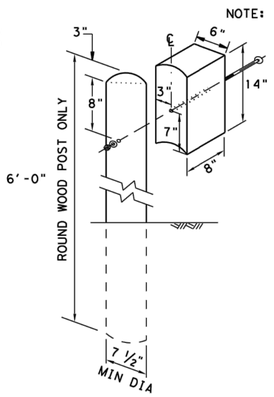
OIL DOCK #6
EAST PIPE BRIDGE
CONNECTION DETAILS

SHEET NO.
S5

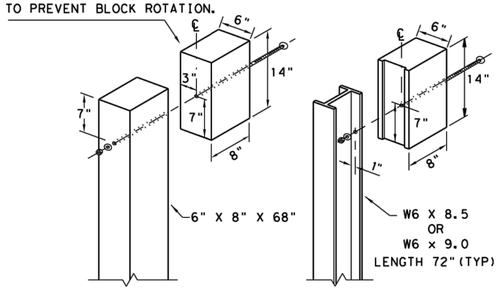
J:\11000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-S05.DWG



TYPICAL POST PLACEMENT



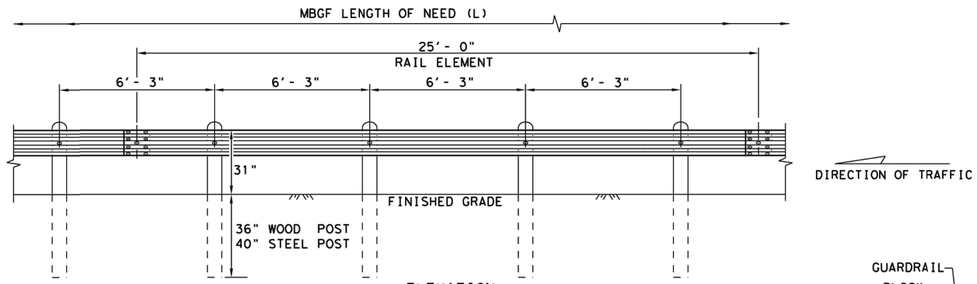
WOOD BLOCK TO ROUND WOOD POST



WOOD BLOCK TO RECTANGULAR WOOD POST

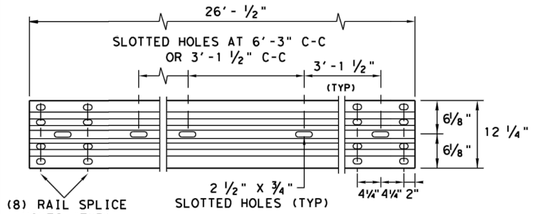
ROUTED WOOD BLOCK TO I-BEAM STEEL POST

NOTE: ** "WOOD" INDICATES DIMENSIONS FOR BOTH ROUND AND RECTANGULAR WOOD POST SYSTEMS.



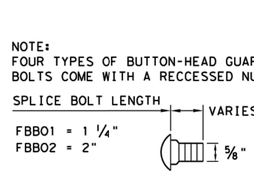
ELEVATION MID-SPAN RAIL SPLICE

SHOWING A 25'- 0" SECTION OF W-BEAM RAIL. (SEE GENERAL NOTE 2)



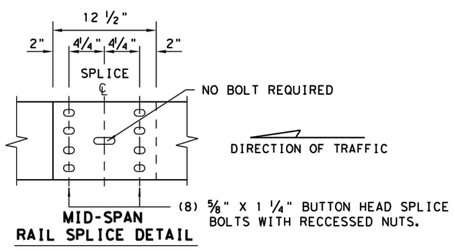
ELEVATION 25'- 0" (NOM.) W-BEAM SECTION

NOTES: SEE GENERAL NOTE 2 FOR ALLOWABLE RAIL TYPES.
SEE RAIL SPLICE DETAIL FOR REQUIRED HARDWARE.



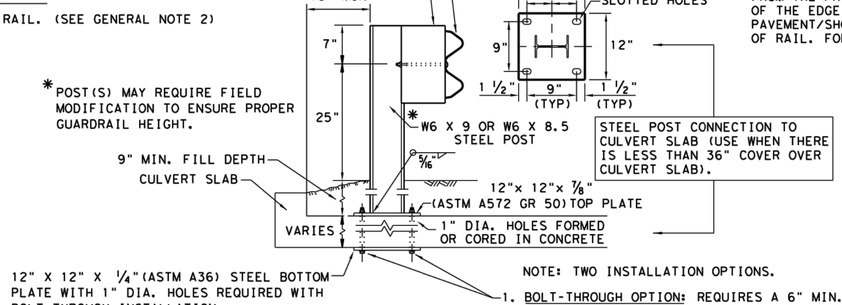
BUTTON HEAD BOLT

NOTE: SEE GENERAL NOTE 3 FOR SPLICE & POST BOLT DETAILS.



MID-SPAN RAIL SPLICE DETAIL

NOTE: GF(31), MID-SPAN RAIL SPLICES ARE REQUIRED WITH 6'-3" POST SPACINGS.



* POST(S) MAY REQUIRE FIELD MODIFICATION TO ENSURE PROPER GUARDRAIL HEIGHT.

STEEL POST CONNECTION TO CULVERT SLAB (USE WHEN THERE IS LESS THAN 36" COVER OVER CULVERT SLAB).

LOW FILL CULVERT POST

NOTE: TWO INSTALLATION OPTIONS.

1. BOLT-THROUGH OPTION: REQUIRES A 6" MIN. SLAB THICKNESS. 7/8" DIA (ASTM A449) HEAVY HEX BOLTS WITH TWO HARDENED WASHER EACH AND HEAVY HEX NUTS.
   NOTE: BOLT LENGTH = SLAB PLUS 2 1/4" MIN.

2. EPOXY ANCHOR OPTION: THIS OPTION MAY ONLY BE USED IF THE CULVERT SLAB IS 9" MIN. THICK. THREADED ANCHOR RODS MUST BE 7/8" DIA. ASTM A449 OR A193 GRADE B7 WITH HEAVY HEX NUT, AND ONE HARDENED WASHER EACH. EMBED ANCHOR RODS 6" WITH HILTI HIT RE 500 EPOXY ADHESIVE. OTHER TYPE III CLASS C EPOXY ADHESIVES MEETING THE REQUIREMENTS OF DMS-6100, "EPOXIES AND ADHESIVES", MAY BE USED IF IT CAN BE DEMONSTRATED THAT THEY MEET OR EXCEED THE STRENGTH OF HILTI HIT RE 500 WITH THE SAME EMBEDMENT DEPTH AND THREADED ROD DIA. FOLLOW THE MANUFACTURER'S REQUIREMENTS FOR INSTALLING EPOXIED THREADED RODS. EXTEND RODS 1/4" MIN. BEYOND NUT.

NOTE: CULVERTS OF 25 FT. OR LESS, SEE GF(31)LS STANDARD FOR "LONG SPAN" OPTION.

GENERAL NOTES

1. THE TYPE OF POST (ROUND WOOD POST, RECTANGULAR WOOD POST, OR STEEL POST) WILL BE AS SHOWN IN THE PLANS. THE EXACT POSITION OF MBGF SHALL BE SHOWN IN THE PLANS OR AS DIRECTED BY THE ENGINEER. STEEL POSTS TO BE GALVANIZED IN ACCORDANCE WITH ITEM 445, "GALVANIZING."
2. RAIL ELEMENTS SHALL MEET THE REQUIREMENTS OF ITEM 540, "METAL BEAM GUARD FENCE" EXCEPT AS MODIFIED IN THE PLANS. THE CONTRACTOR MAY FURNISH RAIL ELEMENTS OF 25'- 0", OR 12'- 6" (NOM.) LENGTHS. RAIL ELEMENTS MAY HAVE SLOTTED HOLES AT 3'-1 1/2" C-C OR 6'-3" C-C. A SPECIAL LENGTH OF RAIL MAY BE MANUFACTURED TO ACCOMMODATE THE DOWNSTREAM ANCHOR TERMINAL (DAT) AND THE TRANSITION SECTIONS OF GUARDRAIL.
3. BUTTON HEAD "POST BOLTS & NUTS" SHALL MEET THE REQUIREMENTS OF (ASTM A307), AND SHALL BE OF SUFFICIENT LENGTH TO EXTEND THROUGH THE FULL THICKNESS OF THE NUT AND 5/8" WASHER (FWC16a) AND NOT MORE THAN 1" BEYOND IT. TRIM REMAINING BOLT LENGTH TO MEET REQUIRED LENGTH.
4. FITTINGS (BOLTS, NUTS, AND WASHERS) SHALL BE GALVANIZED IN ACCORDANCE WITH ITEM 445, "GALVANIZING." FITTINGS SHALL BE SUBSIDIARY TO THE BID ITEM.
5. CROWN SHALL BE WIDENED TO ACCOMMODATE THE METAL BEAM GUARD FENCE.
6. THE LATERAL APPROACH TO THE GUARD FENCE, SHALL HAVE A MAXIMUM SLOPE OF 1V:10H.
7. IF SHOWN ELSEWHERE IN THE PLANS OR AS DIRECTED BY THE ENGINEER, THE GUARD FENCE MAY BE FLARED AT A RATE OF 25:1 OR FLATTER.
8. UNLESS OTHERWISE SHOWN IN THE PLANS, GUARD FENCE PLACED IN THE VICINITY OF CURBS SHALL BE POSITIONED SO THAT THE FACE OF CURB IS LOCATED DIRECTLY BELOW OR BEHIND THE FACE OF THE RAIL. RAIL PLACED OVER CURBS SHALL BE INSTALLED SO THAT THE POST BOLT IS LOCATED APPROXIMATELY 25 INCHES ABOVE THE GUTTER PAN OR EDGE OF SHOULDER.
9. APPLICATIONS IN SOLID ROCK ARE ONLY ALLOWED WITH STEEL POSTS. IF SOLID ROCK IS ENCOUNTERED WITHIN 0 TO 18" OF THE FINISHED GRADE, DRILL A 24" DIA. HOLE, 24" INTO THE ROCK. IF SOLID ROCK IS ENCOUNTERED BELOW 18", DRILL A 12" DIA. HOLE, 12" INTO THE ROCK OR TO THE STANDARD EMBEDMENT DEPTH, WHICHEVER MAYBE LESS. ANY EXCESS POST LENGTH, AFTER MEETING THESE DEPTHS, MAY BE FIELD CUT TO ENSURE PROPER GUARDRAIL MOUNTING HEIGHT. BACKFILL WITH COARSE AGGREGATE MATERIAL.
10. POSTS SHALL NOT BE SET IN CONCRETE, OF ANY DEPTH.
11. SPECIAL FABRICATION WILL BE REQUIRED AT INSTALLATION LOCATIONS HAVING A CURVATURE OF LESS THAN 150 FT. RADIUS.
12. UNLESS OTHERWISE SHOWN IN THE PLANS, A COMPOSITE MATERIAL BLOCK THAT MEETS THE REQUIREMENTS OF DMS-7210, "COMPOSITE MATERIAL POSTS AND BLOCKS FOR METAL BEAM GUARD FENCE" MAY BE SUBSTITUTED FOR BLOCKS OF SIMILAR DIMENSIONS. THE CONSTRUCTION DIVISION, TXDOT MAINTAINS A MATERIAL PRODUCER LIST (MPL) FOR PRODUCERS OF MATERIALS CONFORMING TO DMS-7210 ONLY PRODUCERS ON THE MPL MAY FURNISH COMPOSITE MATERIAL BLOCKS.
13. FOR THE LOW FILL CULVERT OPTION, POSTS LOCATED PARTIALLY OR WHOLLY BETWEEN PRECAST BOX CULVERT UNITS, THE USE OF A CAST-IN-PLACE CONCRETE CLOSURE BETWEEN BOXES IS REQUIRED. THE LENGTH OF THE CAST-IN-PLACE CONCRETE CLOSURE SHALL ACCOMMODATE THE PLACEMENT OF THE LOW FILL CULVERT OPTION. SEE CONCRETE CLOSURE DETAILS ON BRIDGE STANDARD SCP-MD.
14. GUARDRAIL HEIGHT MEASUREMENT: WHEN THE GUARDRAIL IS LOCATED ABOVE PAVEMENT, MEASURE THE HEIGHT FROM THE PAVEMENT TO THE TOP OF THE W-BEAM RAIL. WHEN THE GUARDRAIL IS LOCATED UP TO 2 FT. OFF OF THE EDGE OF PAVEMENT OR FOR A PAVEMENT OVERLAY, USE A 10-FOOT STRAIGHTEDGE TO EXTEND THE PAVEMENT/SHOULDER SLOPE TO THE BACK OF RAIL, MEASURE FROM THE BOTTOM OF STRAIGHTEDGE TO THE TOP OF RAIL. FOR GUARDRAIL LOCATED DOWN A 10:1 SLOPE, MEASURE FROM THE NOMINAL TERRAIN.

NOTE: TRANSISTIONS TO BRIDGE RAILS OR TRAFFIC BARRIERS.
SEE GF(31)TL3 TR STANDARD FOR HIGH-SPEED TL-3 TRANSITIONS.
SEE GF(31)TL2 TR STANDARD FOR LOW-SPEED TL-2 TRANSITIONS.

NOTES:

1. GUARDRAIL DRAWING SHOWN PER TXDOT DRAWING DATED NOVEMBER 2019, FILE NUMBER GF(31)-19.

Texas Department of Transportation — Design Division Standard

METAL BEAM GUARD FENCE
TL-3 MASH COMPLIANT
GF(31)-19

FILE: gf3119.dgn	DN: TxDOT	CK: KM	DW: VP	CK: CGL/AG
©TxDOT: NOVEMBER 2019	CONT	SECT	JOB	HIGHWAY
REVISIONS				
	DIST	COUNTY		SHEET NO.

PRELIMINARY FOR BIDS ONLY
DECEMBER 23, 2021

DATE:
FILE:

J:\10000S\11769 BROWNSVILLE OIL DOCK 6\DRAWINGS\11769-S06.DWG

LANIER & ASSOCIATES
CONSULTING ENGINEERS
INCORPORATED
LA: EF-1120 TX: F-2981
NEW ORLEANS • BEAUMONT • CORPUS CHRISTI • HOUSTON

REV	DATE	BY	DESCRIPTION
*			
A	12/23/21	MEW	FOR BIDS ONLY

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF BIDDING UNDER THE AUTHORITY OF MICHAEL D. FOLSE, P.E. #125661 ON 12/23/21. IT IS NOT TO BE USED FOR CONSTRUCTION PURPOSES.

DATE SEPT. '21
SHT SIZE 22"x34"
DESIGN ETW
DRAWN MEW
CHECK MDF
APPR'D DLK
JOB NO 11769

PORT OF BROWNSVILLE
BROWNSVILLE TEXAS

OIL DOCK #6
EAST PIPE BRIDGE
TXDOT METAL BEAM GUARD FENCE

SHEET NO.
S6

PORT OF BROWNSVILLE
BROWNSVILLE, TX

TECHNICAL SPECIFICATIONS

FOR

OIL DOCK #6 EAST SIDE PIPE BRIDGE

PREPARED BY:

PH: 504-895-0368
WWW.LANIER-ENGINEERS.COM

TEXAS FIRM NO. F-2981

JOB NUMBER 11769

DECEMBER 23, 2021

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NOTE: The specifications referenced above and included in these documents have been provided by the Owner's Engineer. Contractor shall request all standards and construction specifications prepared by the Owner. Where there is similarity between the specifications listed above and those provided by the Owner, the strictest governance shall apply.

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
April 2017

Structural

PIP STC01015
Structural Design Criteria

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PUBLISHING HISTORY

December 1998	*Issued*
February 2002	*Technical Revision*
April 2002	*Editorial Revision*
August 2004	*Complete Revision*
February 2006	*Technical Correction*
September 2007	*Technical Correction*
April 2017	*Complete Revision*

Not printed with State funds

PIP STC01015
Structural Design Criteria

Table of Contents

1. Scope

This Practice describes the minimum requirements for the structural design of process industry facilities at onshore sites.

This Practice is intended to be used in conjunction with *PIP ARC01015*, *PIP ARC01016*, *PIP CVC01015*, *PIP CVC01017*, and *PIP CVC01018*, as applicable.

This Practice does not include design criteria for loads associated with transportation or lifting of modular structures.

This Practice provides triple references to *ASCE/SEI 7-10*, *IBC 2012*, and *IBC 2015*. The applicable code/standard shall be as required by the authority having jurisdiction (AHJ) and as specified in *PIP CVC01017*.

This Practice references U.S. codes and standards, but it can be applied globally. For projects in other countries, a thorough search of applicable codes and standards is required. Where more stringent than U.S. codes and standards, the local codes and standards shall govern. For projects in countries without applicable codes and standards, the U.S. codes and standards shall govern.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP ARC01015 - *Architectural and Building Utilities Design Criteria*
- PIP ARC01016 - *Building Data Sheet*
- PIP CVC01015 - *Civil Design Criteria*
- PIP CVC01017 - *Plant Site Data Sheet*
- PIP CVC01018 - *Project Data Sheet*
- PIP PCCWE001 - *Weighing Systems Design Criteria*
- PIP PCEWE001 - *Weighing Systems Guidelines*
- PIP REIE686/API RP686 - *Recommended Practice for Machinery Installation and Installation Design*
- PIP REIE686A - *Recommended Practice for Machinery Installation and Installation Design (Supplement to PIP REIE686/API RP686)*
- PIP STC01018 - *Blast Resistant Building Design Criteria*
- PIP STE05121 - *Application of ASCE Anchorage Design for Petrochemical Facilities*
- PIP STE03360 - *Heat Exchanger and Horizontal Vessel Foundation Design Guide*

2.2 Industry Codes and Standards

- American Association of State Highway and Transportation Officials (AASHTO)
  - *AASHTO Standard Specifications for Highway Bridges*
- American Concrete Institute (ACI)
  - ACI 318-11 - *Building Code Requirements for Structural Concrete and Commentary*
  - ACI 318-14 - *Building Code Requirements for Structural Concrete and Commentary*
  - ACI 318M-11 - *Building Code Requirements for Structural Concrete and Commentary (Metric)*
  - ACI 318M-14 - *Building Code Requirements for Structural Concrete and Commentary (Metric)*
  - ACI 350 - *Code Requirements for Environmental Engineering Concrete Structures and Commentary*
  - ACI 350M - *Code Requirements for Environmental Engineering Concrete Structures and Commentary (Metric)*
  - ACI 376 - *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases and Commentary*
  - ACI 376M - *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases and Commentary (Metric)*
- American Institute of Steel Construction (AISC)
  - AISC 341 - *Seismic Provisions for Structural Steel Buildings*
  - ANSI/AISC 360 - *Specification for Structural Steel Buildings*
- American Iron and Steel Institute (AISI)
  - AISI S100 - *North American Specification for the Design of Cold-Formed Steel Structural Members*
- American Petroleum Institute (API)
  - API Standard 650 - *Welded Steel Tanks for Oil Storage*
- American Society of Civil Engineers (ASCE)
  - ASCE/SEI 7-10 - *Minimum Design Loads for Buildings and Other Structures*
  - ASCE/SEI 37-14 - *Design Loads on Structures during Construction*
  - *Design of Blast-Resistant Buildings in Petrochemical Facilities* - Task Committee on Blast-Resistant Design of the Petrochemical Committee of the Energy Division of the American Society of Civil Engineers, 2010
  - *Guidelines for Seismic Evaluation and Design of Petrochemical Facilities* - Task Committee on Seismic Evaluation and Design of the Petrochemical Committee of the Energy Division of the American Society of Civil Engineers, 2011

  - *Wind Loads for Petrochemical and Other Industrial Facilities* - Task Committee on Wind-Induced Forces of the Petrochemical Committee of the Energy Division of the American Society of Civil Engineers, 2011

- American Society of Mechanical Engineers (ASME) / Canadian Standards Association (CSA)
  - ASME A17.1/CSA B44 - *Safety Code for Elevators and Escalators*

- ASTM International (ASTM)
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A193/A193M - *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*
  - ASTM A307 - *Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength*
  - ASTM A354 - *Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners*
  - ASTM A500/A500M - *Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes*
  - ASTM A572/A572M - *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*
  - ASTM A615/A615M - *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*
  - ASTM A706/A706M - *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement*
  - ASTM A992/A992M - *Standard Specification for Structural Steel Shapes*
  - ASTM A1064/A1064M - *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*
  - ASTM F1554 - *Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength*
  - ASTM F3125/ASTM F3125M - *Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions*

- American Welding Society (AWS)
  - AWS D1.1/D1.1M - *Structural Welding Code - Steel*

- American Wood Council (AWC)
  - ANSI/AWC NDS - *National Design Specification for Wood Construction*
  - *NDS Supplement - Design Values for Wood Construction*

- Crane Manufacturers Association of America (CMAA)
  - CMAA No. 70 - *Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes*

  - CMAA No. 74 - *Specifications for Top Running and Under Running Single Girder Electric Traveling Cranes Utilizing Under Running Trolley Hoist*

- International Code Council (ICC)
  - International Building Code (IBC) 2012
  - International Building Code (IBC) 2015
- National Fire Protection Association (NFPA)
  - NFPA 59A-01 - *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*
  - NFPA 59A-06 - *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*
  - NFPA 59A-13 - *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*
- Precast/Prestressed Concrete Institute (PCI)
  - PCI MNL-120 - *PCI Design Handbook*
- Research Council on Structural Connections (RCSC)
  - *RCSC Specification for Structural Joints Using High-Strength Bolts*
- Steel Deck Institute (SDI)
  - SDI C1.0 - *Standard for Composite Steel Floor Deck*
  - SDI NC1.0 - *Standard for Non-Composite Steel Floor Deck*
  - SDI RD1.0 - *Standard for Steel Roof Deck*
- Steel Joist Institute (SJI)
  - SJI-CJ - *Standard Specification for Composite Steel Joists CJ-Series*
  - SJI-K - *Standard Specification for Open Web Steel Joists, K-Series*
  - SJI-LH/DLH - *Standard Specification for Long Span Joists, LH-Series and Deep Long Span Joists, DLH-Series*
  - SJI-JG - *Standard Specification for Joist Girders*
- The Masonry Society (TMS) / American Concrete Institute (ACI) / Structural Engineering Institute of the American Society of Civil Engineers (SEI/ASCE)
  - TMS 402/ACI 530/ASCE 5 - *Code Requirements for Masonry Structures*

2.3 Government Regulations

Federal Standards and Instructions of the Occupational Safety and Health Administration (OSHA), including any additional requirements by state or local agencies that have jurisdiction in the state where the project is to be constructed, shall apply.

- U.S. Department of Labor (DOL), Occupational Safety and Health Administration (OSHA)
  - OSHA 29 CFR 1910 Subpart D - *Walking-Working Surfaces*
  - OSHA 29 CFR 1926 - *Safety and Health Regulations for Construction*
- US Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA)
  - PHMSA 49 CFR 193 - *Liquefied Natural Gas Facilities: Federal Safety Standards*

2.4 Other References

- Naqvi, D., Wey, E., and O'Rourke, M., *Snow Loads on Non-Building Structures*, Structures Congress 2012: pp. 1452-1462.
- Federal Energy Regulatory Commission (FERC), *Draft Seismic Design Guidelines and Data Submittal Requirements for LNG Facilities*, January 23, 2007.

3. Definitions

authority having jurisdiction (AHJ): A person who has the delegated authority to determine, mandate, and enforce code requirements established by jurisdictional governing bodies.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of civil works, structures, foundations, materials, and appurtenances described in contract documents. Engineer of record shall be licensed as defined by laws of the locality in which the work is to be constructed, and be qualified to practice in the specialty discipline required for the work described in contract documents.

environmental engineering concrete structures: Concrete structures intended for conveying, storing, or treating water, wastewater, or other liquids and non-hazardous materials such as solid waste, and for secondary containment of hazardous liquids or solid waste.

owner: Party who has authority through ownership, lease, or other legal agreement over the buildings, structures and foundations to be designed.

4. Requirements

4.1 Design Loads

4.1.1 General

4.1.1.1 New facilities, buildings, and other structures, including floor slabs and foundations, shall be designed to resist the minimum loads defined in *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable, local building codes, this section and the loads defined in *PIP CVC01017* and *CVC01018*.

4.1.1.2 In addition to the loads in this section, other loads shall be considered as appropriate. These loads shall include, but are not limited to ice, rain, hydrostatic, dynamic, upset conditions, earth pressure, vehicles, buoyancy, and erection.

4.1.1.3 Loads associated with transportation and lifting of modular structures shall also be considered as appropriate.

4.1.1.4 Future loads shall be considered if specified by the owner.

4.1.1.5 For existing facilities, actual loads may be used in lieu of the minimum specified loads.

4.1.1.6 Eccentric loads (e.g., piping, platforms), particularly on horizontal and vertical vessels and exchangers, shall be considered. For additional information regarding eccentric loads on horizontal vessels and exchangers, see *PIP STE03360*.

4.1.1.7 Risk Categories

1. The owner, AHJ, and project process engineers shall be consulted as applicable to determine the assignment of Risk Categories for buildings and other structures for the purpose of applying wind, earthquake, snow, and ice load provisions in accordance with *ASCE/SEI 7-10*, Section 1.5; *IBC 2012*, Section 1604.5; or *IBC 2015*, Section 1604.5 as applicable.

   Comment: For process industry facilities, Risk Category III is the most likely classification because of the presence of toxic, highly toxic, or explosive substances. In some cases, it may be appropriate to select Risk Category IV. Risk Category II may be used if the owner can demonstrate to the satisfaction of the AHJ by a hazard assessment that a release of the toxic, highly toxic, or explosive substances is not sufficient to pose a threat to the public. See *ASCE/SEI 7-10*, Section 1.5.3 and Table 1.5-1; and *ASCE/SEI 7-10*, Commentary for Chapter 1; for specific details.

2. Risk Categories for Liquefied Natural Gas (LNG) facilities shall be in accordance with *NFPA 59A-13*, Sections 5.4.1 and 5.4.2, as applicable.

Comment: *PHMSA 49CFR193*, and *NFPA 59A-01* and *NFPA 59A-06*, which are referenced by *PHMSA 49CFR193*, do not specifically mention Risk Categories (or Occupancy Categories) in their requirements. *NFPA 59A-13* uses the term Occupancy Category which is considered to be equivalent to the term Risk Category used by *ASCE/SEI 7-10*. See Federal Energy Regulatory Commission (FERC), *Draft Seismic Design Guidelines and Data Submittal Requirements for LNG Facilities* for additional guidance on Risk Categories (Occupancy Categories) in conjunction with seismic (earthquake) loads for LNG facilities.

4.1.2 Dead Loads (D)

4.1.2.1 Dead loads are the actual weight of materials forming the building, structure, foundation, and all permanently attached appurtenances (e.g., lighting, instrumentation, HVAC, sprinkler and deluge systems, fireproofing, insulation).

4.1.2.2 Weights of fixed process equipment and machinery, piping, valves, electrical cable trays, and the contents of these items shall also be considered as dead loads.

4.1.2.3 For this Practice, dead loads are designated by the following nomenclature:

D_s, D_f, D_e, D_o, and D_t, where:

D_s = Structure dead load is the weight of materials forming the structure (i.e., not the empty weight of process equipment, vessels, tanks, piping, nor cable trays), foundation, soil above the foundation resisting uplift, and all permanently attached appurtenances (e.g., lighting, instrumentation, HVAC, sprinkler and deluge systems, fireproofing, and insulation, etc.).

D_f = Erection dead load is the fabricated weight of process equipment or vessels. See Section 4.1.2.4 for further definition.

D_e = Empty dead load is the empty weight of process equipment, vessels, tanks, piping, and cable trays. See Sections 4.1.2.4 through 4.1.2.7 for further definition.

D_o = Operating dead load is the empty weight of process equipment, vessels, tanks, piping, and cable trays (D_e) plus the maximum weight of contents during normal operation. See Sections 4.1.2.4 through 4.1.2.8 for further definition.

D_t = Test dead load is the empty weight of process equipment, vessels, tanks, and/or piping (D_e) plus the weight of the test medium contained in the system. See Section 4.1.2.4 for further definition.

4.1.2.4 Process Equipment and Vessel Dead Loads

1. Erection dead load (D_f) for process equipment and vessels is normally the fabricated weight of the equipment or vessel and is generally taken from the certified equipment or vessel drawing.
2. Empty dead load (D_e) for process equipment and vessels is the empty weight of the equipment or vessels, including all attachments, trays, internals, insulation, fireproofing, agitators, piping, ladders, platforms, etc. Empty dead load also includes weight of machinery (e.g., pumps, compressors, turbines, and packaged units).
3. Operating dead load (D_o) for process equipment and vessels is the empty dead load (D_e) plus the maximum weight of contents (including packing/catalyst) during normal operation.
4. Test dead load (D_t) for process equipment and vessels is the empty dead load (D_e) plus the weight of test medium contained in the system. The test medium shall be as specified in the contract documents or as specified by the owner. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium. Equipment and pipes that may be simultaneously tested shall be included. Cleaning load shall be used for test dead load if the cleaning fluid is heavier than the test medium.

4.1.2.5 Equipment/Platform Structure Dead Loads

1. In addition to primary dead loads for the structural steel, fireproofing, major equipment and large bore piping, dead loads on equipment/platform structures shall be included to account for grating, checkered plate, concrete decking, guard systems, ladders and cages, small equipment, piping, electrical conduits, lighting and other miscellaneous items.
2. Unless more determinate load information is available and requires otherwise, dead loads for the following items shall be estimated as follows:
   a. Uniformly distributed loads for grating, checkered plate, and concrete decking (D_s):
      (1) Grating: 9.1 psf (0.44 kN/m^2) for 1-1/4 inches x 3/16 inch (32 mm x 5 mm) plain grating
      (2) Checkered Plate: 11.25 psf (0.54 kN/m^2) for 1/4 inch (6 mm) checkered plate
      (3) Concrete Deck: based upon deck manufacturer's tables.
   b. Guard systems and ladders and cages (D_s):
      (1) Angle Guard Systems with Toe Plate: 15 lbs/ft (0.22 kN/m) of guard length (L 2 ½ x 2 ½ x ¼).
      (2) Pipe Guard Systems with Toe Plate: 11 lbs/ft (0.16 kN/m) of guard length for pipe guard (NPS 1 ½ STD or HSS 1.900 x 0.145)

(2) Ladders with Cages: 30 lbs/ft (0.44 kN/m) of ladder length

(3) Ladders without Cages: 11 lbs/ft (0.16 kN/m) of ladder length

c. Empty dead load (D_e) for small equipment, piping, electrical conduits, lighting and other miscellaneous items:

For checking uplift and components controlled by minimum loading, a uniformly distributed load of 0 psf (0 kN/m^2) to 20 psf (1.0 kN/m^2) as determined by engineering judgment for load combinations that include wind load or earthquake load

d. Operating dead load (D_o) for small equipment, piping, electrical conduits, lighting and other miscellaneous items:

A uniformly distributed load of 10 psf (0.5 kN/m^2) to 30 psf (1.5 kN/m^2) as determined by engineering judgment

4.1.2.6 Pipe Rack Piping Loads

1. Unless more determinate load information is available and requires otherwise, dead loads for piping on pipe racks shall be estimated as follows:

   a. Operating dead load (D_o): A uniformly distributed load of 20 psf (1.0 kN/m^2) to 60 psf (3.0 kN/m^2) as determined by engineering judgment for piping, product, valves, fittings, and insulation based on the average size of piping on each level.

      Comment: A uniformly distributed load of 40 psf (2.0 kN/m^2) is equivalent to NPS 8 (DN 200) STD pipes, full of water, at 15-inch (375-mm) spacing.

   b. Empty dead load (D_e): For checking uplift and components controlled by minimum loading, 40% to 60% of the estimated operating dead load (D_o) shall be used as determined by engineering judgment for load combinations that include wind load or earthquake load. Empty dead load shall not be included for unutilized portions of piping levels.

   c. Test dead load (D_t) is the empty weight of the pipe (D_e) plus the weight of test medium contained in a set of simultaneously tested piping systems. The test medium shall be as specified in the contract documents or as specified by the owner. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium.

2. For any pipe at least two sizes larger than the average pipe size on the piping level being considered, an additional uniform or concentrated load, including the weight of piping, product, valves, fittings, and insulation shall be used for dead load not included in the regular uniformly distributed piping loads specified in Section 4.1.2.6.1.a.

3. The normal operating weight of vapor and flare pipes, pipes with commodities significantly lighter than water, and NPS 20 (DN500) and larger pipes shall be considered separately.

Comment: The loads for these piping systems can be significantly different than loads determined for other piping and can significantly affect the design of the pipe rack, especially for load combinations that include wind load or earthquake load.

4. When applying dead loads for piping, consideration shall be given to unsymmetrical loading of the piping levels that can impact the minimum and maximum controlling cases for elements of the pipe rack and foundations.
5. Pipe racks and their foundations shall be designed to support loads associated with full utilization of the available space on piping levels for operating load combinations.
6. Pipe racks and their foundations shall be designed to support any specified future piping level expansion.

4.1.2.7 Pipe Rack Cable Tray Loads

1. Unless more determinate load information is available and requires otherwise, dead loads for cable trays on pipe racks shall be estimated as follows:
   a. Operating dead load (D_o): A uniformly distributed dead load of 20 psf (1.0 kN/m^2) to 40 psf (2.0 kN/m^2) per level of cable trays as determined by engineering judgment based on the weight of the trays, the types of cables supported in the trays and the weight of those cables loaded to the full (i.e., maximum) capacity that can be placed in the trays considering electrical code spacing requirements for the cables.
   b. Empty dead load (D_e): For checking uplift and components controlled by minimum loading, a reduced level of cable tray load that considers how full the trays may actually be loaded shall be considered as the empty dead load for load combinations that include wind load or earthquake load. The tray load for the empty condition is often significantly less than the full cable tray condition. Empty dead load shall not be included for unutilized portions of cable tray levels.
2. When applying dead loads for cable trays, consideration shall be given to unsymmetrical loading of the cable tray levels that can impact the minimum and maximum controlling cases for elements of the pipe rack and foundations.
3. Pipe racks and their foundations shall be designed to support loads associated with full utilization of the available space on cable tray levels for operating load combinations.
4. Pipe racks and their foundations shall be designed to support any specified future cable tray level expansion.

4.1.2.8 Ground-Supported Storage Tank Loads

1. Dead loads for ground-supported storage tanks are shown in Table 12 with the same nomenclature as other dead loads in this Practice for consistency.
2. The individual load components making up the dead loads may have to be separated for actual use in design in accordance with the following considerations:
   a. Operating dead load (D_o): Operating dead load consists of the weight of the tank shell, roof, insulation, platforms, piping, and attachments vertically applied through the tank shell, in addition to the fluid load from the stored product. The fluid load shall be applied directly to the floor of the tank rather than through the shell.
   b. Empty dead load (D_e): Empty dead load consists of the weight of the tank shell, roof, insulation, platforms, piping, and attachments vertically applied through the tank shell only. For checking uplift and components controlled by minimum loading, the corroded metal weight, if a corrosion allowance is specified, shall be considered for empty dead load.
   c. Test dead load (D_t): Test dead load consists of the weight of the tank shell, roof, insulation, platforms, piping, and attachments vertically applied through the tank shell, in addition to the fluid load from the test medium. The fluid load shall be applied directly to the floor of the tank rather than through the shell. The test medium shall be as specified in the contract documents or as specified by the owner. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium.

4.1.3 Live Loads (L) and Roof Live Loads (L_r)

4.1.3.1 Live loads are loads produced by the use and occupancy of the building or structure. These include the weight of all movable loads (e.g., personnel, tools, miscellaneous equipment, movable partitions, wheel loads, parts of dismantled equipment, stored material).

4.1.3.2 Areas specified for maintenance (e.g., heat exchanger tube bundle servicing) shall be designed to support the live loads.

4.1.3.3 Unless otherwise specified in Table 1, minimum live loads (L) and roof live loads (L_r) shall be in accordance with *ASCE/SEI 7-10*, Chapter 4; *IBC 2012*, Section 1607; or *IBC 2015*, Section 1607 as applicable, and other applicable codes and standards.

Table 1 - Minimum Live Loads

	Uniform	Concentrated
Stairs and Exitways	**100 psf (4.79 kN/m^2)**	1,000 lb (4.45 kN)
Operating, Access Platforms, and Walkways	**60 psf (2.87 kN/m^2)** (Framing Design) 100 psf (4.79 kN/m^2) (Grating Design)	1,000 lb (4.45 kN) (Framing and Grating Design)
Control, I/O, HVAC Room Floors	100 psf (4.79 kN/m^2)	1,000 lb (4.45 kN)
Manufacturing Floors and Storage Areas:		
Light	**125 psf (6.00 kN/m^2)**	**2,000 lb (8.90 kN)**
Heavy	**250 psf (11.97 kN/m^2)** (Note 2)	**3,000 lb (13.40 kN)**
Ground-Supported Storage Tank Roof	**20 psf (0.96 kN/m^2)**	NA

NOTES:

1. Minimum live loads shown in **bold text** are based on *ASCE/SEI 7-10*, Chapter 4; *IBC 2012*, Section 1607; or *IBC 2015*, Section 1607 as applicable.
2. This live load includes small equipment.

4.1.3.4 Uniform and concentrated live loads listed in Table 1 shall not be applied simultaneously. Use of either uniform or concentrated live loads shall be based on whichever produces the greatest load effect.

4.1.3.5 Unless otherwise specified, concentrated loads shall be assumed to be uniformly distributed over an area of 2.5 ft (762 mm) by 2.5 ft (762 mm) and shall be located so as to produce the maximum load effects in the structural members in accordance with *ASCE/SEI 7-10*, Chapter 4; *IBC 2012*, Section 1607.4; or *IBC 2015*, Section 1607.4 as applicable.

4.1.3.6 Reduction in uniform live loads shall be in accordance with *ASCE/SEI 7-10*, Sections 4.7 and 4.8; *IBC 2012*, Section 1607.10; or *IBC 2015*, Section 1607.10 as applicable.

4.1.3.7 For manufacturing floor areas not used for storage, the uniform live load reduction specified by *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable for lower live loads may be used.

4.1.3.8 Live loads for stairs and stair treads shall be in accordance with *ASCE/SEI 7-10*, Table 4-1; *IBC 2012*, Table 1607.1; or *IBC 2015*, Table 1607.1 as applicable.

4.1.3.9 Live loads on fixed ladders shall be in accordance with *ASCE/SEI 7-10*, Section 4.5.4.

4.1.3.10 Live loads on handrail and guard systems for process equipment structures shall be in accordance with *ASCE/SEI 7-10*, Section 4.5.1; *IBC 2012*, Section 1607.8.1; or *IBC 2015*, Section 1607.8.1 as applicable and *OSHA 29 CFR 1910 Subpart D*.

4.1.3.11 Live loads on handrail and guard systems for buildings and structures under the jurisdiction of a building code shall be in accordance with the applicable building code.

4.1.3.12 Live loads for cranes shall be in accordance with *ASCE/SEI 7-10*, Section 4.9; *IBC 2012*, Section 1607.13; or *IBC 2015*, Section 1607.13 as applicable.

4.1.4 Wind Loads (W)

4.1.4.1 Unless otherwise specified, wind loads shall be computed and applied in accordance with *ASCE/SEI 7-10*, Chapters 26 through 30; *IBC 2012*, Section 1609; or *IBC 2015*, Section 1609 as applicable, and the recommended guidelines in *ASCE Wind Loads for Petrochemical and Other Industrial Facilities*.

Comment: Wind loads in accordance with *ASCE/SEI 7-10*, *IBC 2012*, and *IBC 2015* are strength design (i.e., limit state) loads; whereas, wind loads in accordance with versions previous to *ASCE/SEI 7-10* and *IBC 2012* and in some codes/standards referenced by *ASCE/SEI 7-10*, *IBC 2012*, and *IBC 2015* are allowable stress design loads. This should be taken into account when applying load factors in load combinations.

4.1.4.2 Wind loads for design of Liquefied Natural Gas (LNG) facilities shall also be in accordance with *PHMSA 49 CFR 193.2067* and *NFPA 59A* as applicable.

Comment: The design wind speed of 150 mph (241 km/h) specified in *PHMSA 49 CFR 193.2067* is a sustained, 60-second wind speed. This translates to a 183 mph (295 km/h) 3-second gust wind speed for use with *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable. There are different interpretations within the industry as to whether the design wind speed specified in *PHMSA 49 CFR 193*.2067 is to be considered as an allowable stress design level or strength design level wind speed. If it is considered as an allowable stress design level wind speed, the load factors for wind should be multiplied by a factor of (1.0/0.6) for allowable stress design load combinations and a factor of (1.6/1.0) for strength design load combinations prescribed in *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable, and this Practice. If it is considered as a strength design level wind speed, the load factors for wind should remain as is for allowable stress design load combinations and strength design load combinations prescribed in *ASCE/SEI 7-10*, *IBC 2012*, or

IBC 2015 as applicable, and this Practice. See *ASCE Wind Loads for Petrochemical and Other Industrial Facilities* for additional information.

4.1.4.3 Site specific design parameters shall be in accordance with *PIP CVC01017*.

4.1.4.4 For calculating wind drift, the full design wind load shall be used . See Section 4.3.6.

4.1.4.5 Partial Wind Load (W_p)

1. Partial wind load (W_P) shall be based on the requirements of *ASCE/SEI 37-14*, Section 6.2.1, for the specified test or erection duration. The design wind speed shall be 86.3 mph (38.3 m/s) which is calculated based on a 0.75 factor times the basic wind speed of 115 mph (51 m/s) from *ASCE/SEI 7-10* in accordance with *ASCE/SEI 37-14* for test or erection periods of less than 6 weeks.
2. For test or erection periods of 6 weeks or more, or if the test or erection is in a hurricane-prone area and is planned during the peak hurricane season (i.e., from July 1 to October 31 in the U.S.), see *ASCE/SEI 37-14*, Section 6.2.1, to determine the appropriate design wind speed to be used.
3. For continuously monitored work periods, lower wind speeds may be used in accordance with *ASCE/SEI 37-14*, Section 6.2.1.2.

4.1.4.6 Non-orthogonal wind loads shall be considered where appropriate and required by *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable. For open structures, see *ASCE Wind Loads for Petrochemical and Other Industrial Facilities*.

4.1.5 Earthquake Loads (E)

4.1.5.1 Unless otherwise specified, earthquake loads shall be computed and applied in accordance with *ASCE/SEI 7-10*, Chapters 11 through 23; *IBC 2012*, Section 1613; or *IBC 2015*, Section 1613 as applicable, and the recommended guidelines in *ASCE Guidelines for Seismic Evaluation and Design of Petrochemical Facilities*.

Comment: Earthquake loads in *ASCE/SEI 7-10*, *IBC 2012*, and *IBC 2015* are strength design (limit state) loads; whereas, earthquake loads in some codes/standards referenced by *ASCE/SEI 7-10*, *IBC 2012*, and *IBC 2015* are allowable stress design loads. This should be taken into account when applying load factors in load combinations.

4.1.5.2 Earthquake loads for design of Liquefied Natural Gas (LNG) facilities shall also be in accordance with *PHMSA 49 CFR Part 193* and *NFPA 59A* as applicable.

Comment: See Federal Energy Regulatory Commission (FERC), *Draft Seismic Design Guidelines and Data Submittal Requirements for LNG Facilities* for guidance on seismic (i.e., earthquake) loads for LNG facilities.

4.1.5.3 Site specific design parameters shall be in accordance with *PIP CVC01017*.

4.1.5.4 Earthquake loading for nonbuilding structures shall be determined using *ASCE/SEI 7-10*, Chapter 15, and the recommended guidelines in *ASCE Guidelines for Seismic Evaluation and Design of Petrochemical Facilities*.

Comment: Nonbuilding structures include but are not limited to elevated tanks or vessels, stacks, pipe racks, and cooling towers.

4.1.5.5 The importance factor "I_e" for nonbuilding structures shall be determined using *ASCE/SEI 7-10*, Section 15.4.1.1.

4.1.5.6 For the load combinations in Section 4.2, the following designations are used:

E_o = Earthquake load considering the unfactored operating dead load and the applicable portion of the unfactored structure dead load

E_e = Earthquake load considering the unfactored empty dead load and the applicable portion of the unfactored structure dead load

4.1.5.7 Non-orthogonal earthquake loads shall be considered where appropriate and required by *ASCE/SEI 7-10*, *IBC 2012*, or *IBC 2015* as applicable.

4.1.6 Impact Loads

4.1.6.1 Vertical impact loads for cranes shall be in accordance with *ASCE/SEI 7-10*, Section 4.9.3; *IBC 2012*, Section 1607.13.2; or *IBC 2015*, Section 1607.13.2 as applicable.

4.1.6.2 Impact loads for davits shall be the same as those for powered, monorail cranes.

4.1.6.3 Lifting lugs or pad eyes and internal members, including both end connections, framing into the joint where the lifting lug or pad eye is located shall be designed for 100% impact.

4.1.6.4 All other structural members transmitting lifting forces shall be designed for 15% impact.

4.1.6.5 Allowable stresses shall not be increased when combining impact with dead load.

4.1.7 Thermal / Self-Straining Loads

4.1.7.1 Thermal (and/or self-straining) loads shall be designated as either sustained (T_s) or temporary (T_t)

4.1.7.2 Sustained thermal (and/or self-straining) loads (T_s) include:

a. Pipe anchor and guide forces caused by restrained dimensional changes caused by thermal expansion or contraction of piping under normal operating conditions (e.g., loads from a pipe stress analysis).

b. Restrained dimensional changes caused by thermal expansion or contraction of vertical vessels, horizontal vessels, or heat exchangers under normal operating conditions.

c. Forces on vertical vessels, horizontal vessels, or heat exchangers caused by restrained dimensional changes caused by thermal expansion or contraction of piping attached to the vessel or exchanger under normal operating conditions.

d. Restrained dimensional changes caused by thermal expansion or contraction of structural steel members in pipe racks or structures caused by sustained change in ambient temperature.

e. Restrained dimensional changes in concrete caused by moisture, shrinkage, creep, and similar effects.

f. Differential settlement of foundations.

4.1.7.3 Temporary thermal (and/or self-straining) loads (T_t) include:

a. Friction forces caused by the sliding of pipes on their supports caused by thermal expansion or contraction during startup or shutdown of piping systems.

b. Friction forces caused by the sliding of heat exchangers or horizontal vessels on their supports, caused by thermal expansion or contraction during startup or shutdown of equipment.

c. Thermal loads and displacements caused by differential temperatures between steel on one side of a structure exposed to sunlight and steel on the other side of the structure that is shaded.

4.1.7.4 Thermal loads and displacements shall be calculated as follows:

a. Loads and displacements shall be based on the difference between ambient temperature or equipment design temperature and installed temperature.

b. Ambient temperature shall be taken as the minimum ambient temperature or maximum ambient temperature as applicable to account for controlling effects of contraction or expansion.

c. To account for the significant increase in temperatures of steel exposed to sunlight, an additional 35° F (20° C) minimum shall be added to the maximum ambient temperature or as otherwise determined by engineering judgement.

4.1.7.5 The thermal (and/or self-straining) load caused by thermal expansion or contraction of horizontal vessels or exchangers (T_s or T_t) to be used for design of vessel or exchanger supports or foundations shall be the lesser of the following:

a. The force required to deflect the support or foundation pier an amount equal to half of the thermal growth between the exchanger or vessel saddles, applied as a sustained load (T_s)

b. The force required to overcome static friction at the sliding surface between the bottom of the exchanger or vessel saddle and the support or foundation pier at the sliding end of the exchanger or vessel, applied as a temporary load (T_t)

4.1.7.6 Friction forces caused by thermal expansion or contraction shall be determined using the appropriate static coefficient of friction. Coefficients of friction shall be in accordance with Table 2.

Table 2 - Coefficients of Friction

Steel to Steel	0.4
Steel to Concrete	0.6
Proprietary Sliding Surfaces or Coatings (e.g., "Teflon")	According to Manufacturer's Instructions

4.1.7.7 Because of uneven thermal strain in pipes at any given time, friction forces of individual pipes shall be assumed to be partially resisted by adjacent pipes on the same piping level. The nominal unbalanced friction load acting in the longitudinal direction on the piping level can be estimated as a percentage of the total pipe weight tributary to that piping level according to the number of pipes on the piping level as shown in Table 3.

Table 3 - Friction Load Based on Number of Pipes

Number of Pipes on Piping Level	Friction Load as a Percentage of Total Piping Weight
1	40%
2 or 3	30%
4 to 6	20%
>6	10%

4.1.7.8 The friction loads from pipes specified in Section 4.1.7.7 above are to be used for local member design only. Unless a higher load is justified, 50% of the total specified local friction loads shall be considered for global design of the pipe support system (i.e., pipe rack struts, columns, longitudinal braced frames, and foundations).

Comment: Under normal loading conditions with multiple pipes, torsional effects on the local beam need not be considered because the pipes supported by the beam limit the rotation of the beam to the extent that the torsional stresses are minimal. Under certain circumstances (e.g., large pipes), a higher friction load and/or torsional effects should be considered.

4.1.7.9 Consideration shall be given to circumstances where heavier pipes acting alone produce a larger friction load than the group of pipes associated with the heavy pipe on the same piping level. This can occur when considering 40% of the heavy pipe versus 10% of the uniformly distributed dead load of the piping on the piping level. These different friction loads can lead to different governing factors (e.g., one governing weak axis bending, and another weak axis shear).

4.1.7.10 Loading conditions can arise where the reduced percentage for friction loads for a group of pipes might be unconservative and should not be used (e.g., near expansion loops where all pipes are likely to be moving in the same direction at the same time). Engineering judgment shall be used in considering such circumstances in determining the appropriate friction loads to use for the design of the supports.

4.1.7.11 Internal pressure and surge shall be considered for pipe anchor and guide loads.

4.1.7.12 The pipe support system (i.e., pipe rack struts, columns, longitudinal braced frames, and foundations) shall be designed to resist all tributary pipe anchor and guide loads without a reduction factor as permitted for friction loads.

4.1.7.13 For local beam design, only the top flange shall be considered effective for resisting horizontal loads unless the pipe anchor engages both flanges of the beam.

4.1.8 Bundle Pull Load (Bp)

4.1.8.1 Structures and foundations supporting heat exchangers subject to bundle pulling shall be designed for a horizontal load equal to 1.0 times the weight of the removable tube bundle but not less than 2,000 lb (9.0 kN). If the total weight of the exchanger is less than 2,000 lb (9.0 kN), the bundle pull design load need not be greater than the total weight of the exchanger.

4.1.8.2 Bundle pull load shall be applied at the center of the bundle.

Comment: If it can be assured that the bundles are to be removed strictly by the use of a bundle extractor attached directly to the exchanger (i.e., the bundle pull force is not transferred to the structure or foundation), the structure or foundation need not be designed for the bundle pull force. Such assurance typically requires the addition of a sign posted on the exchanger to indicate bundle removal by an extractor only.

4.1.8.3 The portion of the bundle pull load at the sliding end support shall equal the friction force or half the total bundle pull load, whichever is less. The remainder of the bundle pull load shall be resisted at the anchor end support.

4.1.9 Traffic Loads

4.1.9.1 Building floors, bridges, trenches, and underground installations accessible to truck loading shall be designed to withstand HS20 load as defined by *AASHTO Standard Specifications for Highway Bridges* as a minimum or more severe traffic loads where applicable.

4.1.9.2 Forklift, maintenance, or construction crane loads shall also be considered where applicable.

4.1.9.3 Truck or crane loads shall have the same load factor as live load.

4.1.10 Blast Load

4.1.10.1 Blast load is the load on a structure caused by overpressure resulting from the ignition and explosion of flammable material or by overpressure resulting from a vessel burst.

4.1.10.2 Control houses or other buildings housing personnel and control equipment near processing plants may need to be designed for blast resistance.

4.1.10.3 Blast load shall be computed and applied in accordance with *PIP STC01018* and the *ASCE Design of Blast-Resistant Buildings in Petrochemical Facilities*.

4.1.11 Pressure Loads (Ground-Supported Tanks Only)

Pressure loads for ground-supported tanks are designated by the following nomenclature:

P_i, P_e, and P_t, where:

P_i = design internal pressure

P_e = external pressure

P_t = test internal pressure

4.1.12 Snow Loads (S)

4.1.12.1 Unless otherwise specified, snow loads shall be computed and applied in accordance with *ASCE/SEI 7-10*, Chapter 7; *IBC 2012*, Section 1608; or *IBC 2015*, Section 1608 as applicable, and the recommended guidelines in *Snow Loads on Non-Building Structures*.

4.1.12.2 Site specific design parameters shall be in accordance with *PIP CVC01017*.

4.2 Load Combinations

4.2.1 General

Buildings, structures, and supports and foundations for equipment, vessels, and tanks, shall be designed for all of the following:

a. Appropriate load combinations in accordance with *ASCE/SEI 7-10*, Chapter 2; *IBC 2012*, Section 1605; or *IBC 2015*, Section 1605 as applicable

b. Load combinations specified in this Practice adapted from *ASCE/SEI 7-10*, Chapter 2; *IBC 2012*, Section 1605; or *IBC 2015*, Section 1605 as applicable, and *API Standard 650* for process industries application

c. Local building codes mandated by the AHJ of the facility

d. Any other applicable design codes and standards mandated by the AHJ of the facility

e. Other loads and load combinations specified by the engineer of record

4.2.2 Typical Load Combinations (for Buildings, Structures and Foundations)

4.2.2.1 General

1. Load combinations are provided in Sections 4.2.2.2 through 4.2.2.6 for specific types of buildings, structures and foundations in both allowable stress design and strength design format.
2. Allowable Stress Design
   a. The noncomprehensive list of typical load combinations for each type of structure provided in Sections 4.2.2.2 through 4.2.2.6 shall be considered and used as applicable.
   b. Engineering judgment shall be used in establishing all appropriate load combinations.
   c. The allowable stress design load combinations in Sections 4.2.2.2 through 4.2.2.6 are appropriate for use with the allowable strength design (ASD) provisions of *ANSI/AISC 360*.
   d. The use of a one-third stress increase for load combinations including wind or earthquake loads shall not be permitted for designs using ASD provisions of *ANSI/AISC 360*.
   e. Sustained and temporary thermal (and/or self-straining) loads (T_s and T_t) are included and factored in load combinations based on *ASCE/SEI 7-10*, Commentary Section C2.4.4. Temporary thermal (and/or self-straining) loads (T_t) are not included in load combinations that include wind or earthquake loads.
3. Strength Design
   a. The noncomprehensive list of typical factored load combinations for each type of structure provided in Sections 4.2.2.2 through 4.2.2.6 shall be considered and used as applicable.
   b. Engineering judgment shall be used in establishing all appropriate load combinations.
   c. The strength design load combinations in Sections 4.2.2.2 through 4.2.2.6 are appropriate for use with strength design provisions of *ACI 318 / ACI 318M* and load and resistance factor design (LRFD) provisions of *ANSI/AISC 360*.
   d. Sustained and temporary thermal (and/or self-straining) loads (T_s and T_t) are included and factored in load combinations based on *ASCE/SEI 7-10*, Commentary Section C2.3.5. Temporary thermal (and/or self-straining) loads (T_t) are not included in load combinations that include wind or earthquake loads.

4.2.2.2 Buildings and Open Frame Structures

Load combinations for buildings and open frame structures are shown in the following tables:

a. For Allowable Stress Design, Table 4

b. For Strength Design, Table 5

Table 4 - Buildings and Open Frame Structures
Allowable Stress Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Buildings and Open Frame Structures Specific Load Combination**	**Description**
1	D	4-1.1	$D_s + D_o + T_s$	Operating Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement)
		4-1.2	$D_s + D_o + T_s + T_t$	Operating Weight + Sustained Thermal + Temporary Thermal
		4-1.3	$D_s + D_t^a + T_s^b + T_t^c$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c]
2	D + L	4-2.1	$D_s + D_o + T_s + L$	Operating Weight + Sustained Thermal + Live
		4-2.2	$D_s + D_t^a + T_s^b + L$	Test Weight[a] + Sustained Thermal[b] + Live
3	D + (L_r or S or R)	4-3.1	$D_s + D_o + T_s + (L_r^d$ or S or $R^d)$	Operating Weight + Sustained Thermal + (Roof Live[d] or Snow or Rain[d])
		4-3.2	$D_s + D_t^a + T_s^b + (L_r^d$ or S or $R^d)^e$	Test Weight[a] + Sustained Thermal[b] + (Roof Live[d] or Snow or Rain[d])[e]
4	D + 0.75 L + 0.75 (L_r or S or R)	4-4.1	$D_s + D_o + T_s + 0.75\ T_t +$ $0.75\ L + 0.75\ (L_r^d$ or S or $R^d)$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[d] or Snow or Rain[d])
		4-4.2	$D_s + D_t^a + T_s^b + 0.75\ T_t^c +$ $0.75\ L + 0.75\ (L_r^d$ or S or $R^d)^e$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] + Live + (Roof Live[d] or Snow or Rain[d])[e]
5	D + (0.6 W or 0.7 E)	4-5.1	$D_s + D_o + T_s + 0.6\ W$	Operating Weight + Sustained Thermal + Wind
		4-5.2	$D_s + D_o + T_s + 0.7\ E_o$	Operating Weight + Sustained Thermal + Earthquake
		4-5.3	$D_s + D_t^a + T_s^b + 0.6\ W_p$	Test Weight[a] + Sustained Thermal[b] + Partial Wind

Table 4 - Buildings and Open Frame Structures
Allowable Stress Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Buildings and Open Frame Structures Specific Load Combination**	**Description**
6a	D + 0.75 L + 0.75 (0.6 W) + 0.75 (L_r or S or R)	4-6a.1	$D_s + D_o + T_s$ + 0.75 L + 0.75 (0.6 W) + 0.75 (L_r[d] or S or R[d])	Operating Weight + Sustained Thermal + Live + Wind + (Roof Live[d] or Snow or Rain[d])
		4-6a.2	$D_s + D_t$[a] + T_s[b] + 0.75 L + 0.75 (0.6 W_p) + 0.75 (L_r[d] or S or R[d])[e]	Test Weight[a] + Sustained Thermal[b] + Live + Partial Wind + (Roof Live[d] or Snow or Rain[d])[e]
6b	D + 0.75 L + 0.75 (0.7 E) + 0.75 S	4-6b	$D_s + D_o + T_s$ + 0.75 L + 0.75 (0.7 E_o) + 0.75 S	Operating Weight + Sustained Thermal + Live + Earthquake + Snow
7	0.6 D + 0.6 W	4-7.1	0.6 ($D_s + D_e$) + T_s[f,g] + 0.6 W	Empty Weight + Sustained Thermal[f,g] + Wind (Wind Uplift Case)
		4-7.2	0.6 ($D_s + D_o$) + T_s[g] + 0.6 W	Operating Weight + Sustained Thermal[g] + Wind (Sustained Thermal and Wind Uplift Case)
8	0.6 D + 0.7 E	4-8.1	0.6 ($D_s + D_e$) + T_s[f,g] + 0.7 E_e	Empty Weight + Sustained Thermal[f,g] + Earthquake (Earthquake Uplift Case)
		4-8.2	0.6 ($D_s + D_o$) + T_s[g] + 0.7 E_o[h]	Operating Weight + Sustained Thermal[g] + Earthquake[h] (Sustained Thermal and Earthquake Uplift Case)

NOTES:

a. Load combinations 4-1.3, 4-2.2, 4-3.2, 4-4.2, 4-5.3, and 4-6a.2 normally are required only for local member design because hydrotesting is not typically performed on all pipes and equipment simultaneously.
b. For load combinations 4-1.3, 4-2.2, 4-3.2, 4-4.2, 4-5.3, and 4-6a.2, only T_s loads expected during hydrotesting period shall be considered.
c. For load combinations 4-1.3 and 4-4.2, only T_t loads expected during hydrotesting period shall be considered.
d. L_r and R do not apply to open frame structures with no roof.
e. For load combinations 4-3.2, 4-4.2, and 4-6a.2, roof live load, snow load or rain load can be excluded if it is determined that those loads cannot be present during the hydrotesting period.
f. For load combinations 4-7.1 and 4-8.1, only T_s loads expected during empty dead load condition shall be considered.
g. For load combinations 4-7.1, 4-7.2, 4-8.1 and 4-8.2 (uplift cases), load factor for T_s (from piping) shall be 0.6 if the load contributes to the resisting forces and 1.0 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be 1.0.
h. For load combination 4-8.2, full $D_s + D_o$ value shall be used for the calculation of E_o.

Table 5 - Buildings and Open Frame Structures
Strength Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Buildings and Open Frame Structures Specific Load Combination**	**Description**
1	1.4 D	5-1.1	$1.4\ (D_s + D_o) + 1.2\ T_s$	Operating Weight + Sustained Thermal
		5-1.2	$1.4\ (D_s + D_t^a) + 1.2\ T_s^b$	Test Weight[a] + Sustained Thermal[b]
2	1.2 D + 1.6 L + 0.5 (L_r or S or R)	5-2.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[c] or Snow or Rain[c])
		5-2.2	$1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ T_t^d + 1.6\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)^e$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + Live + (Roof Live[c] or Snow or Rain[c])[e]
3	1.2 D + 1.6 (L_r or S or R) + (L or 0.5 W)	5-3.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ (L_r^c \text{ or } S \text{ or } R^c) + 0.5\ L^f$	Operating Weight + Sustained Thermal + Temporary Thermal + (Roof Live[c] or Snow or Rain[c]) + Live[f]
		5-3.2	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.6\ (L_r^c \text{ or } S \text{ or } R^c) + 0.5\ W$	Operating Weight + Sustained Thermal + (Roof Live[c] or Snow or Rain[c]) + Wind
		5-3.3	$1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ T_t^d + 1.6\ (L_r^c \text{ or } S \text{ or } R^c)^e + 0.5\ L^f$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + (Roof Live[c] or Snow or Rain[c])[e] + Live[f]
		5-3.4	$1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.6\ (L_r^c \text{ or } S \text{ or } R^c)^e + 0.5\ W$	Test Weight[a] + Sustained Thermal[b] + (Roof Live[c] or Snow or Rain[c])[e] + Wind
4	1.2 D + 1.0 W + L + 0.5 (L_r or S or R)	5-4.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ W + 0.5\ L^f + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)$	Operating Weight + Sustained Thermal + Wind + Live[f] + (Roof Live Load[c] or Snow or Rain[c])
		5-4.2	$1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ W_p + 0.5\ L^f + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)^e$	Test Weight[a] + Sustained Thermal[b] + Partial Wind + Live[f] + (Roof Live[c] or Snow or Rain[c])[e]
5	1.2 D + 1.0 E + L + 0.2 S	5-5	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ E_o + 0.5\ L^f + 0.2\ S$	Operating Weight + Sustained Thermal + Earthquake + Live[f] + Snow
6	0.9 D + 1.0 W	5-6.1	$0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ W$	Empty Weight + Sustained Thermal[g,h] + Wind (Wind Uplift Case)
		5-6.2	$0.9\ (D_s + D_o) + 1.2\ T_s^h + 1.0\ W$	Operating Weight + Sustained Thermal[h] + Wind (Wind Uplift Case)

Table 5 - Buildings and Open Frame Structures
Strength Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Buildings and Open Frame Structures Specific Load Combination**	**Description**
7	0.9 D + 1.0 E	5-7.1	$0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ E_e$	Empty Weight + Sustained Thermal[g,h] + Earthquake (Earthquake Uplift Case)
		5-7.2	$0.9\ (D_s + D_o) + 1.2\ T_s^{h} + 1.0\ E_o^{i}$	Operating Weight + Sustained Thermal[h] + Earthquake[i] (Earthquake Uplift Case)
N/A[j]	N/A[j]	5-8.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.2\ T_t + 0.5\ L + 0.5\ (L_r^{c}$ or S or $R^{c})$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[c] or Snow or Rain[c])
		5-8.2	$1.2\ (D_s + D_t^{a}) + 1.2\ T_s^{b} + 1.2\ T_t^{d} + 0.5\ L + 0.5\ (L_r^{c}$ or S or $R^{c})^{e}$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + Live + (Roof Live[c] or Snow or Rain[c])[e]

NOTES:

a. Load combinations 5-1.2, 5-2.2, 5-3.3, 5-3.4, 5-4.2, and 5-8.2 normally are required only for local member design because hydrotesting is not typically performed on all pipes and equipment simultaneously.
b. For load combinations 5-1.2, 5-2.2, 5-3.3, 5-3.4, 5-4.2, and 5-8.2, only T_s loads expected during hydrotesting period shall be considered.
c. L_r and R do not apply to open frame structures with no roof.
d. For load combinations 5-2.2, 5-3.3, and 5-8.2, only T_t loads expected during hydrotesting period shall be considered.
e. For load combinations 5-2.2, 5-3.3, 5-3.4, 5-4.2, and 5-8.2, roof live load, snow load or rain load can be excluded if it is determined that those loads cannot be present during the hydrotesting period.
f. For load combinations 5-3.1, 5-3.3, 5-4.1, 5-4.2, and 5-5, the 0.5 load factor on L is permitted for L = 100 psf or less. For L > 100 psf, load factor on L in these combinations shall be 1.0.
g. For load combinations 5-6.1 and 5-7.1, only T_s loads expected during empty dead load condition shall be considered.
h. For load combinations 5-6.1, 5-6.2, 5-7.1 and 5-7.2 (uplift cases), load factor for T_s (from piping) shall be 0.9 if the load contributes to the resisting forces and 1.2 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be the same as the load factor for the dead load.
i. For load combination 5-7.2, full $D_s + D_o$ value shall be used for the calculation of E_o.
j. Load combinations 5-8.1 and 5-8.2 are based on *ASCE/SEI 7-10*, Commentary Section C2.3.5.

4.2.2.3 Vertical Vessel Supports and Foundations

Load combinations for vertical vessel supports and foundations are shown in the following tables:

a. For Allowable Stress Design, Table 6

b. For Strength Design, Table 7

Table 6 - Vertical Vessel Supports and Foundations
Allowable Stress Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Vertical Vessel Supports and Foundations Specific Load Combination**	**Description**
1	D	6-1.1	$D_s + D_o + T_s$	Operating Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement)
		6-1.2	$D_s + D_o + T_s + T_t$	Operating Weight + Sustained Thermal + Temporary Thermal
		6-1.3	$D_s + D_t + T_s^a + T_t^b$	Test Weight + Sustained Thermal[a] + Temporary Thermal[b]
2	D + L	6-2.1	$D_s + D_o + T_s + L$	Operating Weight + Sustained Thermal + Live
		6-2.2	$D_s + D_t + T_s^a + L$	Test Weight + Sustained Thermal[a] + Live
3	D + (L_r or S or R)	6-3.1	$D_s + D_o + T_s + S$	Operating Weight + Sustained Thermal + Snow
		6-3.2	$D_s + D_t + T_s^a + S^c$	Test Weight + Sustained Thermal[a] + Snow[c]
4	D + 0.75 L + 0.75 (L_r or S or R)	6-4.1	$D_s + D_o + T_s + 0.75\ T_t + 0.75\ L + 0.75\ S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + Snow
		6-4.2	$D_s + D_t + T_s^a + 0.75\ T_t^b + 0.75\ L + 0.75\ S^c$	Test Weight + Sustained Thermal[a] + Temporary Thermal[b] + Live + Snow[c]

Table 6 - Vertical Vessel Supports and Foundations
Allowable Stress Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Vertical Vessel Supports and Foundations Specific Load Combination**	**Description**
5	D + (0.6 W or 0.7 E)	6-5.1	$D_s + D_o + T_s + 0.6\ W$	Operating Weight + Sustained Thermal + Wind
		6-5.2	$D_s + D_o + T_s + 0.7\ E_o$[d]	Operating Weight + Sustained Thermal + Earthquake[d]
		6-5.3	$D_s + D_t + T_s$[a] $+ 0.6\ W_p$	Test Weight + Sustained Thermal[a] + Partial Wind
6a	D + 0.75 L + 0.75 (0.6 W) + 0.75 (L_r or S or R)	6-6a.1	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.6\ W) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Wind + Snow
		6-6a.2	$D_s + D_t + T_s$[a] $+ 0.75\ L + 0.75\ (0.6\ W_p) + 0.75\ S$[c]	Test Weight + Sustained Thermal[a] + Live + Partial Wind + Snow[c]
6b	D + 0.75 L + 0.75 (0.7 E) + 0.75 S	6-6b	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.7\ E_o$[d]$) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Earthquake[d] + Snow
7	0.6 D + 0.6 W	6-7.1	$0.6\ (D_s + D_f$[e]$) + 0.6\ W_p$	Erection Weight[e] + Partial Wind (Wind Uplift Case)
		6-7.2	$0.6\ (D_s + D_e) + T_s$[f,g] $+ 0.6\ W$	Empty Weight + Sustained Thermal[f,g] + Wind (Wind Uplift Case)
		6-7.3	$0.6\ (D_s + D_o) + T_s$[g] $+ 0.6\ W$	Operating Weight + Sustained Thermal[g] + Wind (Wind Uplift Case)
8	0.6 D + 0.7 E	6-8.1	$0.6\ (D_s + D_e) + T_s$[f,g] $+ 0.7\ E_e$[d]	Empty Weight + Sustained Thermal[f,g] + Earthquake[d] (Earthquake Uplift Case)
		6-8.2	$0.6\ (D_s + D_o) + T_s$[g] $+ 0.7\ E_o$[d,h]	Operating Weight + Sustained Thermal[g] + Earthquake[d,h] (Earthquake Uplift Case)

Table 6 - Vertical Vessel Supports and Foundations
Allowable Stress Design Load Combinations (Continued)

NOTES:

a. For load combinations 6-1.3, 6-2.2, 6-3.2, 6-4.2, 6-5.3, and 6-6a.2, only T_s loads expected during hydrotesting period shall be considered.

b. For load combinations 6-1.3 and 6-4.2, only T_t loads expected during hydrotesting period shall be considered.

c. For load combinations 6-3.2, 6-4.2, and 6-6a.2, snow load can be excluded if it is determined that this load cannot be present during the hydrotesting period.

d. For skirt-supported vertical vessels and skirt-supported elevated tanks classified as Risk Category IV in accordance with Section 1.5 and Table 1.5-1 of *ASCE/SEI 7-10*, the critical earthquake provisions and implied load combination of Section 15.7.10.5 of *ASCE/SEI 7-10* shall be followed.

e. Load combination 6-7.1 is required only if the erection weight of the vessel is significantly less than the empty weight of the vessel.

f. For load combinations 6-7.2 and 6-8.1, only T_s loads expected during empty dead load condition shall be considered.

g. For load combinations 6-7.2, 6-7.3, 6-8.1 and 6-8.2 (uplift cases), load factor for T_s (from piping) shall be 0.6 if the load contributes to the resisting forces and 1.0 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be 1.0.

h. For load combination 6-8.2, full $D_s + D_o$ value shall be used for the calculation of E_o.

i. Load combinations 6-7.1, 6-7.2, 6-7.3, 6-8.1, and 6-8.2 address an overturning condition for foundation design. They do not apply to design of anchorage (if any) to the foundation.

j. Roof live and rain are not included in this table because they do not apply to vertical vessels.

Table 7 - Vertical Vessel Supports and Foundations
Strength Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Vertical Vessel Supports and Foundations Specific Load Combination**	**Description**
1	1.4 D	7-1.1	$1.4\ (D_s + D_o) + 1.2\ T_s$	Operating Weight + Sustained Thermal
		7-1.2	$1.4\ (D_s + D_t) + 1.2\ T_s$[a]	Test Weight + Sustained Thermal[a]
2	1.2 D + 1.6 L + 0.5 (L_r or S or R)	7-2.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ L + 0.5\ S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live Load + Snow
		7-2.2	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.0\ T_t$[b] $+ 1.6\ L + 0.5\ S$[c]	Test Weight + Sustained Thermal[a] + Temporary Thermal[b] + Live + Snow[c]
3	1.2 D + 1.6 (L_r or S or R) + (L or 0.5 W)	7-3.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ S + 0.5\ L$[d]	Operating Weight + Sustained Thermal + Temporary Thermal + Snow + Live[d]
		7-3.2	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.6\ S + 0.5\ W$	Operating Weight + Sustained Thermal + Snow + Wind
		7-3.3	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.0\ T_t$[b] $+ 1.6\ S$[c] $+ 0.5\ L$[d]	Test Weight + Sustained Thermal[a] + Temporary Thermal[b] + Snow[c] + Live[d]
		7-3.4	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.6\ S$[c] $+ 0.5\ W$	Test Weight + Sustained Thermal[a] + Snow[c] + Wind
4	1.2 D + 1.0 W + L + 0.5 (L_r or S or R)	7-4.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ W + 0.5\ L$[d] $+ 0.5\ S$	Operating Weight + Sustained Thermal + Wind + Live[d] + Snow
		7-4.2	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.0\ W_p + 0.5\ L$[d] $+ 0.5\ S$[c]	Test Weight + Sustained Thermal[a] + Partial Wind + Live[d] + Snow[c]
5	1.2 D + 1.0 E + L + 0.2 S	7-5	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ E_o$[e] $+ 0.5\ L$[d] $+ 0.2\ S$	Operating Weight + Sustained Thermal + Earthquake[e] + Live[d] + Snow
6	0.9 D + 1.0 W	7-6.1	$0.9\ (D_s + D_f$[f]$) + 1.0\ W_p$	Erection Weight[f] + Partial Wind (Wind Uplift Case)
		7-6.2	$0.9\ (D_s + D_e) + 1.2\ T_s$[g,h] $+ 1.0\ W$	Empty Weight + Sustained Thermal[g,h] + Wind (Wind Uplift Case)
		7-6.3	$0.9\ (D_s + D_o) + 1.2\ T_s$[h] $+ 1.0\ W$	Operating Weight + Sustained Thermal[h] + Wind (Wind Uplift Case)

Table 7 - Vertical Vessel Supports and Foundations
Strength Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Vertical Vessel Supports and Foundations Specific Load Combination**	**Description**
7	0.9 D + 1.0 E	7-7.1	$0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ E_e^{e}$	Empty Weight + Sustained Thermal[g,h] + Earthquake[e] (Earthquake Uplift Case)
		7-7.2	$0.9\ (D_s + D_o) + 1.2\ T_s^{h} + 1.0\ E_o^{e,i}$	Operating Weight + Sustained Thermal[h] + Earthquake[e,i] (Earthquake Uplift Case)
N/A[j]	N/A[j]	7-8.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.2\ T_t + 0.5\ L + 0.5\ S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + Snow
		7-8.2	$1.2\ (D_s + D_t) + 1.2\ T_s^{a} + 1.2\ T_t^{b} + 0.5\ L + 0.5\ S^{c}$	Test Weight + Sustained Thermal[a] + Temporary Thermal[b] + Live + Snow[c]

NOTES:

a. For load combinations 7-1.2, 7-2.2, 7-3.3, 7-3.4, 7-4.2, and 7-8.2, only T_s loads expected during hydrotesting period shall be considered.
b. For load combinations 7-2.2, 7-3.3 and 7-8.2, only T_t loads expected during hydrotesting period shall be considered.
c. For load combinations 7-2.2, 7-3.3, 7-3.4, 7-4.2, and 7-8.2, snow load can be excluded if it is determined that this load cannot be present during the hydrotesting period.
d. For load combinations 7-3.1, 7-3.3, 7-4.1, 7-4.2, and 7-5, the 0.5 load factor on L is permitted for L = 100 psf or less. For L > 100 psf, load factor on L in these combinations shall be 1.0.
e. For skirt-supported vertical vessels and skirt-supported elevated tanks classified as Risk Category IV in accordance with Section 1.5 and Table 1.5-1 of *ASCE/SEI 7-10*, the critical earthquake provisions and implied load combination of Section 15.7.10.5 of *ASCE/SEI 7-10* shall be followed.
f. Load combination 7-6.1 is required only if the erection weight of the vessel is significantly less than the empty weight of the vessel.
g. For load combinations 7-6.2 and 7-7.1, only T_s loads expected during empty dead load condition shall be considered.
h. For load combinations 7-6.2, 7-6.3, 7-7.1 and 7-7.2 (uplift cases), load factor for T_s (from piping) shall be 0.9 if the load contributes to the resisting forces and 1.2 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be the same as the load factor for the dead load.
i. For load combination 7-7.2, full $D_s + D_o$ value shall be used for the calculation of E_o.
j. Load combinations 7-8.1 and 7-8.2 are based on *ASCE/SEI 7-10*, Commentary Section C2.3.5.
k. Roof live and rain are not included in this table because they do not apply to vertical vessels.

4.2.2.4 Horizontal Vessel and Heat Exchanger Supports and Foundations

Load combinations for vessels and heat exchanger supports and foundations are shown in the following tables:

a. For Allowable Stress Design, Table 8

b. For Strength Design, Table 9

Table 8 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Allowable Stress Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Horizontal Vessel / Heat Exchanger Supports and Foundations Specific Load Combination**	**Description**
1	D	8-1.1	$D_s + D_o + T_s$	Operating Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement)
		8-1.2	$D_s + D_o + T_s^a + T_t^a$	Operating Weight + Sustained Thermal[a] + Temporary Thermal[a]
		8-1.3	$D_s + D_t + T_s^b + T_t^c$	Test Weight + Sustained Thermal[b] + Temporary Thermal[c] (For Horizontal Vessels Only)
2	D + L	8-2.1	$D_s + D_o + T_s + L$	Operating Weight + Sustained Thermal + Live
		8-2.2	$D_s + D_t + T_s^b + L$	Test Weight + Sustained Thermal[b] + Live (For Horizontal Vessels only)
3	D + (L_r or S or R)	8-3.1	$D_s + D_o + T_s + S$	Operating Weight + Sustained Thermal + Snow
		8-3.2	$D_s + D_t + T_s^b + S^d$	Test Weight + Sustained Thermal[b] + Snow[d] (For Horizontal Vessels only)
4	D + 0.75 L + 0.75 (L_r or S or R)	8-4.1	$D_s + D_o + T_s^a + 0.75\ T_t^a + 0.75\ L + 0.75\ S$	Operating Weight + Sustained Thermal[a] + Temporary Thermal[a] + Live + Snow
		8-4.2	$D_s + D_t + T_s^b + 0.75\ T_t^c + 0.75\ L + 0.75\ S^d$	Test Weight + Sustained Thermal[b] + Temporary Thermal[c] + Live + Snow[d] (For Horizontal Vessels Only)

Table 8 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Allowable Stress Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Horizontal Vessel / Heat Exchanger Supports and Foundations Specific Load Combination**	**Description**
5	D + (0.6 W or 0.7 E)	8-5.1	$D_s + D_o + T_s + 0.6\ W$	Operating Weight + Sustained Thermal + Wind
		8-5.2	$D_s + D_o + T_s + 0.7\ E_o$	Operating Weight + Sustained Thermal + Earthquake
		8-5.3	$D_s + D_t + T_s^b + 0.6\ W_p$	Test Weight + Sustained Thermal[b] + Partial Wind (For Horizontal Vessels Only)
6a	D + 0.75 L + 0.75 (0.6 W) + 0.75 (L_r or S or R)	8-6a.1	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.6\ W) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Wind + Snow
		8-6a.2	$D_s + D_t + T_s^b + 0.75\ L + 0.75\ (0.6\ W_p) + 0.75\ S^d$	Test Weight + Sustained Thermal[b] + Live + Partial Wind + Snow[d] (For Horizontal Vessels only)
6b	D 0.75 L + 0.75 (0.7 E) + 0.75 S	8-6b	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.7\ E_o) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Earthquake + Snow
7	0.6 D + 0.6 W	8-7.1	$0.6\ (D_s + D_f^e) + 0.6\ W_p$	Erection Weight[e] + Partial Wind (Wind Uplift Case)
		8-7.2	$0.6\ (D_s + D_e) + T_s^{f,g} + 0.6\ W$	Empty Weight + Sustained Thermal[f,g] + Wind (Wind Uplift Case)
		8-7.3	$0.6\ (D_s + D_o) + T_s^g + 0.6\ W$	Operating Weight + Sustained Thermal[g] + Wind (Wind Uplift Case)
8	0.6 D + 0.7 E	8-8.1	$0.6\ (D_s + D_e) + T_s^{f,g} + 0.7\ E_e$	Empty Weight + Sustained Thermal[f,g] + Earthquake (Earthquake Uplift Case)
		8-8.2	$0.6\ (D_s + D_o) + T_s^g + 0.7\ E_o^h$	Operating Weight + Sustained Thermal[g] + Earthquake[h] (Earthquake Uplift Case)
N/A	N/A	8-9	$D_s + D_e^i + Bp$	Empty Weight[i] + Bundle Pull (For Heat Exchangers Only)
N/A	N/A	8-10	$0.6\ (D_s + D_e^i) + Bp$	Empty Weight[i] + Bundle Pull (Bundle Pull Uplift Case) (For Heat Exchangers Only)

Table 8 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Allowable Stress Design Load Combinations (Continued)

NOTES:

a. For load combinations 8-1.2 and 8-4.1, thermal load for heat exchangers and horizontal vessels shall be the lesser of T_s or T_t as specified in Section 4.1.7.5 of this Practice.
b. For load combinations 8-1.3, 8-2.2, 8-3.2, 8-4.2, 8-5.3, and 8-6a.2, only T_s loads expected during hydrotesting period shall be considered.
c. For load combinations 8-1.3 and 8-4.2, only T_t loads expected during hydrotesting period shall be considered.
d. For load combinations 8-3.2, 8-4.2, and 8-6a.2, snow load can be excluded if it is determined that this load cannot be present during the hydrotesting period.
e. Load combination 8-7.1 is required only if the erection weight of the vessel is significantly less than the empty weight of the vessel.
f. For load combinations 8-7.2 and 8-8.1, only T_s loads expected during empty dead load condition shall be considered.
g. For load combinations 8-7.2, 8-7.3, 8-8.1 and 8-8.2 (uplift cases), load factor for T_s (from piping) shall be 0.6 if the load contributes to the resisting forces and 1.0 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be 1.0.
h. For load combination 8-8.2, full $D_s + D_o$ value shall be used for the calculation of E_o.
i. For load combinations 8-9 and 8-10, a reduced empty dead load shall be used for heat exchangers during bundle pull due to the removal of the bundle head.
j. Roof live and rain are not included in this table because they do not apply to horizontal vessels and heat exchangers.

Table 9 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Strength Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Horizontal Vessel / Heat Exchanger Supports and Foundations Specific Load Combination**	**Description**
1	1.4 D	9-1.1	$1.4\ (D_s + D_o) + 1.2\ T_s$	Operating Weight + Sustained Thermal
		9-1.2	$1.4\ (D_s + D_t) + 1.2\ T_s$[a]	Test Weight + Sustained Thermal[a] (For Horizontal Vessels Only)
2	1.2 D + 1.6 L + 0.5 (L_r or S or R)	9-2.1	$1.2\ (D_s + D_o) + 1.2\ T_s$[b] $+ 1.0\ T_t$[b] $+$ 1.6 L + 0.5 S	Operating Weight + Sustained Thermal[b] + Temporary Thermal[b] + Live + Snow
		9-2.2	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.0\ T_t$[c] $+$ 1.6 L + 0.5 S[d]	Test Weight + Sustained Thermal[a] + Temporary Thermal[c] + Live + Snow[d] (For Horizontal Vessels Only)
3	1.2 D + 1.6 (L_r or S or R) + (L or 0.5 W)	9-3.1	$1.2\ (D_s + D_o) + 1.2\ T_s$[b] $+ 1.0\ T_t$[b] $+$ 1.6 S + 0.5 L[e]	Operating Weight + Sustained Thermal[b] + Temporary Thermal[b] + Snow + Live[e]
		9-3.2	$1.2\ (D_s + D_o) + 1.2\ T_s +$ 1.6 S + 0.5 W	Operating Weight + Sustained Thermal + Snow + Wind
		9-3.3	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+ 1.0\ T_t$[c] $+$ 1.6 S[d] + 0.5 L[e]	Test Weight + Sustained Thermal[a] + Temporary Thermal[c] + Snow[d] + Live[e] (For Horizontal Vessels Only)
		9-3.4	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+$ 1.6 S[d] + 0.5 W	Test Weight + Sustained Thermal[a] + Snow[d] + Wind (For Horizontal Vessels Only)
4	1.2 D + 1.0 W + L + 0.5 (L_r or S or R)	9-4.1	$1.2\ (D_s + D_o) + 1.2\ T_s +$ 1.0 W + 0.5 L[e] + 0.5 S	Operating Weight + Sustained Thermal + Wind + Live[e] + Snow
		9-4.2	$1.2\ (D_s + D_t) + 1.2\ T_s$[a] $+$ 1.0 W_p + 0.5 L[e] + 0.5 S[d]	Test Weight + Sustained Thermal[a] + Partial Wind + Live[e] + Snow[d] (For Horizontal Vessels Only)
5	1.2 D + 1.0 E + L + 0.2 S	9-5	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ E_o +$ 0.5 L[e] + 0.2 S	Operating Weight + Sustained Thermal + Earthquake + Live[e] + Snow

Table 9 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Strength Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Horizontal Vessel / Heat Exchanger Supports and Foundations Specific Load Combination**	**Description**
6	0.9 D + 1.0 W	9-6.1	$0.9\ (D_s + D_f^{f}) + 1.0\ W_p$	Erection Weight[f] + Partial Wind (Wind Uplift Case)
		9-6.2	$0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ W$	Empty Weight + Sustained Thermal[g,h] + Wind (Wind Uplift Case)
		9-6.3	$0.9\ (D_s + D_o) + 1.2\ T_s^{h} + 1.0\ W$	Operating Weight + Sustained Thermal[h] + Wind (Wind Uplift Case)
7	0.9 D + 1.0 E	9-7.1	$0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ E_e$	Empty Weight + Sustained Thermal[g,h] + Earthquake (Earthquake Uplift Case)
		9-7.2	$0.9\ (D_s + D_o) + 1.2\ T_s^{h} + 1.0\ E_o^{i}$	Operating Weight + Sustained Thermal[h] + Earthquake[i] (Earthquake Uplift Case)
N/A[k]	N/A[k]	9-8.1	$1.2\ (D_s + D_o) + 1.2\ T_s^{b} + 1.2\ T_t^{b} + 0.5\ L + 0.5\ S$	Operating Weight + Sustained Thermal[b] + Temporary Thermal[b] + Live + Snow
		9-8.2	$1.2\ (D_s + D_t) + 1.2\ T_s^{a} + 1.2\ T_t^{c} + 0.5\ L + 0.5\ S^{d}$	Test Weight + Sustained Thermal[a] + Temporary Thermal[c] + Live + Snow[d] (For Horizontal Vessels Only)
N/A	N/A	9-9	$1.2\ (D_s + D_e^{j}) + 1.6\ Bp$	Empty Weight[j] + Bundle Pull (For Heat Exchangers Only)
N/A	N/A	9-10	$0.9\ (D_s + D_e^{j}) + 1.6\ Bp$	Empty Weight[j] + Bundle Pull (Bundle Pull Uplift Case) (For Heat Exchangers Only)

Table 9 - Horizontal Vessel and Heat Exchanger Supports and Foundations
Strength Design Load Combinations (Continued)

NOTES:

a. For load combinations 9-1.2, 9-2.2, 9-3.3, 9-3.4, 9-4.2, and 9-8.2, only T_s loads expected during hydrotesting period shall be considered.
b. For load combinations 9-2.1, 9-3.1 and 9-8.1, thermal load for heat exchangers and horizontal vessels shall be the lesser of T_s or T_t as specified in Section 4.1.7.5 of this Practice.
c. For load combinations 9-2.2, 9-3.3 and 9-8.2, only T_t loads expected during hydrotesting period shall be considered.
d. For load combinations 9-2.2, 9-3.3, 9-3.4, 9-4.2, and 9-8.2, snow load can be excluded if it is determined that this load cannot be present during the hydrotesting period.
e. For load combinations 9-3.1, 9-3.3, 9-4.1, 9-4.2, and 9-5, the 0.5 load factor on L is permitted for L = 100 psf or less. For L > 100 psf, load factor on L in these combinations shall be 1.0.
f. Load combination 9-6.1 is required only if the erection weight of the vessel is significantly less than the empty weight of the vessel.
g. For load combinations 9-6.2 and 9-7.1, only T_s loads expected during empty dead load condition shall be considered.
h. For load combinations 9-6.2, 9-6.3, 9-7.1 and 9-7.2 (uplift cases), load factor for T_s (from piping) shall be 0.9 if the load contributes to the resisting forces and 1.2 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be the same as the load factor for the dead load.
i. For load combination 9-7.2, full $D_s + D_o$ value shall be used for the calculation of E_o.
j. For load combinations 9-9 and 9-10, a reduced empty dead load shall be used for heat exchangers during bundle pull due to the removal of the bundle head.
k. Load combinations 9-8.1 and 9-8.2 are based on *ASCE/SEI 7-10*, Commentary Section C2.3.5.
l. Roof live and rain are not included in this table because they do not apply to horizontal vessels and heat exchangers.

4.2.2.5 Pipe Racks and Pipe Bridges

Load combinations for pipe racks and pipe bridges are shown in the following tables:

a. For Allowable Stress Design, Table 10

b. For Strength Design, Table 11

Table 10 - Pipe Racks and Pipe Bridges
Allowable Stress Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Pipe Racks and Pipe Bridges Specific Load Combination**	**Description**
1	D	10-1.1	$D_s + D_o + T_s$	Operating Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement)
		10-1.2	$D_s + D_o + T_s + T_t$	Operating Weight + Sustained Thermal + Temporary Thermal
		10-1.3	$D_s + D_t^a + T_s^b + T_t^c$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c]
2	D + L	10-2.1	$D_s + D_o + T_s + L$	Operating Weight + Sustained Thermal + Live
		10-2.2	$D_s + D_t^a + T_s^b + L$	Test Weight[a] + Sustained Thermal[b] + Live
3	D + (L_r or S or R)	10-3.1	$D_s + D_o + T_s + S$	Operating Weight + Sustained Thermal + Snow
		10-3.2	$D_s + D_t^a + T_s^b + S$	Test Weight[a] + Sustained Thermal[b] + Snow
4	D + 0.75 L + 0.75 (L_r or S or R)	10-4.1	$D_s + D_o + T_s + 0.75\ T_t + 0.75\ L + 0.75\ S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + Snow
		10-4.2	$D_s + D_t^a + T_s^b + 0.75\ T_t^c + 0.75\ L + 0.75\ S$	Test Weight[a] + Sustained Thermal [b] + Temporary Thermal[c] + Live + Snow

Table 10 - Pipe Racks and Pipe Bridges
Allowable Stress Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Pipe Racks and Pipe Bridges Specific Load Combination**	**Description**
5	D + (0.6 W or 0.7 E)	10-5.1	$D_s + D_o + T_s + 0.6\ W$	Operating Weight + Sustained Thermal + Wind
		10-5.2	$D_s + D_o + T_s + 0.7\ E_o$	Operating Weight + Sustained Thermal + Earthquake
		10-5.3	$D_s + D_t^a + T_s^b + 0.6\ W_p$	Test Weight[a] + Sustained Thermal[b] + Partial Wind
6a	D + 0.75 L + 0.75 (0.6 W) + 0.75 (L_r or S or R)	10-6a.1	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.6\ W) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Wind + Snow
		10-6a.2	$D_s + D_t^a + T_s^b + 0.75\ L + 0.75\ (0.6\ W_p) + 0.75\ S$	Test Weight[a] + Sustained Thermal[b] + Live + Partial Wind + Snow
6b	D + 0.75 L + 0.75 (0.7 E) + 0.75 S	10-6b	$D_s + D_o + T_s + 0.75\ L + 0.75\ (0.7\ E_o) + 0.75\ S$	Operating Weight + Sustained Thermal + Live + Earthquake + Snow
7	0.6 D + 0.6 W	10-7.1	$0.6\ (D_s + D_e) + T_s^{e,f} + 0.6\ W$	Empty Weight + Sustained Thermal[e,f] + Wind (Wind Uplift Case)
		10-7.2	$0.6\ (D_s + D_o) + T_s^f + 0.6\ W$	Operating Weight + Sustained Thermal[f] + Wind (Sustained Thermal and Wind Uplift Case)
8	0.6 D + 0.7 E	10-8.1	$0.6\ (D_s + D_e) + T_s^{e,f} + 0.7\ E_e$	Empty Weight + Sustained Thermal[e,f] + Earthquake (Earthquake Uplift Case)
		10-8.2	$0.6\ (D_s + D_o) + T_s^f + 0.7\ E_o^g$	Operating Weight + Sustained Thermal[f] + Earthquake[g] (Sustained Thermal and Earthquake Uplift Case)

Table 10 - Pipe Racks and Pipe Bridges
Allowable Stress Design Load Combinations (Continued)

NOTES:

a. Load combinations 10-1.3, 10-2.2, 10-3.2, 10-4.2, 10-5.3, and 10-6a.2 normally are required only for local member design because hydrotesting is not typically performed on all pipes simultaneously.

b. For load combinations 10-1.3, 10-2.2, 10-3.2, 10-4.2, 10-5.3, and 10-6a.2, only T_s loads expected during hydrotesting period shall be considered.

c. For load combinations 10-1.3 and 10-4.2, only T_t loads expected during hydrotesting period shall be considered.

d. For load combinations 10-3.2, 10-4.2, and 10-6a.2, snow load can be excluded if it is determined that it cannot be present during the hydrotesting period.

e. For load combinations 10-7.1 and 10-8.1, only T_s loads expected during empty dead load condition shall be considered.

f. For load combinations 10-7.1, 10-7.2, 10-8.1 and 10-8.2 (uplift cases), load factor for T_s (from piping) shall be 0.6 if the load contributes to the resisting forces and 1.0 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be 1.0.

g. For load combination 10-8.2, full $D_s + D_o$ value shall be used for the calculation of E_o.

h. For pipe racks with air coolers or other types of equipment and vessels, loads and load combinations used for equipment structures and vessel supports (Tables 4, 6, and 8) shall also be considered as applicable.

i. Roof live and rain are not included in this table because they do not apply to pipe racks and pipe bridges.

Table 11 - Pipe Racks and Pipe Bridges
Strength Design Load Combinations

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Pipe Racks and Pipe Bridges Specific Load Combination**	**Description**
1	1.4 D	11-1.1	$1.4 (D_s + D_o) + 1.2 T_s$	Operating Weight + Sustained Thermal
		11-1.2	$1.4 (D_s + D_t^a) + 1.2 T_s^b$	Test Weight[a] + Sustained Thermal[b]
2	1.2 D + 1.6 L + 0.5 (L_r or S or R)	11-2.1	$1.2 (D_s + D_o) + 1.2 T_s + 1.0 T_t + 1.6 L + 0.5 S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + Snow
		11-2.2	$1.2 (D_s + D_t^a) + 1.2 T_s^b + 1.0 T_t^c + 1.6 L + 0.5 S^d$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] + Live + Snow[d]
3	1.2 D + 1.6 (L_r or S or R) + (L or 0.5 W)	11-3.1	$1.2 (D_s + D_o) + 1.2 T_s + 1.0 T_t + 1.6 S + 0.5 L^e$	Operating Weight + Sustained Thermal + Temporary Thermal + Snow + Live[e]
		11-3.2	$1.2 (D_s + D_o) + 1.2 T_s + 1.6 S + 0.5 W$	Operating Weight + Sustained Thermal + Snow + Wind
		11-3.3	$1.2 (D_s + D_t^a) + 1.2 T_s^b + 1.0 T_t^c + 1.6 S^d + 0.5 L^e$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] + Snow[d] + Live[e]
		11-3.4	$1.2 (D_s + D_t^a) + 1.2 T_s^b + 1.6 S^d + 0.5 W$	Test Weight[a] + Sustained Thermal[b] + Snow[d] + Wind
4	1.2 D + 1.0 W + L + 0.5 (L_r or S or R)	11-4.1	$1.2 (D_s + D_o) + 1.2 T_s + 1.0 W + 0.5 L^e + 0.5 S$	Operating Weight + Sustained Thermal + Wind + Live[e] + Snow
		11-4.2	$1.2 (D_s + D_t^a) + 1.2 T_s^b + 1.0 W_p + 0.5 L^e + 0.5 S^d$	Test Weight[a] + Sustained Thermal[b] + Partial Wind + Live[e] + Snow[d]
5	1.2 D + 1.0 E + L + 0.2 S	11-5	$1.2 (D_s + D_o) + 1.2 T_s + 1.0 E_o + 0.5 L^e + 0.2 S$	Operating Weight + Sustained Thermal + Earthquake + Live[e] + Snow
6	0.9 D + 1.0 W	11-6.1	$0.9 (D_s + D_e) + 1.2 T_s^{f,g} + 1.0 W$	Empty Weight + Sustained Thermal[f,g] + Wind (Wind Uplift Case)
		11-6.2	$0.9 (D_s + D_o) + 1.2 T_s^g + 1.0 W$	Operating Weight + Sustained Thermal[g] + Wind (Wind Uplift Case)

Table 11 - Pipe Racks and Pipe Bridges
Strength Design Load Combinations (Continued)

***ASCE 7-10*, *IBC 2012* or *IBC 2015* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Pipe Racks and Pipe Bridges Specific Load Combination**	**Description**
7	0.9 D + 1.0 E	11-7.1	$0.9\ (D_s + D_e) + 1.2\ T_s^{f,g} + 1.0\ E_e$	Empty Weight + Sustained Thermal[f,g] + Earthquake (Earthquake Uplift Case)
		11-7.2	$0.9\ (D_s + D_o) + 1.2\ T_s^{g} + 1.0\ E_o^{h}$	Operating Weight + Sustained Thermal[g] + Earthquake[h] (Earthquake Uplift Case)
N/A[j]	N/A[j]	11-8.1	$1.2\ (D_s + D_o) + 1.2\ T_s + 1.2\ T_t + 0.5\ L + 0.5\ S$	Operating Weight + Sustained Thermal + Temporary Thermal + Live + Snow
		11-8.2	$1.2\ (D_s + D_t^{a}) + 1.2\ T_s^{b} + 1.2\ T_t^{c} + 0.5\ L + 0.5\ S^{d}$	Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] + Live + Snow[d]

NOTES:

a. Load combinations 11-1.2, 11-2.2, 11-3.3, 11-3.4, 11-4.2, and 11-8.2 normally are required only for local member design because hydrotesting is not typically performed on all pipes simultaneously.
b. For load combinations 11-1.2, 11-2.2, 11-3.3, 11-3.4, 11-4.2, and 11-8.2, only T_s loads expected during hydrotesting period shall be considered.
c. For load combinations 11-2.2, 11-3.3, and 11-8.2, only T_t loads expected during hydrotesting period shall be considered.
d. For load combinations 11-2.2, 11-3.3, 11-3.4, 11-4.2, and 11-8.2, snow load can be excluded if it is determined that it cannot be present during the hydrotesting period.
e. For load combinations 11-3.1, 11-3.3, 11-4.1, 11-4.2, and 11-5, the 0.5 load factor on L is permitted for L = 100 psf or less. For L > 100 psf, load factor on L in these combinations shall be 1.0.
f. For load combinations 11-6.1 and 11-7.1, only T_s loads expected during empty dead load condition shall be considered.
g. For load combinations 11-6.1, 11-6.2, 11-7.1 and 11-7.2 (uplift cases), load factor for T_s (from piping) shall be 0.9 if the load contributes to the resisting forces and 1.2 if the load contributes to the uplift or overturning forces. For all other load combinations, load factor for T_s (from piping) shall be the same as the load factor for the dead load.
h. For load combination 11-7.2, full $D_s + D_o$ value shall be used for the calculation of E_o.
i. For pipe racks with air coolers or other types of equipment and vessels, loads and load combinations used for equipment structures and vessel supports (Tables 5, 7, and 9) shall also be considered as applicable.
j. Load combinations 11-8.1 and 11-8.2 are based on *ASCE/SEI 7-10*, Commentary Section C2.3.5.
k. Roof live and rain are not included in this table because they do not apply to pipe racks and pipe bridges.

4.2.2.6 Ground-Supported Storage Tank Foundations

Load combinations for ground-supported storage tank foundations shall be in accordance with *API Standard 650* as referenced by *ASCE/SEI 7-10*. Load combinations from *API Standard 650* modified for use with *ASCE/SEI 7-10* loads as applicable and Process Industry Practices (PIP) nomenclature are shown in Table 12. Load combinations in Table 12 are for Allowable Stress Design. For design of anchorage and reinforced concrete for foundations, load combinations in Table 12 will need to be converted to Strength Design.

Table 12 - Loading Combinations - Allowable Stress Design

***API STD 650* Comb. No.**	**General Load Combination**	**PIP STC01015 Comb. No.**	**Ground-Supported Storage Tank Foundations Specific Load Combination**	**Description**
a	$D_L + F + P_i$	12-a	$D_s + D_o + P_i$[a]	Operating Weight + Internal Pressure[a]
b	$D_L + H_t + P_i$	12-b	$D_s + D_t + P_t$	Test Weight + Test Pressure
c	$D_L + W + F_P P_i$	12-c.1	$D_s + D_e + W + F_P P_i$[a,b,d]	Empty Weight + Wind + Internal Pressure[a,b,d]
		12-c.2	$D_s + D_o + W + F_P P_i$[a,b,d]	Operating Weight + Wind + Internal Pressure[a,b,d]
d	$D_L + W + 0.4\ P_e$	12-d.1	$D_s + D_e + W + 0.4\ P_e$[b]	Empty Weight + Wind + External Pressure[b]
		12-d.2	$D_s + D_o + W + 0.4\ P_e$[b]	Operating Weight + Wind + External Pressure[b]
e1	$D_L + (L_r \text{ or } S_u \text{ or } S_b) + 0.4\ P_e$	12-e1	$D_s + D_o + (L_r \text{ or } S) + 0.4\ P_e$[b]	Operating Weight + (Roof Live Load or Snow) + External Pressure[b]
e2	$D_L + P_e + 0.4\ (L_r \text{ or } S_u \text{ or } S_b)$	12-e2.1	$D_s + D_e + P_e + 0.4\ (L_r \text{ or } S)$	Empty Weight + External Pressure + (Roof Live Load or Snow)
		12-e2.2	$D_s + D_o + P_e + 0.4\ (L_r \text{ or } S)$	Operating Weight + External Pressure + (Roof Live Load or Snow)
f	$D_L + F + E + 0.1\ S_b + F_P Pi$	12-f	$D_s + D_o + E_o$[c] $+ 0.1\ S + F_P P_i$[a,b,d]	Operating Weight + Earthquake[c] + Snow + Internal Pressure[a,b,d]

NOTES:

a. For internal pressures sufficient to lift the tank shell in accordance with the rules of *API Standard 650*, tank, anchor bolts, and foundation shall be designed to the additional requirements of Appendix F.7 of *API Standard 650*, Appendix F.7.

b. If the ratio of operating pressure to design pressure exceeds 0.4, the owner shall consider specifying a higher factor on design pressure in load combinations 12-c.1, 12-c.2, 12-d.1, 12-d.2, 12-e1, and 12-f.

c. Earthquake loads for *API Standard 650* tanks taken from *ASCE/SEI 7-10* "bridging equations" or from *API Standard 650* already include the 0.7 ASD seismic load factor.

d. The pressure combination factor (F_P) is defined as the ratio of normal operating pressure to design pressure, with a minimum value of 0.4.

4.2.2.7 Load Combinations for Machinery, Skid and Modular Equipment, Filters, and Other Equipment Supports and Foundations

1. Load combinations for static machinery, skid and modular equipment, filters, and other equipment supports and foundations shall be similar to the load combinations for vertical vessel supports and foundations.
2. For rotating or reciprocating machinery, other load combinations that include dynamic loads which are specific to the type of machine shall be considered.

4.2.3 Test Combinations

4.2.3.1 Engineer of record shall determine the appropriate test load combinations to adequately address actual test conditions in accordance with project and code requirements.

4.2.3.2 Consideration shall be given to the sequence and combination of testing for various equipment, vessels, tanks, and/or piping systems supported on common structures, pipe racks, or foundations.

4.2.3.3 Full wind and earthquake loads are typically not combined with test loads unless an unusually long test duration is planned (i.e., if a significant probability exists that the "partial wind velocity" can be exceeded or an earthquake event can occur).

4.2.3.4 If specified in the contract documents, additional loading shall be included with test.

4.2.3.5 For strength design, no load factor reduction shall be permitted for any test load combination.

4.3 Structural Design

Structural design shall be in accordance with appropriate sections of *IBC 2012* or *IBC 2015* as applicable.

4.3.1 Steel

4.3.1.1 Structural steel shall be designed in accordance with *ANSI/AISC 360* and where required, *AISC 341*.

4.3.1.2 Steel cold-formed shapes shall be designed in accordance with *AISI S100*.

4.3.1.3 Steel joists shall be designed in accordance with *SJI-CJ*, *SJI-K*, *SJI-LH/DLH*, or *SJI-J*.

4.3.1.4 Steel deck shall be designed in accordance with *SDI C1.0*, *SDI NC1.0*, or *SDI RD1.0*.

4.3.1.5 Steel, including steel joists and metal decking, shall be designed in accordance with *OSHA 29 CFR 1926*, Subpart R, to provide structural stability during erection and to protect employees from the hazards associated with steel erection activities.

4.3.1.6 Unless otherwise specified in contract documents, all welded structural connections shall use weld filler material in accordance with *AWS*

D1.1/D1.1M, Section 3.3 including Table 3.1, and have an electrode strength of 58 ksi (400 MPa) minimum yield strength and 70 ksi (490 MPa) tensile strength.

4.3.1.7 Unless otherwise specified in contract documents, structural steel wide-flange shapes, including WT shapes, shall be in accordance with *ASTM A992/A992M*.

4.3.1.8 Unless otherwise specified in contract documents, hollow structural sections (HSS shapes) shall be in accordance with *ASTM A500* Grade B.

4.3.1.9 Unless otherwise specified in the contract documents, all other structural shapes, plates, and bars shall be in accordance with *ASTM A36/A36M* or *ASTM A572/A572M* Grade 50.

4.3.1.10 Preference in design shall be given to shop-welded, field-bolted connections.

4.3.1.11 Compression flanges of floor beams, not supporting equipment, may be considered braced by decking (i.e., concrete or floor plate) if positively connected thereto.

4.3.1.12 Grating shall not be considered as lateral bracing for support beams.

4.3.1.13 Unless otherwise specified in contract documents, high-strength bolts for structural members shall be *ASTM F3125*, Grade A325 (*ASTM F3125M*, Grade A325M), Type 1, type-N (i.e., bearing-type with threads included in the shear plane) except where type-SC bolts are required for slip-critical connections in accordance with *RCSC Specification for Structural Joints Using High-Strength Bolts*.

4.3.1.14 Bolt size shall be as follows:

a. For structural members, 3/4 inch (M20) minimum

b. For railings, ladders, purlins, and girts, 5/8 inch (16 mm) in accordance with *ASTM A307*

4.3.1.15 Minimum thickness of bracing gusset plates shall be 3/8 inch (10 mm).

4.3.2 Concrete

4.3.2.1 All concrete shall be designed in accordance with *ACI 318 / ACI 318M*.

4.3.2.2 Concrete for environmental engineering concrete structures shall also be designed in accordance with *ACI 350 / ACI 350M* as applicable.

4.3.2.3 Concrete structures for Liquefied Natural Gas (LNG) facilities shall also be designed in accordance with *NFPA 59A* as applicable.

4.3.2.4 Concrete structures for the containment of refrigerated liquefied gases shall also be designed in accordance with *ACI 376 / ACI 376M* as applicable.

4.3.2.5 Concrete Durability

1. Engineer of record shall determine exposure class based on the severity of the anticipated exposure of structural concrete members for each exposure category in accordance with *ACI 318-11 / ACI*

318M-11, Table 4.2.1 or *ACI 318-14 / ACI 318M-14*, Table 19.3.1.1 as applicable.

2. Concrete shall be designed in accordance with the durability requirements of *ACI 318-11 / ACI 318M-11*, Chapter 4 or *ACI 318-14 / ACI 318M-14*, Chapter 19 as applicable.

3. Environmental engineering concrete structures shall also be designed in accordance with the durability requirements of *ACI 350 / ACI 350M*, Chapter 4, as applicable.

4.3.2.6 Unless otherwise specified in the contract documents, all reinforcing steel shall be in accordance with *ASTM A615/A615M* Grade 60 (420) deformed.

4.3.2.7 *ASTM A615/A615M* Grade 60 (420) plain wire in accordance with *ASTM A1064/A1064M* may be used for spiral reinforcement.

4.3.2.8 Welded wire reinforcement shall be in accordance with *ASTM A1064/A1064M*.

4.3.2.9 Reinforcement designed to resist earthquake-induced flexural and axial forces in frame members and in wall boundary elements shall be in accordance with *ASTM A706/A706M*. *ASTM A615/A615M* Grade 60 (420) reinforcement is acceptable for these members under the following conditions:

a. The actual yield strength based on mill tests is not greater than the specified yield strength by more than 18,000 psi (125 MPa). Retests shall not be greater than this value by more than an additional 3,000 psi (21 MPa).

b. The ratio of the actual ultimate tensile strength to the actual tensile yield strength is not less than 1.25.

4.3.2.10 Precast and prestressed concrete shall be designed in accordance with *PCI MNL-120.*

4.3.3 Masonry

Masonry shall be designed in accordance with *TMS 402/ACI 530/ASCE 5*.

4.3.4 Elevator Supports

Elevator supports shall be designed in accordance with *ASME A17.1/CSA B44*.

4.3.5 Crane Supports

4.3.5.1 Vertical deflection of support runway girders shall not be greater than the limits shown in Table 13 when loaded with the maximum wheel loads, without impact. L is the span length, based on classification of cranes in accordance with *CMAA No. 70* and *CMAA No. 74*.

Table 13 - Maximum Allowable Support Runway Girder Vertical Deflections

Top-Running CMAA Class A, B, and C Cranes	L/600
Top-Running CMAA Class D Cranes	L/800
Top-Running CMAA Class E and F Cranes	L/1000
Under-Running CMAA Class A, B, and C Cranes	L/450
Monorails	L/450

4.3.5.2 Vertical deflection of jib crane support beams shall not be greater than L/225, where L is the maximum distance from the support column to load location along the length of the jib beam, if loaded with the maximum lifted plus hoist loads, without impact.

4.3.5.3 Lateral deflection of support runway girders for cranes with lateral moving trolleys shall not be greater than L/400, where L is the span length, when loaded with a total crane lateral force not less than 20% of the sum of the weights of the lifted load (without impact) and the crane trolley. The lateral force shall be distributed to each runway girder with consideration for the lateral stiffness of the runway girders and the structure supporting the runway girders.

4.3.5.4 Crane stops shall be designed in accordance with the crane manufacturer's requirements or, if not specified, for the following load:

$$F = W\ V^2/(2gTn)$$

where:

F = Design force on crane stop, kips (kN)

W = 50% of bridge weight + 90% of trolley weight, excluding the lifted load, kips (kN)

V = Rated crane speed, ft/sec (m/sec)

g = Acceleration of gravity, 32.2 ft/sec^2 (9.8 m/sec^2)

T = Length of travel (ft) of spring or plunger required to stop crane, from crane manufacturer, typically 0.15 ft (0.05 m)

n = Bumper efficiency factor (0.5 for helical springs. Consult crane manufacturer for hydraulic plunger.)

4.3.6 Allowable Deflection and Drift Limits

4.3.6.1 Deflection and drift limits should be based on serviceability of interconnected, drift or deflection-sensitive equipment, piping systems, and/or building systems and components supported by the structure or building.

4.3.6.2 Drift limits specified in this Section are based on service level loads and should be evaluated by the engineer of record for application in particular circumstances.

4.3.6.3 Allowable wind drift limits for pipe racks shall not be greater than H/100, where H is the pipe rack height.

4.3.6.4 Except as specified in the following subsections, the allowable wind story drift limits for occupied buildings shall not be greater than H/200, where H is the story height.

4.3.6.5 Allowable wind drift limits for pre-engineered metal buildings shall not be greater than H/80, where H is the building height.

4.3.6.6 Allowable wind drift limits for a building with a bridge crane that is required to be in service even during hurricanes shall not be greater than H/400 or 2 inches (50 mm), whichever is less, where H is the height from the base of the crane support structure to the top of the runway girder.

4.3.6.7 Allowable wind drift limits for buildings with bridge cranes that are not to be in service during hurricanes shall not be greater than H/200 or 2 inches (50 mm), whichever is less, where H is the height from the base of the crane support structure to the top of the runway girder.

4.3.6.8 Allowable wind drift limits for process structures and personnel access platforms shall not be greater than H/200, where H is the structure height at elevation of drift consideration.

4.3.6.9 Allowable seismic drift limits shall be in accordance with *ASCE/SEI 7*.

4.3.7 Foundations

4.3.7.1 Foundation design shall be based on the results of a geotechnical engineering investigation.

4.3.7.2 The minimum overturning "stability ratio" for the load combinations in Section 4.2, except for load combinations with earthquake load, shall be 1.0. See Section 4.3.7.4 for the minimum overturning "stabili**ty** ratio" for earthquake loads.

Comment: This requirement is consistent with *ASCE/SEI 7* provisions, in which the "factor of safety" is built into the load factors in the load combinations for uplift cases.

4.3.7.3 The minimum factor of safety against sliding for the load combinations in Section 4.2, except for load combinations with earthquake load, shall be 1.0. See Section 4.3.7.4 for minimum sliding factor of safety for earthquake loads.

Comment: This requirement is consistent with *ASCE/SEI 7* provisions, in which the "factor of safety" is built into the load factors in the load combinations for uplift cases.

4.3.7.4 Overturning and sliding caused by earthquake loads shall be checked in accordance with *ASCE/SEI 7-10*, Chapter 12. The minimum overturning "stability ratio" and the minimum factor of safety against sliding for load combinations with earthquake load shall be 1.0. In addition, the minimum overturning "stability ratio" for the anchorage and foundations of skirt-supported vertical vessels and skirt-supported elevated tanks classified as Risk Category IV in accordance with *ASCE/SEI 7-10*, Section 1.5 and Table 1.5-1, shall be 1.2 for the critical earthquake loads specified in *ASCE/SEI 7-10*, Section 15.7.10.5.

4.3.7.5 The minimum factor of safety against buoyancy shall be 1.2 if using actual unfactored service loads.

4.3.7.6 Long-term and differential settlement criteria shall be determined by the engineer of record. Special consideration shall be given to differential settlement of foundations supporting interconnected, settlement-sensitive equipment or piping systems.

4.3.7.7 Unless otherwise specified in the contract documents, the top of concrete or grout, if required, of pedestals, piers, and ringwalls shall be 1 ft (300 mm) above the high point of finished grade.

4.3.7.8 Except for foundations supporting ground-supported storage tanks, uplift load combinations containing earthquake loads do not need to include the vertical components of the seismic load effect, E, if used to size foundations.

4.3.7.9 Foundations for ground-supported storage tanks that have sufficient internal pressure to lift the shell shall also be designed in accordance with *API Standard 650,* Appendix F.7.5.

4.3.7.10 Foundations for Liquefied Natural Gas (LNG) Facilities shall also be designed in accordance with *NFPA 59A* as applicable.

4.3.8 Supports for Vibrating Machinery

4.3.8.1 Machinery foundations shall be designed in accordance with *PIP REIE686/API RP686*, Chapter 4; *PIP REIE686A*, Chapter 4; equipment manufacturer's recommendations; and published design procedures and criteria for dynamic analysis.

4.3.8.2 If equipment manufacturer's vibration criteria are not available, the maximum velocity of movement during steady-state normal operation shall be limited to 0.12 inch (3.0 mm) per second for centrifugal machines and to 0.15 inch (3.8 mm) per second for reciprocating machines.

4.3.8.3 Support structures or foundations for centrifugal machinery greater than 500 horsepower shall be designed for the expected dynamic forces using dynamic analysis procedures.

4.3.8.4 Unless specified otherwise by the equipment manufacturer, for grade mounted centrifugal machinery 500 horsepower or less, in the absence of a detailed dynamic analysis, the foundation weight shall be designed to be at least three times the total machinery weight. Weight of a grouted equipment skid can be considered part of the foundation weight for this provision.

4.3.8.5 Support structures or foundations for reciprocating machinery greater than 200 horsepower shall be designed for the expected dynamic forces using dynamic analysis procedures.

4.3.8.6 Unless specified otherwise by the manufacturer, for grade mounted reciprocating machinery 200 horsepower or less, in the absence of a detailed dynamic analysis, the foundation weight shall be designed to be at least five times the total machinery weight. Weight of a grouted

equipment skid can be considered part of the foundation weight for this provision.

4.3.8.7 The allowable soil-bearing or allowable pile capacity for foundations for equipment designed for dynamic loads shall be a maximum of half of the normal allowable for static loads.

4.3.8.8 The maximum eccentricity between the center of gravity of the combined weight of the foundation and machinery and the bearing surface shall be 5% in each direction.

4.3.8.9 Unless otherwise specified in the contract documents, if equipment manufacturer's frequency criteria are not available, structures and foundations that support vibrating equipment shall have primary modes of natural frequency that are outside the range of 0.80 to 1.20 times the exciting frequency.

4.3.9 Cast-in-place Anchors in Concrete

4.3.9.1 Cast-in-place anchors in concrete shall be headed type or rods with threaded ends with compatible nuts using *ASTM A36/A36M*, *ASTM A307*, *ASTM F1554* Grade 36, *ASTM F1554* Grade 55, *ASTM F1554* Grade 105, *ASTM A193/A193M* Grade B7, *ASTM A354* Grade BC, or *ASTM A354* Grade BD material.

4.3.9.2 All *ASTM A36/A36M*, *ASTM A307*, and *ASTM F1554* Grade 36 anchors shall be hot dip galvanized.

4.3.9.3 Anchorage design shall be in accordance with *PIP STE05121*.

4.3.10 Wood

Wood design shall be in accordance with the *ANSI/AWS NDS* and with the *NDS Supplement - Design Values for Wood Construction*.

4.3.11 Design of Drilled Shafts

4.3.11.1 Minimum vertical reinforcement shall be 0.50% of the pier gross area or as required to resist axial loads and bending moments.

4.3.11.2 The minimum clear spacing of vertical bars shall not be less than three times the maximum coarse aggregate size nor less than three times the vertical bar diameter.

4.3.11.3 Reinforcing steel shall permit a minimum of 3 inches (75 mm) of concrete cover on piers without casing and 4 inches (100 mm) of concrete cover on piers in which the casing is to be withdrawn.

4.3.12 Design of Driven Piles

4.3.12.1 In addition to in-place conditions, piles shall be designed to resist handling, transportation, and installation stresses.

4.3.12.2 Unless otherwise specified in the contract documents, the exposure condition shall be evaluated to establish the corrosion allowances for steel piles.

4.3.12.3 The top of piles shall penetrate a minimum of 4 inches (100 mm) into the pile cap.

4.3.13 Vessel Load Cell Supports

Supports for vessel load cells shall be designed in accordance with *PIP PCCWE001* and *PIP PCEWE001*.

4.4 Existing Structures

If the owner and the engineer of record agree that the integrity of an existing structure is 100% of the original design and the existing loading on the structure is 100% or less of the original allowable capacity based on the materials used and design codes in effect at the time of original design, structural designs shall be performed in accordance with the following:

a. If additions or alterations to an existing structure do not increase the force in any structural element or connection by more than 5%, no further analysis is required.

b. If the increased forces on the element or connection are greater than 5%, the element or connection shall be analyzed to show that it is in accordance with the applicable design code for new construction.

c. The strength of any structural element or connection shall not be decreased to less than that required by the applicable design code or standard for new construction for the structure in question.

PROCESS INDUSTRY PRACTICES

EDITORIAL REVISION
November 2017

Structural

PIP STF05121
Anchor Fabrication and Installation into Concrete

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

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PIP STF05121
Anchor Fabrication and Installation into Concrete

Table of Contents

1. Scope

This Practice provides details and requirements for anchor fabrication and installation into concrete. Anchors are anchor rod assemblies that include a rod threaded at the two ends, nuts, washers, and anchor plates and/or sleeves if required. J-bolts and L-bolts are not included. Three standard lengths are shown for each diameter anchor rod in both U.S. Customary units and Metric (SI) units.

This Practice also provides requirements for non-standard anchor rod lengths.

The "Comments" shown in boxes in the Practice are provided for use by the anchor design engineer only.

2. References

Applicable requirements in the following Practices and industry codes and standards shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP STE05121 - *Application of ASCE Anchorage Design for Petrochemical Facilities*
- PIP STS03001 - *Plain and Reinforced Concrete Specification*

2.2 Industry Codes and Standards

- American Society of Testing and Materials (ASTM)
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A563 - *Standard Specification for Carbon and Alloy Steel Nuts*
  - ASTM A563M - *Standard Specification for Carbon and Alloy Steel Nuts [Metric]*
  - ASTM F436/F436M - *Standard Specification for Hardened Steel Washers Inch and Metric Dimensions*
  - ASTM F1554 - *Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength*
  - ASTM F2329/ F2329M - *Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners*
- American Society of Mechanical Engineers (ASME)
  - ASME B1.13M - *Metric Screw Threads: M Profile*
  - ASME B18.2.1 - *Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)*
  - ASME B18.2.3.6M - *Metric Heavy Hex Bolts*

3. Definitions

anchor: General term for the anchor bolt or anchor rod assembly. This does not include the concrete and rebar which are parts of the anchorage.

anchor plate: Circular plate bolted at the bottom of an anchor bolt or anchor rod to increase the pull out capacity of the anchor. Typically, this is required to make the anchorage ductile.

anchor rod assembly: Fabricated assembly that includes a rod threaded at the two ends, nuts, washers, and anchor plates if required. J-bolts and L-bolts are not included.

constructor: Party responsible for supplying materials, equipment, tools, supervision, and labor for installation of anchors in accordance with contract documents. The term constructor shall apply also to constructor's subcontractor(s) and vendor(s).

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets, that purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between purchaser and fabricator or constructor.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of civil works, structure, foundations, materials, and appurtenances described in contract documents. Engineer of record shall be licensed as defined by laws of the locality in which the work is to be constructed, and be qualified to practice in the specialty discipline required for the work described in contract documents.

fabricator: Party responsible for providing fabricated anchors in accordance with contract documents. The term fabricator shall apply also to fabricator's subcontractor(s) and/or vendor(s).

4. Requirements

4.1 Anchor Dimensional Data and Details

4.1.1 Unless a non-standard anchor rod length is specified on design drawings, the anchors shall be provided in accordance with the dimensional requirements in Table 1 or Table 1M for U.S. Customary or Metric units, respectively.

Comment:

If practical, design engineer should preferentially specify one of the three standard length anchor rods shown in Table 1 or Table 1M. However, non-standard anchor rod lengths may be specified for the following reasons:

a. A longer than necessary anchor rod length causes the foundation to be deeper than practical.

b. A longer than necessary anchor rod length causes the anchor rod to project into the foundation (i.e., mat), increasing construction costs.

c. A longer anchor rod is needed to properly transfer load to the reinforcing steel.

Comment:

If a non-standard anchor rod length is required, the design engineer should specify the rod length as follows:

a. A whole number of inches for U.S. Customary units or a multiple of 10 mm for Metric units.

b. A minimum of 6 inches (150 mm) shorter or longer than the closest standard length anchor rod.

4.1.2 Anchor and sleeve configuration details shall be in accordance with drawing *PIP STF05121-01*.

4.1.3 Anchor types "A", "B", "C" and "N" shall consist of an anchor rod with a tack-welded nut at bottom and nut(s) and washer at top.

4.1.4 Anchor types "ASL", "BSL", "CSL," and "NSL" shall consist of an anchor rod with a tack-welded nut at bottom and sleeve, nut(s), and washer at top.

4.1.5 Anchor Plates

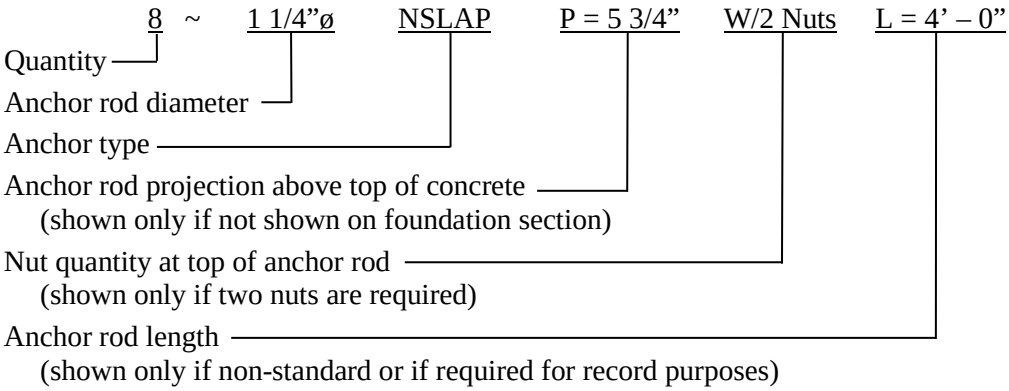
4.1.5.1 If an "AP" is added to the end of the anchor type designation, an anchor plate is required.

4.1.5.2 Anchors having the "AP" suffix shall include components specified in Section 4.1.3 or 4.1.4 of this Practice as applicable, plus an anchor plate and an additional nut above the anchor plate.

4.1.5.3 Example designations for these types of anchors are "AAP" for a type "A" anchor with an anchor plate, and "ASLAP" for a type "ASL" sleeved anchor with an anchor plate.

4.2 Anchor Callout

4.2.1 Anchors with U.S. Customary units are identified in anchor callouts on design drawings as shown in the following example:



Comment:

If required for record purposes, anchor rod lengths of standard length anchors should be specified by the design engineer either in the anchor callout or in notes on design drawings. The design engineer may duplicate Table 1 or Table 1M and drawing *PIP STF05121-01* on design drawings.

4.2.2 Anchor callouts for anchors with Metric units are identified on design drawings similar to the example above, but with metric dimensions for anchor rod diameter, projection, and length.

4.3 Materials

4.3.1 Unless otherwise specified on design drawings, anchor rods shall be in accordance with *ASTM F1554*, Grade 36. The substitution of *ASTM F1554*, weldable Grade 55 anchors for Grade 36 anchors, as allowed by *ASTM F1554* Section 6.4, is not permitted unless approved by the engineer of record.

4.3.2 Components of U.S. Customary unit dimensioned anchors shall be as follows:

a. Unless otherwise specified on design drawings, anchor rods shall have UNC-Class 2A threads.

b. Unless otherwise specified on design drawings, nuts shall have a proof load greater than the minimum tensile strength specified for the anchor and shall be in accordance with *ASTM A563* Grade A, heavy hex with UNC-2B threads.

c. Washers shall be in accordance with *ASTM F436*. If plate washers are specified on design drawings, they shall be in accordance with *ASTM A36* (see drawing *STF05121-01).*

4.3.3 Components of Metric unit dimensioned anchors shall be as follows:

a. Unless otherwise specified on design drawings, anchor rods shall have coarse metric thread form in accordance with *ASME B1.13M*, Class 6g.

b. Unless otherwise specified on design drawings, nuts shall have a proof load greater than the minimum tensile strength specified for the anchor and shall be in accordance with *ASTM A563M*, Property Class 9, heavy hex thread class 6AX. Thread form shall be consistent with the anchor rod specification.

c. Washers shall be in accordance with *ASTM F436M*. If plate washers are specified on design drawings, they shall be in accordance with *ASTM A36M* (see drawing *STF05121-01).*

4.3.4 Headed bolts, in accordance with Section 4.3.1, equal to the length of anchor rods above the bottom nut (see drawing *PIP STF05121-01*) may be provided as a substitution for anchor rods. Bolt head style shall be heavy hex in accordance with *ASME B18.2.1* or *ASME B18.2.3.6M* for U.S. Customary or Metric units, respectively. Thread length at the top of the bolt (TT) shall be exactly the same as shown in Table 1 or 1M.

4.3.5 Anchor Sleeves

4.3.5.1 Anchor sleeves shall be molded from black polyethylene.

4.3.5.2 Sleeves shall be formed with a self-threading neck on one end to match the thread size of the anchor.

4.3.5.3 Sleeves shall have V-shaped ribs around the body diameter to provide structural strength.

4.3.6 Anchor plates shall be circular discs in accordance with *ASTM A36/A36M*, with a center hole, 1/16 inch (1.5 mm) greater in diameter than the anchor rod.

4.4 Fabrication

4.4.1 Unless otherwise specified on design drawings, all anchor rods (i.e., total anchor rod length), anchor plates, nuts, and washers shall be hot-dip galvanized after fabrication in accordance with *ASTM F2329/F2329M*.

4.4.2 Excess galvanizing material shall be removed from threaded portions of anchor rods and nuts by use of a centrifuge or by mechanical chasing of the threads.

4.4.3 Hot-dip galvanized nuts shall be tapped oversize in accordance with *ASTM A563 / ASTM A563M*.

4.4.4 Fit of nuts on threads of anchor rods shall be verified before shipment.

4.4.5 Certified mill test reports shall be submitted to the engineer of record or his designee for all parts of the anchor rod assemblies.

4.5 Installation

4.5.1 Unless otherwise specified on design drawings, installation tolerances shall be as specified in *PIP STS03001*.

4.5.2 Anchors shall be securely tied in position so as not to be dislodged during concrete installation. Tack welding of anchor bolts for securing is strictly forbidden.

4.5.3 If specified on design drawings, anchor rod shall be wrapped with non-bonding tape for the required length and location shown on design drawings.

4.5.4 The top of anchor sleeves shall be cut off at the bottom of the structure or equipment base / top of grout elevation after concrete is placed and before setting the base of the structure or equipment and grouting.

4.5.5 Filling of Sleeves

4.5.5.1 Unless otherwise specified on design drawings, anchor sleeves shall be filled with one of the following materials after concrete is placed and before setting the structure or equipment base and grouting:

a. Nonbonding moldable material (e.g., silicone based compound of heavy consistency)

b. Elastomeric moldable non-hardening material (e.g., acrylic roof coating)

4.5.5.2 Water or other loose particles shall not be permitted to collect in sleeves before sleeves are filled.

4.5.6 Threads at top of anchor rods shall be covered with duct tape or other suitable means to keep them clean and to prevent any damage that might occur during concrete placement, preparation of the foundation for grouting, and grouting.

4.5.7 Unless otherwise specified on design drawings, nuts at top of anchors shall be tightened to a snug-tight condition, defined as the tightness that is attained with a few impacts of an impact wrench or with the full effort of a man using an ordinary spud wrench.

4.5.8 For anchors at locations specified on design drawings that require the structure or equipment base to slide for expansion and/or contraction purposes, the anchors shall be installed as follows:

a. Two top nuts shall be provided at the top of anchor.

b. Lower top nut shall be hand tightened and then backed off a half turn leaving approximately 1/16-inch (1.5 mm) clearance between lower top nut and structure or equipment base.

c. Upper top nut shall then be installed and jammed against lower top nut.

Table 1. Anchor Dimensional Data – U.S. Customary Units

Anchor Types "A", "B", "C", "N" (see Note 1), "ASL", "BSL", "CSL", and "NSL" (see Note 1)

(Anchors with Anchor Plates have an "AP" at end of Anchor Type Designation.)
(See drawing *PIP STF05121-01* for anchor and sleeve details showing locations of dimensions.)

d_a (Anchor Rod Diameter) (inch)	Allowance for Nuts (inch)					Sleeve Size (inch)	"A" & "ASL" Anchors	"B" & "BSL" Anchors	"C" & "CSL" Anchors	Anchor Plate (AP) Dimensions	
	N1 (1 nut) (See Note 2)	N2 (2 nuts) (See Note 2)	TB1 (Thread Length at Bottom with No AP)	TB2 (Thread Length at Bottom with AP)	TT (Thread Length at Top)		L (Std Anchor Rod Length)	L (Std Anchor Rod Length)	L (Std Anchor Rod Length)	AP Diameter (inch)	AP Thickness (inch)
5/8	1 1/2	2 1/4	1 1/4	—	3	2 x 7	1'- 6"	2'- 6"	—	NR	NR
3/4	1 3/4	2 1/2	1 1/4	2 1/4	3 1/4	2 x 7	1'- 6"	2'- 7"	3'- 0"	1 1/2	1/4
7/8	2	2 3/4	1 1/2	2 1/2	3 1/2	2 x 7	1'- 6"	2'- 8"	3'- 0"	1 3/4	1/4
1	2	3	1 3/4	3	3 3/4	3 x 10	2'- 0"	3'- 0"	3'- 6"	2	1/4
1 1/4	2 1/4	3 1/2	2	3 1/2	4 1/4	—	2'- 0"	3'- 6"	4'- 2"	2 1/2	3/8
1 1/2	2 3/4	4 1/4	2 1/4	4	5	—	2'- 2"	3'-10"	4'- 6"	2 3/4	3/8
1 3/4	3	4 3/4	2 1/2	4 3/4	5 1/2	—	2'- 6"	4'- 2"	4'-11"	3 1/4	3/8
2	3 1/4	5 1/2	2 3/4	5 1/4	6 1/4	—	2'-10"	4'- 5"	5'- 2"	3 3/4	1/2
2 1/4	3 3/4	6	3	5 3/4	6 3/4	—	3'- 2"	4'- 9"	5'- 9"	4 1/4	1/2
2 1/2	4	6 1/2	3 1/2	6 1/2	7 1/4	—	3'- 6"	5'- 1"	6'- 1"	4 1/2	1/2
2 3/4	4 1/4	7	3 3/4	7	7 3/4	—	3'- 9"	5'- 5"	6'- 4"	5	5/8
3	4 1/2	7 1/2	4	7 3/4	8 1/4	—	4'- 1"	5'- 9"	6'-10"	5 1/2	3/4

Note 1: Type "N" and "NSL" anchors have non-standard anchor rod lengths. See anchor callout on design drawings for anchor rod length.

Note 2: If an *ASTM A36* plate washer in addition to the *ASTM F436* washer is specified on design drawings, corresponding revised N1 or N2 dimensions will also be specified on design drawings.

Notes for design engineer:

1. It is intended that type "A" and "ASL" anchors be used unless a longer anchor rod length is required. If a longer anchor rod length is required, use type "B" and "BSL" anchors, or "C" and "CSL" anchors. Types "C" and "CSL" anchors are intended if vessel or column chairs or base rings are used. If none of these lengths is suitable, designate the anchor as type "N" (i.e., non-standard anchor rod length with no sleeves required) or as type "NSL" (i.e., non-standard anchor rod length with sleeves required), and specify the required anchor rod length in the anchor callout on the design drawing.
2. Sleeves used for the purpose of anchor alignment are not recommended for anchors rods with diameters greater than 1 inch.
3. Anchor plates are sized for ductile anchors using f'c = 4,000 psi. These plates can be used for higher strength concrete but may not be needed and can be made smaller. See *PIP STE05121*, Table 4. "NR" shown in Table 1 means anchor plates are not required for a ductile connection.
4. If *ASTM A36* plate washers are required in addition to *ASTM F436* washers, they should be specified on design drawings along with corresponding revised N1 or N2 dimensions.

Table 1M. Anchor Dimensional Data – Metric (SI) Units
Anchor Types "A", "B", "C", "N" (see Note 1), "ASL", "BSL", "CSL", and "NSL" (see Note 1)
(Anchors with Anchor Plates have an "AP" at end of Anchor Type Designation.)
(See drawing *PIP STF05121-01* for anchor and sleeve details showing locations of dimensions.)

d_a (Anchor Rod Diameter) (mm)	Allowance for Nuts (mm)					Sleeve Size (mm)	"A" & "ASL" Anchors	"B" & "BSL" Anchors	"C" & "CSL" Anchors	Anchor Plate (AP) Dimensions	
	N1 (1 nut) (See Note 2)	N2 (2 nuts) (See Note 2)	TB1 (Thread Length at Bottom with No AP)	TB2 (Thread Length at Bottom with AP)	TT (Thread Length at Top)		L (Std Anchor Rod Length) (mm)	L (Std Anchor Rod Length) (mm)	L (Std Anchor Rod Length) (mm)	AP Diameter (mm)	AP Thickness (mm)
16	40	55	30	—	75	50 x 175	450	750	--	NR	NR
20	45	65	35	—	85	50 x 175	450	825	950	NR	NR
24	50	75	40	—	95	75 x 250	600	900	1000	NR	NR
30	55	85	45	85	105	—	600	1050	1250	55	10
36	65	100	50	100	120	—	650	1150	1350	70	10
42	75	115	60	110	135	—	725	1250	1500	80	15
48	80	130	65	130	150	—	825	1350	1600	90	15
56	90	145	75	145	165	—	925	1450	1750	105	15
64	100	165	85	165	185	—	1050	1600	1850	120	15
72	110	180	90	185	200	—	1175	1750	2050	135	20

Note 1: Type "N" and "NSL" anchors have non-standard anchor rod lengths. See anchor callout on design drawings for anchor rod length.

Note 2: If an *ASTM A36M* plate washer in addition to the *ASTM F436M* washer is specified on design drawings, corresponding revised N1 or N2 dimensions will also be specified on design drawings.

Notes for design engineer:

1. It is intended that type "A" and "ASL" anchors be used unless a longer anchor rod length is required. If a longer anchor rod length is required, use type "B" and "BSL" anchors or "C" and "CSL" anchors. Types "C" and "CSL" anchors are intended if vessel or column chairs or base rings are used. If none of these lengths is suitable, designate the anchor as type "N" (i.e., non-standard anchor rod length with no sleeves required) or as type "NSL" (i.e., non-standard anchor rod length with sleeves required), and specify the required anchor rod length in the anchor callout on the design drawing.
2. Sleeves used for the purpose of anchor alignment are not recommended for anchor rods with diameters greater than 24 mm.
3. Anchor plates are sized for ductile anchors using f'c = 28 Mpa. These plates can be used for higher strength concrete but may not be needed and can be made smaller. See *PIP STE05121*, Table 4M. "NR" shown in Table 1M means anchor plates are not required for a ductile connection.
4 If *ASTM A36M* plate washers are required in addition to *ASTM F436M* washers, they should be specified on design drawings along with corresponding revised N1 or N2 dimensions.

ANCHOR AND SLEEVE DETAILS

STF05121-01
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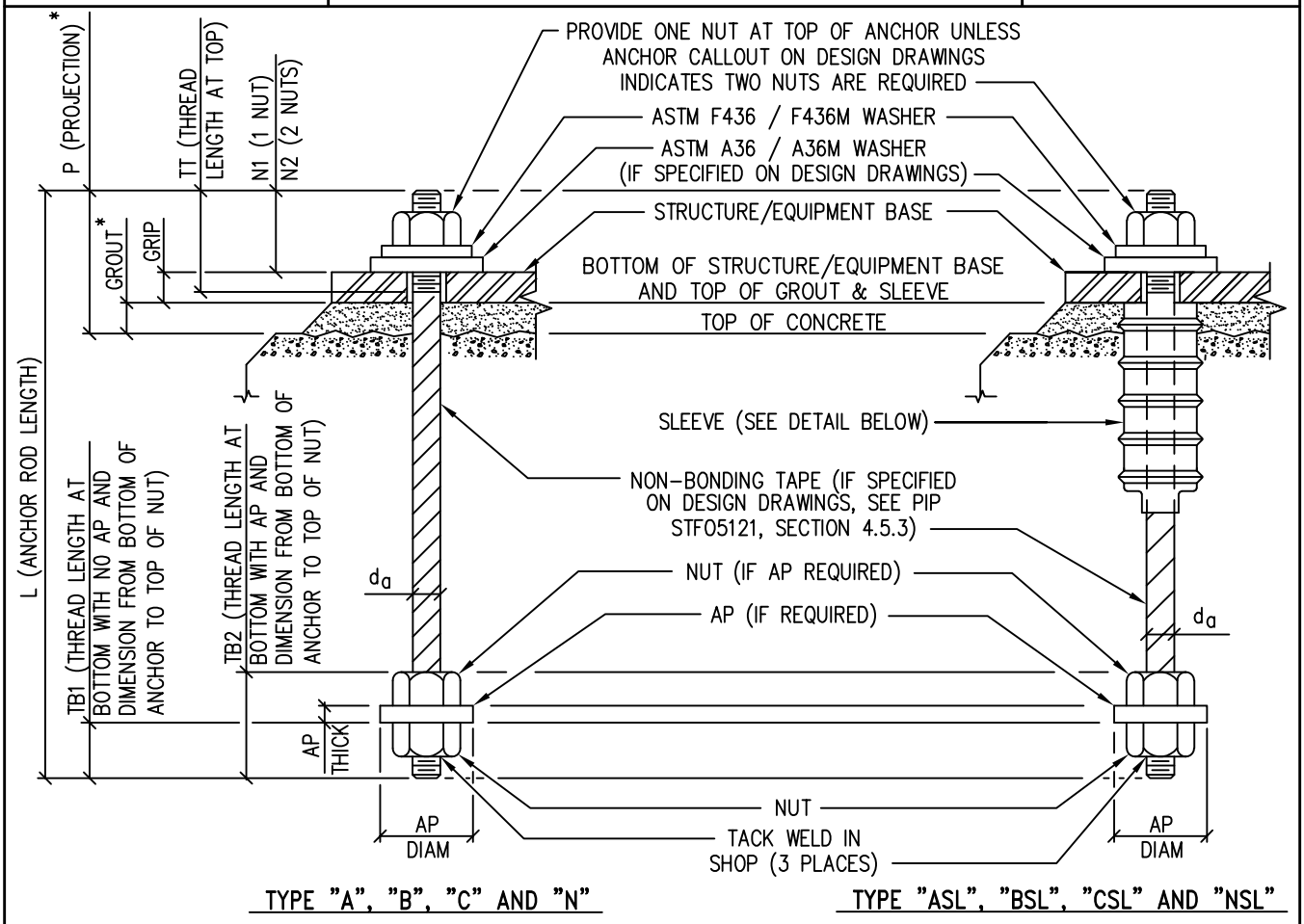
PAGE 1 OF 1
STF05121



TYPE "A", "B", "C" AND "N" TYPE "ASL", "BSL", "CSL" AND "NSL"

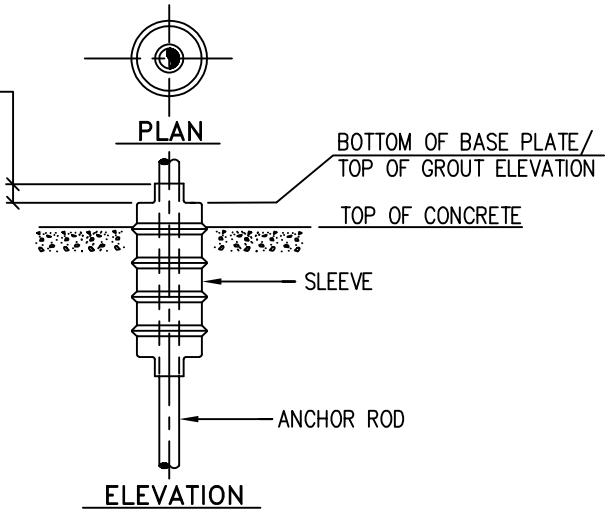
ANCHOR DETAILS

(FOR ANCHOR DIMENSIONAL DATA, SEE PIP STF05121, TABLE 1 FOR U.S. CUSTOMARY UNITS OR TABLE 1M FOR METRIC UNITS)

* – PROJECTION AND GROUT THICKNESS AS SPECIFIED ON DESIGN DRAWINGS

AP – ANCHOR PLATE (IF AP IS REQUIRED "AP" IS ADDED TO THE ANCHOR TYPE DESIGNATION ON DESIGN DRAWINGS. EXAMPLE "AAP", "ASLAP")

CUT OFF TOP OF SLEEVE AFTER CONCRETE IS PLACED AND PRIOR TO SETTING STRUCTURE/EQUIPMENT BASE AND GROUTING. FILL SLEEVE WITH A NON-BONDING MOLDABLE MATERIAL OR AN ELASTOMERIC MOLDABLE NON-HARDENING MATERIAL UNLESS OTHERWISE SPECIFIED ON DESIGN DRAWINGS (SEE PIP STF05121, SECTIONS 4.5.5.1a OR 4.5.5.1b)



NOTE: SLEEVE DETAIL IS SHOWN PRIOR TO GROUTING

SLEEVE DETAIL

COMPLETE REVISION
October 2011

Process Industry Practices
Structural

PIP STI03310
Concrete General Notes and Typical Details

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PRINTING HISTORY

June 2005 Issued
October 2011 Complete Revision

Not printed with State funds

Process Industry Practices
Structural

PIP STI03310
Concrete General Notes and Typical Details

Table of Contents

Drawings

1. Introduction

1.1 Purpose

This Practice provides concrete general notes and typical details for use in conjunction with design drawings and project specifications.

1.2 Scope

This Practice provides typical details for concrete pads for ladders and stairs, octagon foundation drains, ledger and curb angles for grating and floor plate; and describes clearances and spacing requirements for reinforcing steel for foundations and structural columns and beams. General concrete notes are provided to supplement the requirements shown on design drawings and project specifications. Abbreviations commonly used on design drawings are also listed in this Practice.

2. References

Applicable parts of the following Practices and industry codes and standards shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles will be used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP STF05121 - *Fabrication and Installation of Anchor Bolts*
- PIP STF05501 - *Fixed Ladders and Cages Fabrication Details*
- PIP STF05511 - *Fixed Industrial Stairs*
- PIP STS03001 - *Plain and Reinforced Concrete Specification*
- PIP STS03600 - *Nonshrink Cementitious Grout Specification*
- PIP STS03601 - *Epoxy Grout Specification*
- PIP STS05120 – *Structural and Miscellaneous Steel Fabrication Specification*

2.2 Industry Codes and Standards

- American Concrete Institute (ACI)
  - ACI 301- *Specification for Structural Concrete*
  - ACI 301M - *Specification for Structural Concrete (Metric)*
  - ACI SP-66 - *ACI Detailing Manual*
- ASTM International (ASTM)
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A123/A123M - *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*
  - ASTM A185/A185M - *Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete*

  - ASTM A615/A615M - *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*

- American Welding Society
  - AWS D1.1/D1.1M - *Structural Welding Code–Steel*

3. Definitions

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets, that the purchaser has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between the purchaser and the installer.

4. Abbreviations

Abbreviations commonly used on design drawings are listed in Table 1.

Table 1. Typical Concrete Details Abbreviations

AB = ANCHOR BOLT	GALV = GALVANIZED	REQD = REQUIRED
B = BOTTOM	HP = HIGH POINT	SCH = SCHEDULE
BC = BOLT CIRCLE	HORIZ = HORIZONTAL	SIM = SIMILAR
BOT = BOTTOM	ID = INSIDE DIAMETER	SPA = SPACE OR SPACES
BO = BOTTOM OF	L = LENGTH	SPCD = SPACED
C/C = CENTER TO CENTER	LG = LONG	SPCG = SPACING
CL = CENTERLINE	LOC = LOCATION	SPEC = SPECIFICATION
CLR = CLEAR OR CLEARANCE	LP = LOW POINT	STD = STANDARD
COL = COLUMN	MAX = MAXIMUM	SUCT = SUCTION
CONC = CONCRETE	MES = MISCELLANEOUS ELECTRICAL SUPPORT	SUPT = SUPPORT
CONST = CONSTRUCTION	MFG = MANUFACTURER	SYMM = SYMETRICAL
CONT = CONTINUOUS	MIN = MINIMUM	T = TOP
CTRD = CENTERED	MISC = MISCELLANEOUS	THD = THREAD
DET = DETAIL	MPS = MISCELLANEOUS PIPE SUPPORT	THK = THICK
DIA = DIAMETER	MS = MISCELLANEOUS SUPPORT	T.O. = TOP OF
DISCH = DISCHARGE	N = NUMBER	TOC = TOP OF CONCRETE
DWL = DOWEL	NF = NEAR FACE	TOG = TOP OF GROUT
DWG = DRAWING	NO. = NUMBER	TYP = TYPICAL
EA = EACH	NS = NEAR SIDE	UON = UNLESS OTHERWISE NOTED
EF = EACH FACE	NTD = NOTED	VERT = VERTICAL
EL = ELEVATION (HEIGHT)	NTS = NOT TO SCALE	W/ = WITH
ELEV = ELEVATION VIEW	OC = ON CENTER	W/O = WITHOUT
EQ = EQUAL OR EQUALLY	OD = OUTSIDE DIAMETER	WP = WORK POINT
EW = EACH WAY	OPNG = OPENING	WWF = WELDED WIRE FABRIC
EXIST = EXISTING	OPP = OPPOSITE	@ = AT
FDN = FOUNDATION	P = PROJECTION	℄ = CENTERLINE
FF = FAR FACE	PL = PLATE	∅ = DIAMETER
FIN = FINISH	PROJ = PROJECTION	
FS = FAR SIDE	RAD = RADIUS	
FTG = FOOTING	REF = REFERENCE	
GA = GAUGE OR GAGE	REINF = REINFORCING	

CONCRETE
GENERAL NOTES

STI03310-00
ISSUED: OCT 2011
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PAGE 1 OF 1
STI03310

GENERAL NOTES

1. Materials, construction, and workmanship shall be in accordance with the latest edition of applicable federal, state, and local codes; and PIP STS03001, PIP STS05120, ACI 301 (ACI301M), and ACI SP-66.
2. Unless otherwise noted, concrete shall have a minimum compressive strength of 5,000 psi (28 MPa) at 28 days.
3. Reinforcing steel shall be deformed bars in accordance with ASTM A615/A615M, Grade 60 (420).
4. Welded Wire Reinforcement (WWR) shall be in accordance with ASTM A185/A185M.
5. Reinforcing steel is measured out to out of bar. Hooks and bends shall be in accordance with ACI SP-66.
6. If total number of reinforcing bars is shown on design drawings and spacing is not specified, bars shall be equally spaced.
7. Lap splices for reinforcing steel shall be as shown on design drawings.
8. Cast-in-place anchor bolts and sleeves shall be in accordance with design drawings and PIP STF05121. All other steel embedded items shall be ASTM A36/A36M hot dip galvanized in accordance with ASTM A123/A123M, unless otherwise noted in the contract documents. Welding shall be in accordance with AWS D1.1/D1.1M.
9. Post-installed adhesive anchors and dowels shall be in accordance with the contract documents and the manufacturers written recommendations.
10. All conduits, ground wires, drains, anchor bolts, other embedded items, etc. shall be in place before concrete placement.
11. All exposed corners of concrete above grade shall have minimum 3/4" (20) x 45 degree chamfer finished edge.
12. Unless otherwise noted, structural base plates and non-machinery equipment shall be grouted with non-shrink cementitious grout in accordance with PIP STS03600.
13. Unless otherwise noted, all machinery equipment, including pumps and compressors, shall be grouted with epoxy grout in accordance with PIP STS03601.
14. Unless otherwise noted on design drawings, 1" (25) grout shall be provided under structural base plates and equipment bases.

FOUNDATION DETAILS
LADDER PAD AT PAVED AREA

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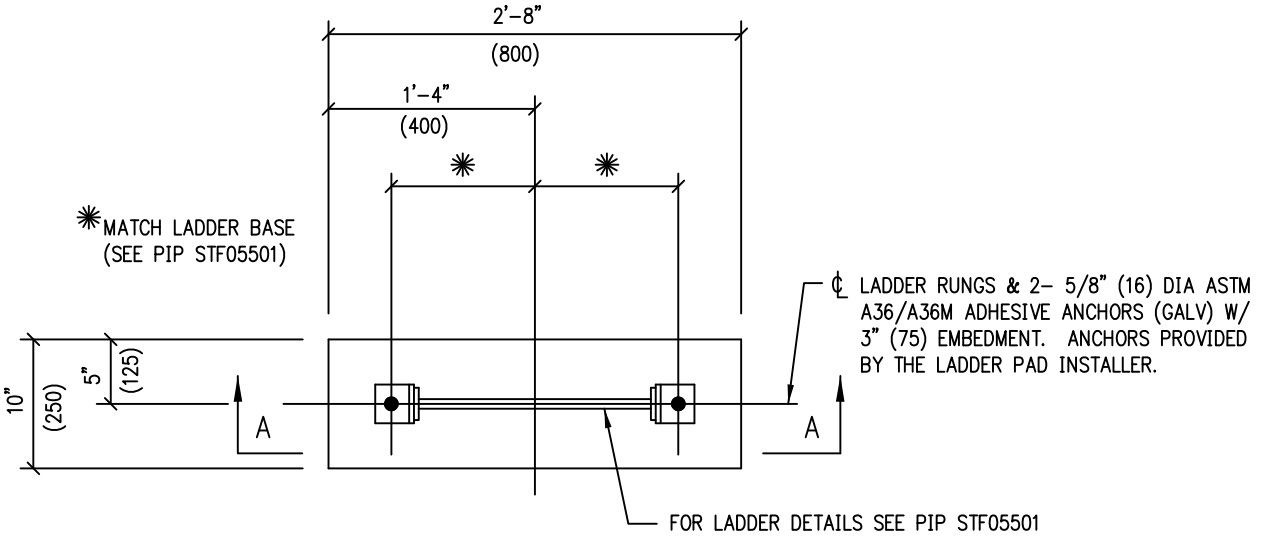
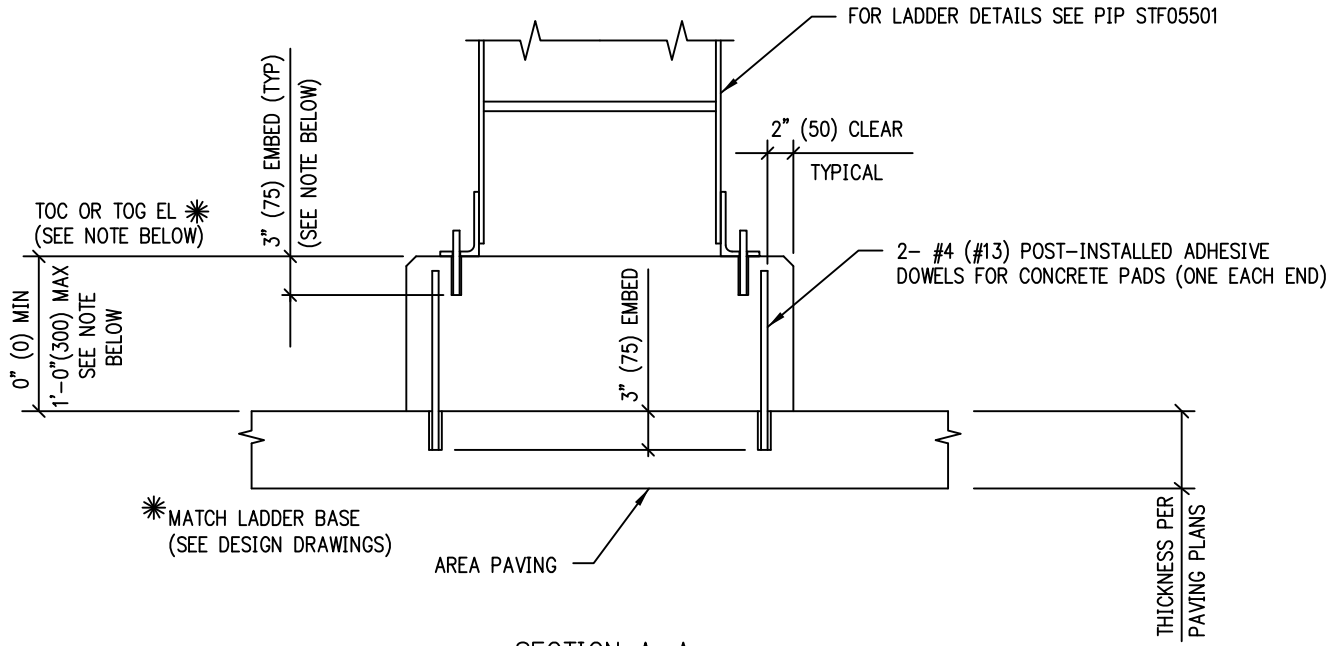
STI03310



PLAN
LADDER PAD



SECTION A-A

NOTE:
- FOR NO PAD, ANCHORS EMBEDDED 3" (75) INTO PAVING SHALL BE PROVIDED.
- FOR PAD UP TO 2" (50), INDIVIDUAL UNREINFORCED GROUT PADS AND ANCHORS EMBEDDED 3" (75) INTO PAVING SHALL BE PROVIDED.
- FOR PADS > 2" (50) TO < 4" (100), FULL LENGTH UNREINFORCED GROUT PAD AND ANCHORS EMBEDDED 3" (75) INTO PAVING SHALL BE PROVIDED.
- FOR PADS 4" (100) TO 1'-0" (300), FULL LENGTH CONCRETE PAD WITH DOWELS AS DESCRIBED ABOVE AND ANCHORS EMBEDDED 3" (75) INTO PAD SHALL BE PROVIDED.
- FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

FOUNDATION DETAILS
LADDER PAD AT GRADE

STI03310-02
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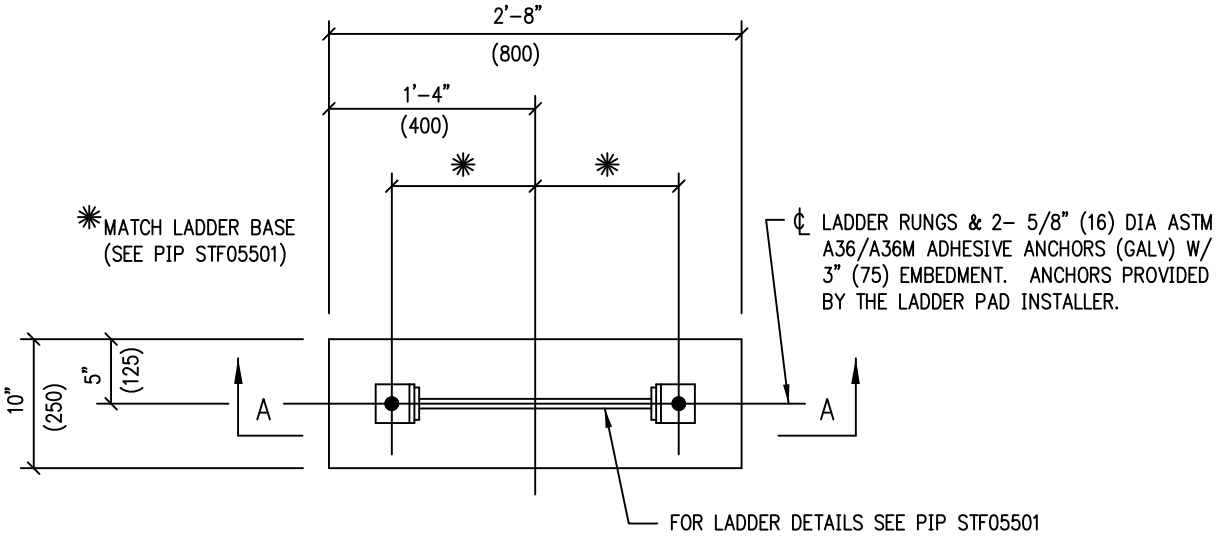
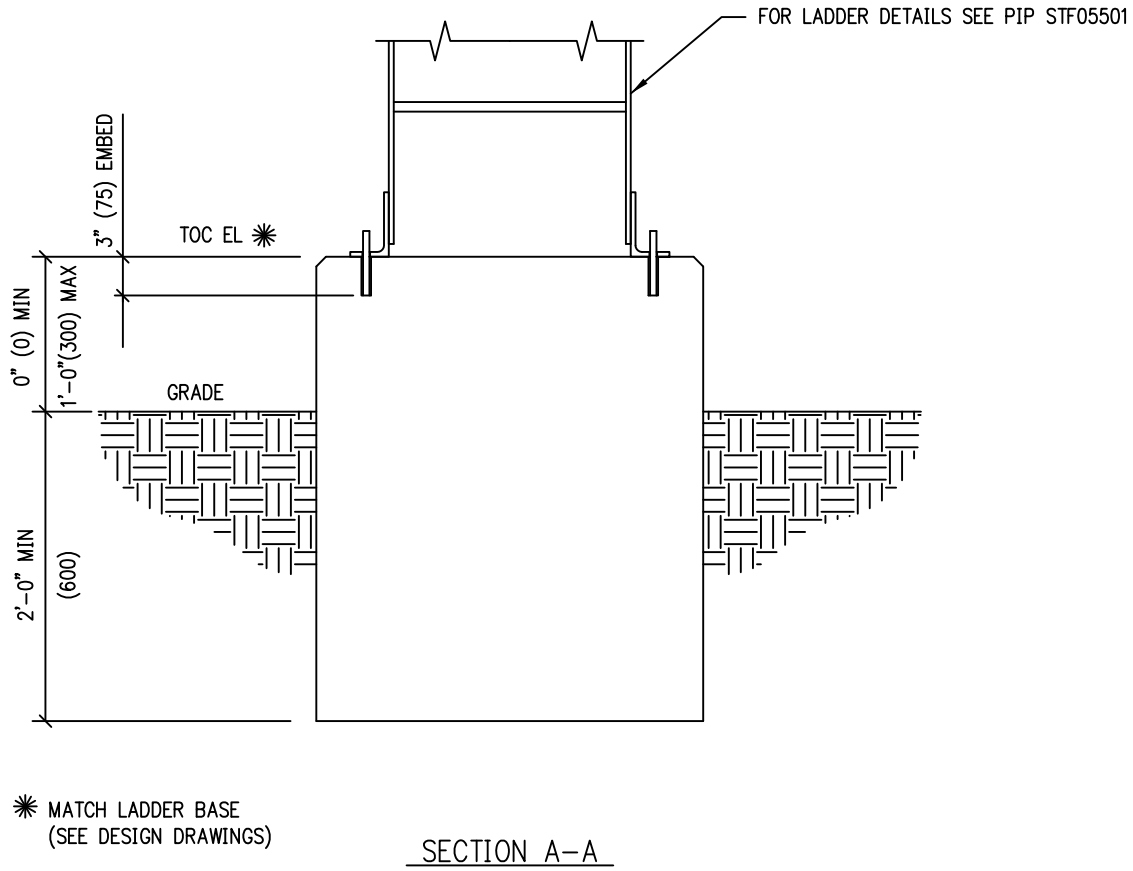
STI03310



PLAN
LADDER PAD



SECTION A-A

NOTES:
1. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

FOUNDATION DETAILS
STAIR PAD AT PAVED AREA

STI03310-03
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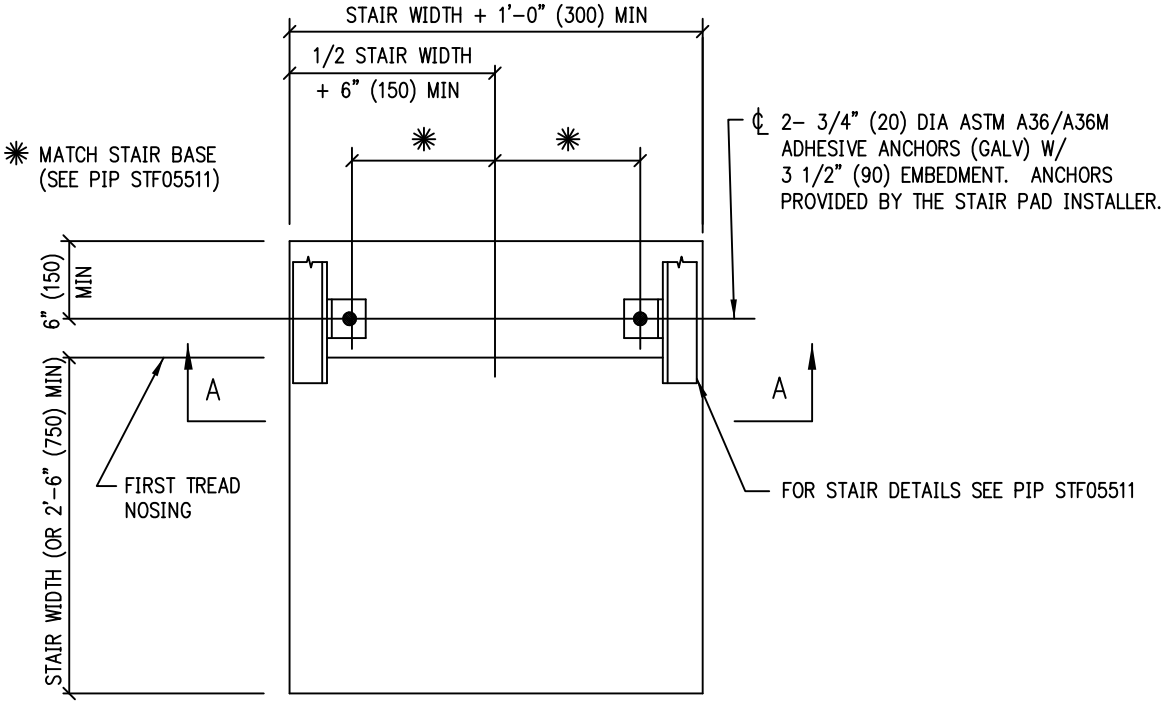
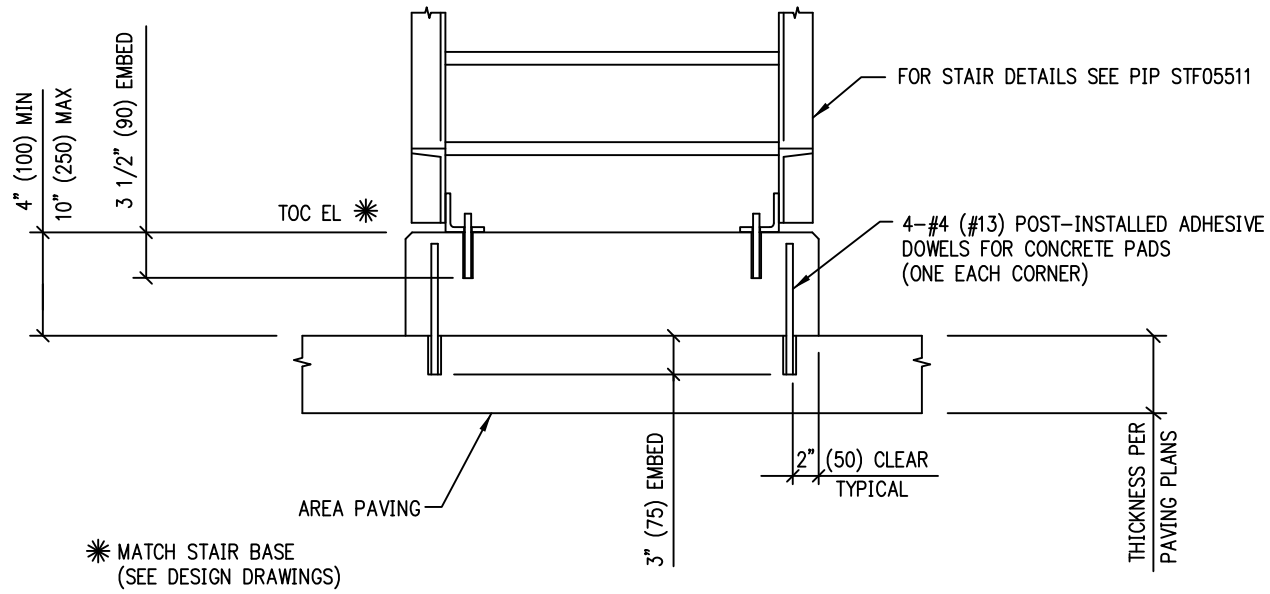
PAGE 1 OF 1
STI03310



PLAN
STAIR PAD



SECTION A-A

NOTES:
1. FOR GENERAL NOTES, SEE STI03310-00.

FOUNDATION DETAILS
STAIR PAD AT GRADE

STI03310-04
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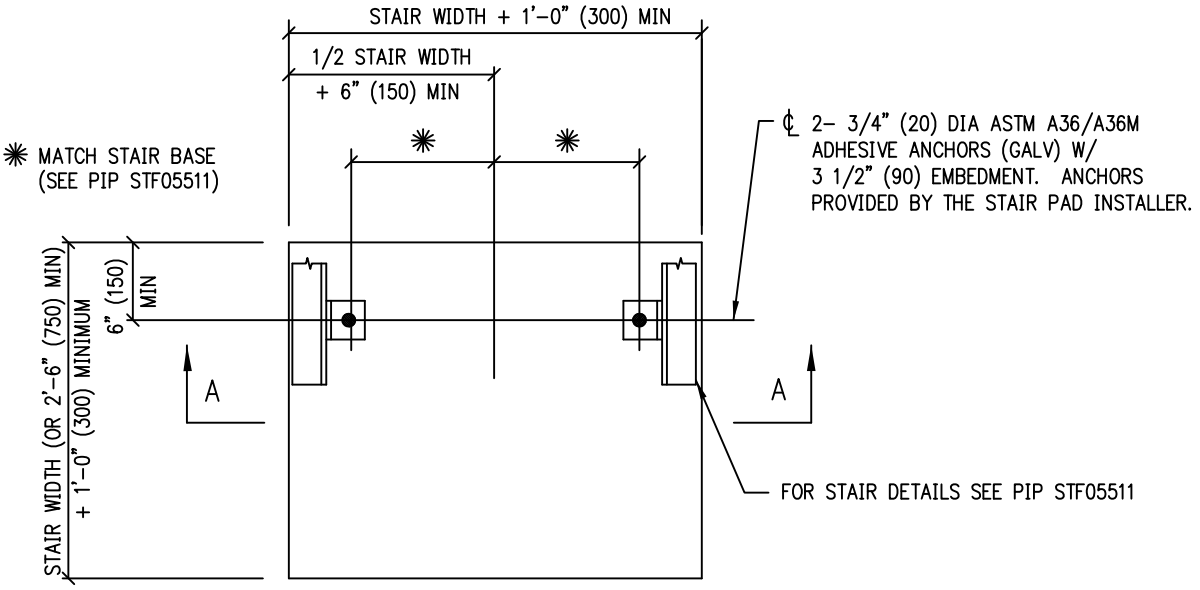
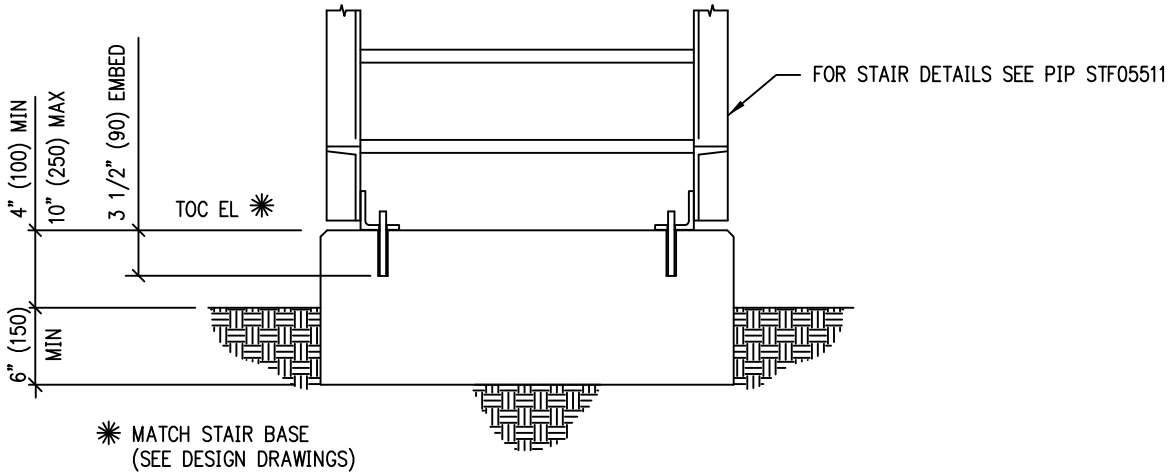
PAGE 1 OF 1
STI03310



PLAN
STAIR PAD



SECTION A-A

NOTES:
1. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

FOUNDATION DETAILS
OCTAGON FOUNDATION DRAIN

STI03310-05
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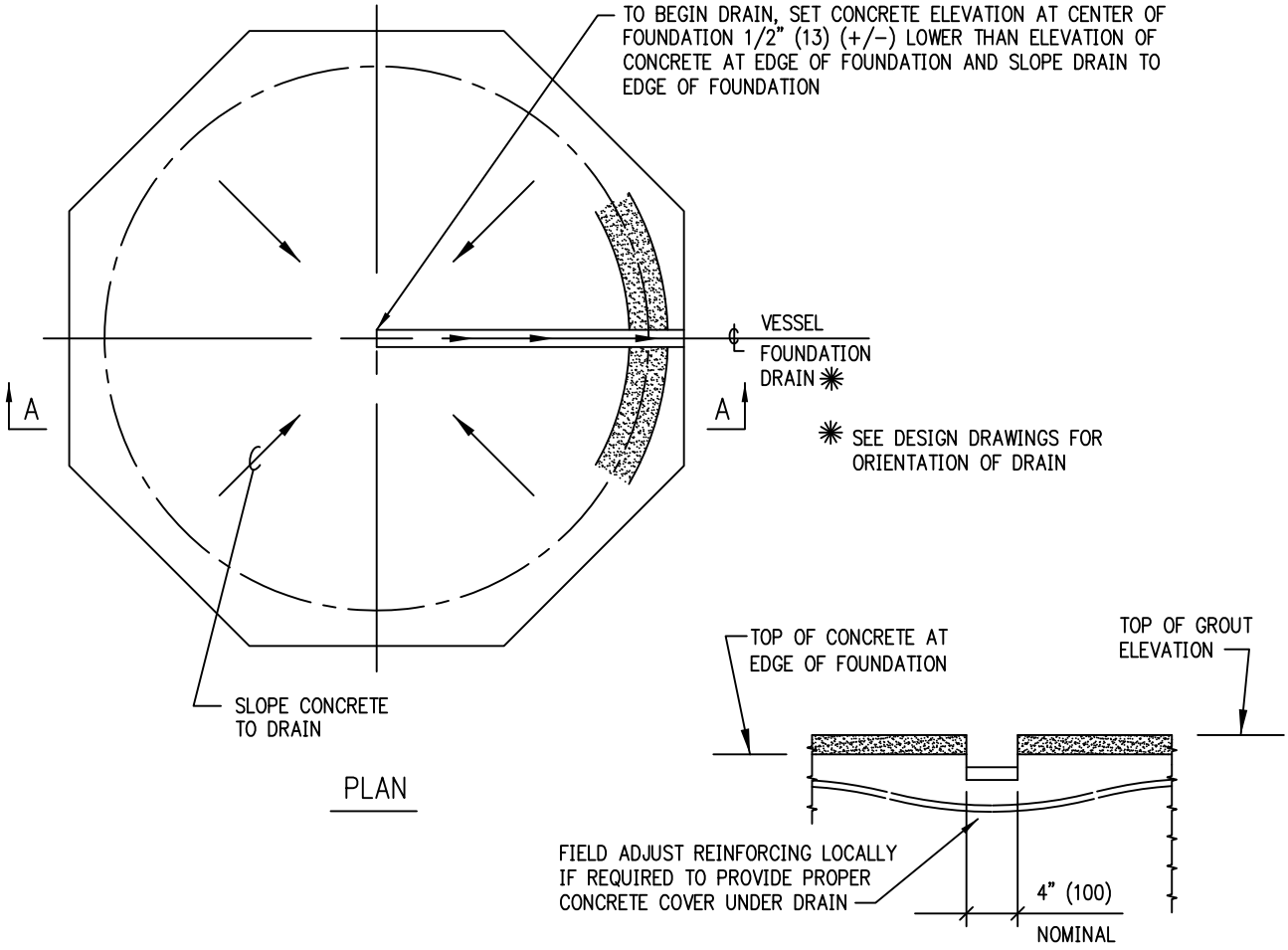

NOTES:
1. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

FOUNDATION DETAILS
REINFORCING CLEARANCES AND TIE SPACING

STI03310-06
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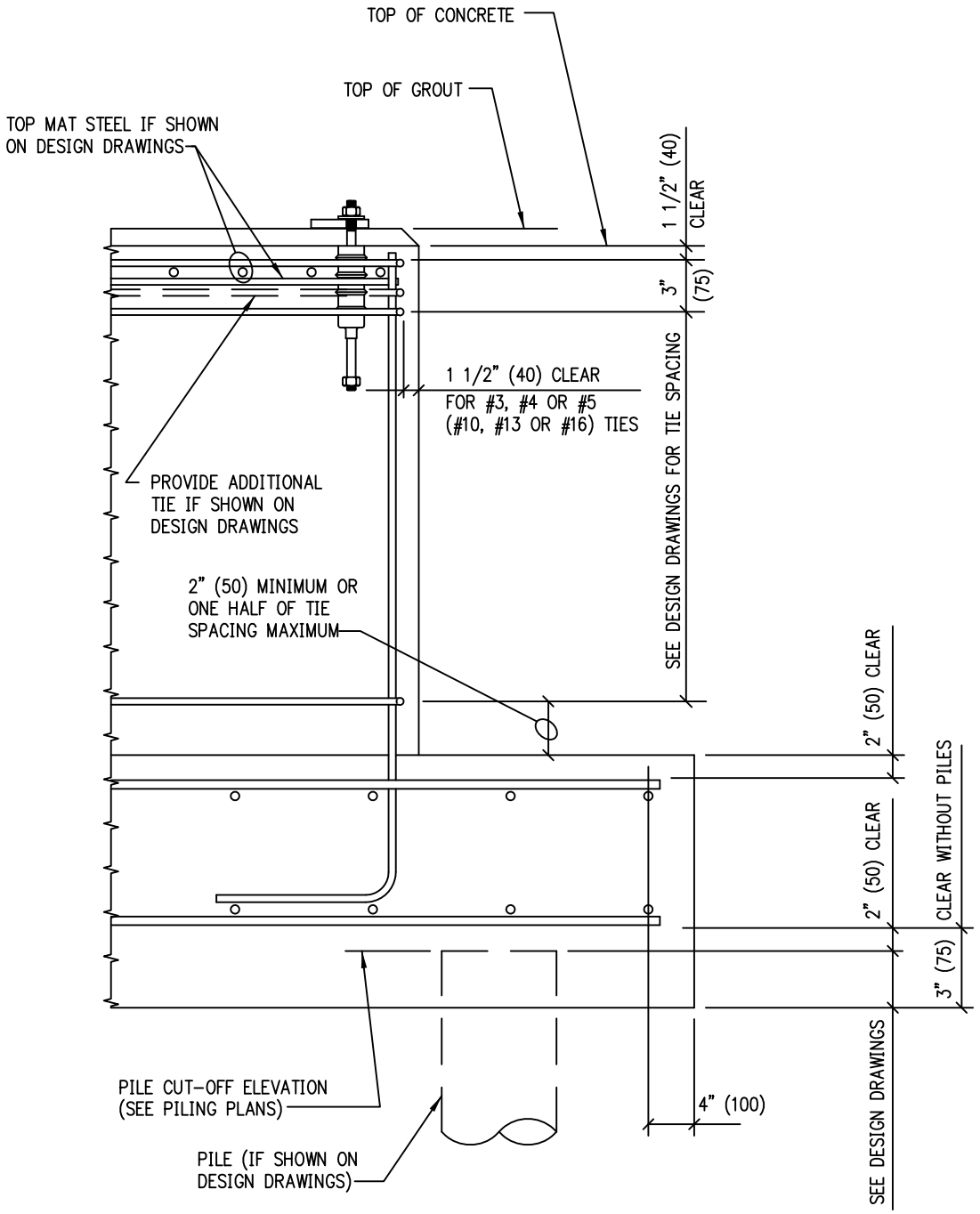
STI03310



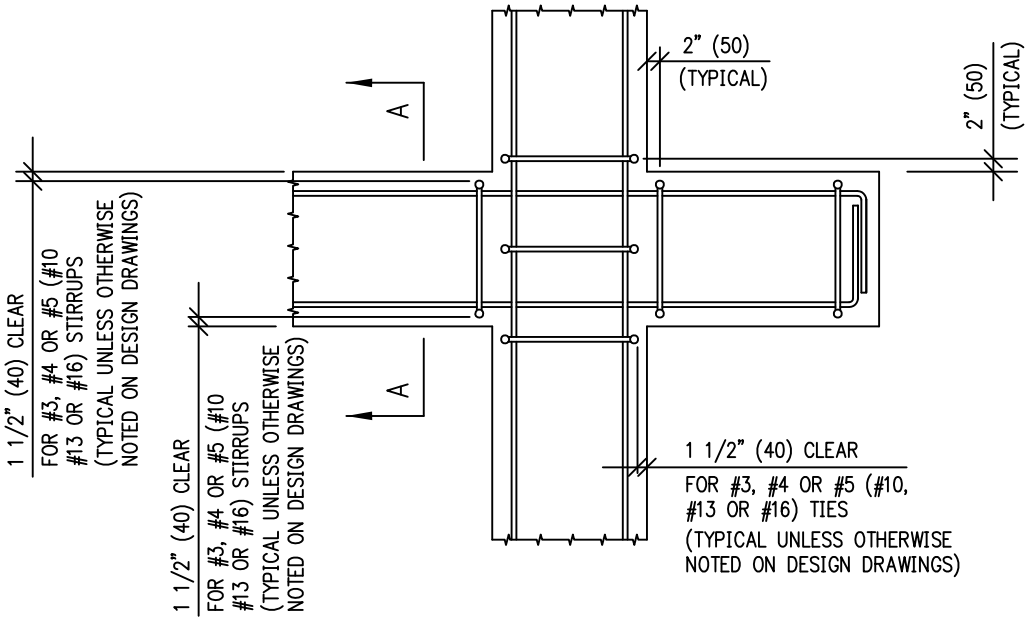
TYPICAL REINFORCING CLEARANCES AND TIE SPACING

DIMENSIONS ARE TYPICAL UNLESS OTHERWISE NOTED ON DESIGN DRAWINGS.

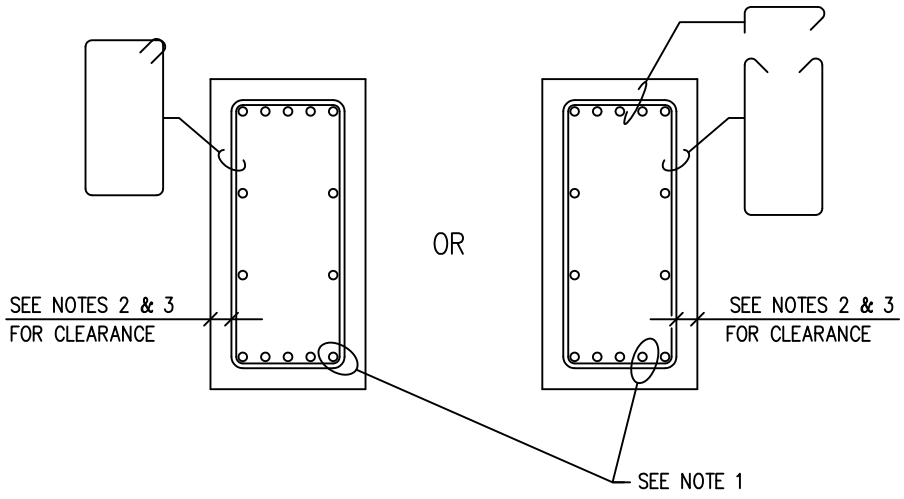
NOTES:

1. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

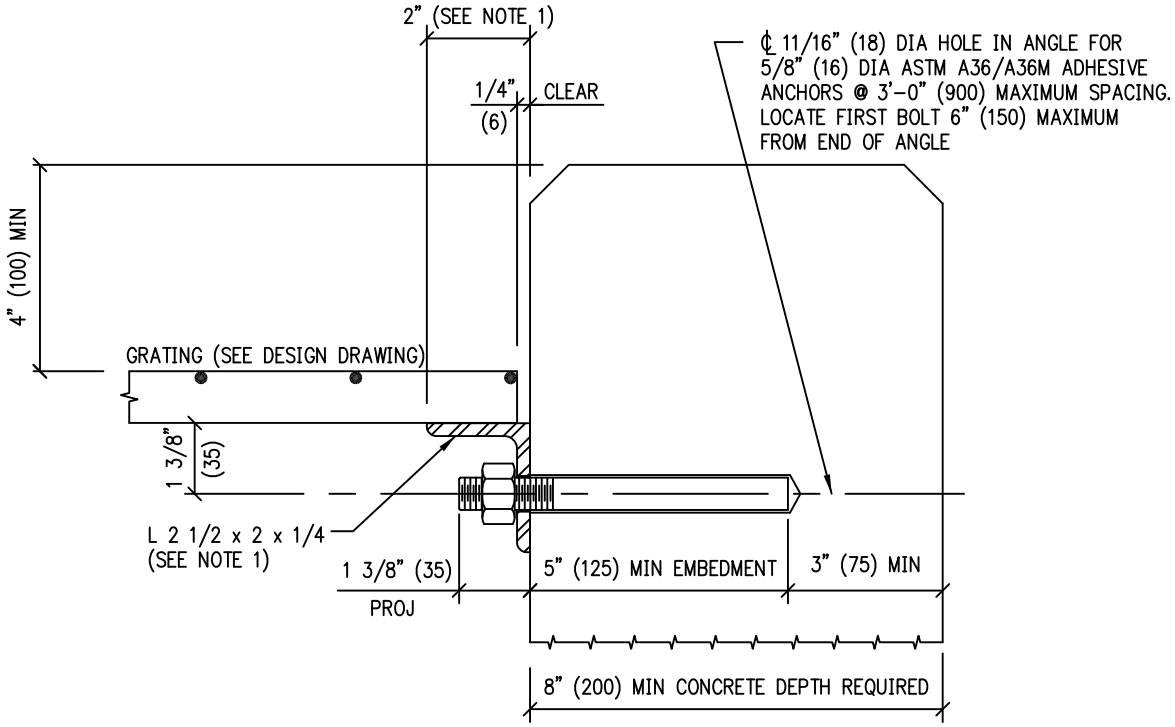


ELEVATION
CONCRETE COLUMN & BEAM

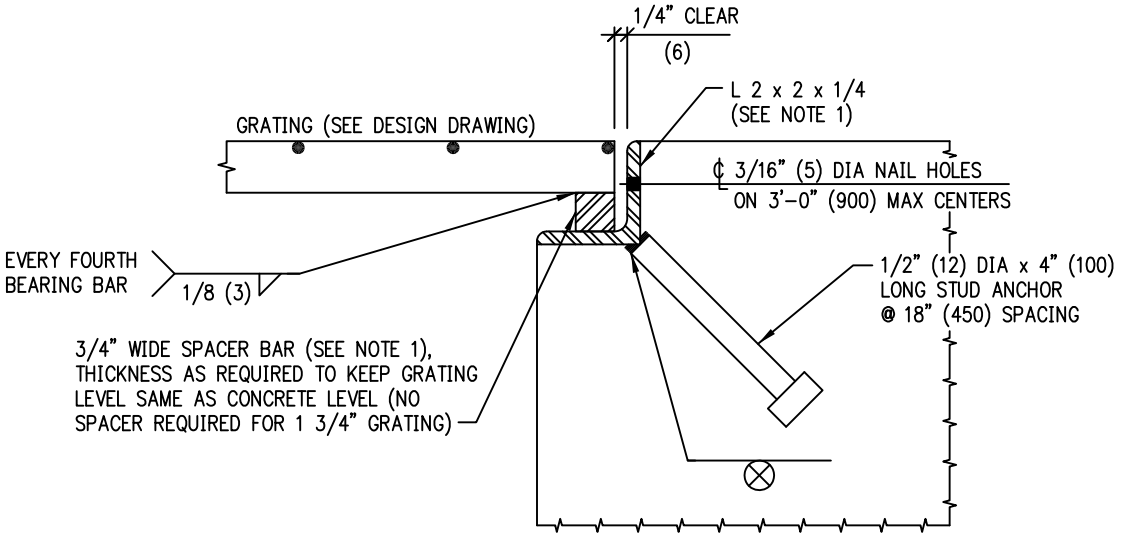


SECTION A-A

NOTES:
1. FOR REINFORCING, SEE DESIGN DRAWINGS.
2. IF BEAM WIDTH IS EQUAL TO COLUMN WIDTH, CLEARANCE TO BEAM STIRRUPS AT SIDE OF BEAM SHALL BE THE DIAMETER OF THE COLUMN MAIN REINFORCING PLUS DIAMETER OF THE COLUMN TIE PLUS 1 1/2" (40) MINUS THE DIAMETER OF THE BEAM STIRRUP FOR THE ENTIRE BEAM LENGTH (TYPICAL UNLESS OTHERWISE NOTED ON DESIGN DRAWINGS).
3. IF BEAM WIDTH IS LESS THAN COLUMN WIDTH, CLEARANCE TO BEAM STIRRUPS AT SIDE OF BEAM SHALL BE 1 1/2" (40) FOR #3, #4 OR #5 (#10, #13 OR #16) STIRRUPS (TYPICAL UNLESS OTHERWISE NOTED ON DESIGN DRAWINGS).
4. FOR GENERAL NOTES, SEE STI03310-00.



BOLTED LEDGER ANGLE FOR 1" TO 1 3/4" GRATING
(SEE NOTE 1)



EMBEDDED CURB ANGLE FOR 1" TO 1 3/4" GRATING
(SEE NOTE 1)

NOTES:
1. IF APPLICABLE, METRIC EQUIVALENT ANGLES, BARS AND GRATING SHALL BE AS SPECIFIED IN CONTRACT DOCUMENTS.
2. ANGLE ASSEMBLIES SHALL BE FABRICATED AND HOT DIP GALVANIZED AFTER FABRICATION IN ACCORDANCE WITH PIP STS05120.
3. LEDGER AND CURB ANGLES FOR GRATING OVER 1 3/4" THICK SHALL BE AS SHOWN ON DESIGN DRAWINGS.
4. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS
IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

MISCELLANEOUS DETAILS
FLOOR PLATE LEDGER AND CURB ANGLES

STI03310-21
ISSUED: OCT 2011
REAFFIRMED: N/A
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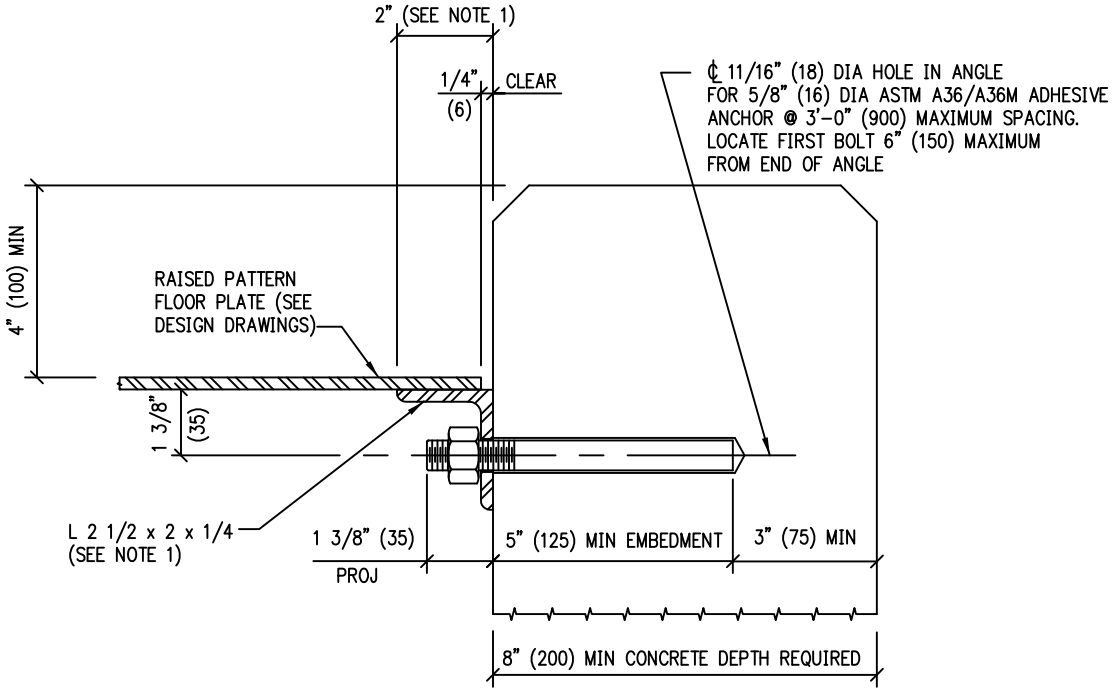
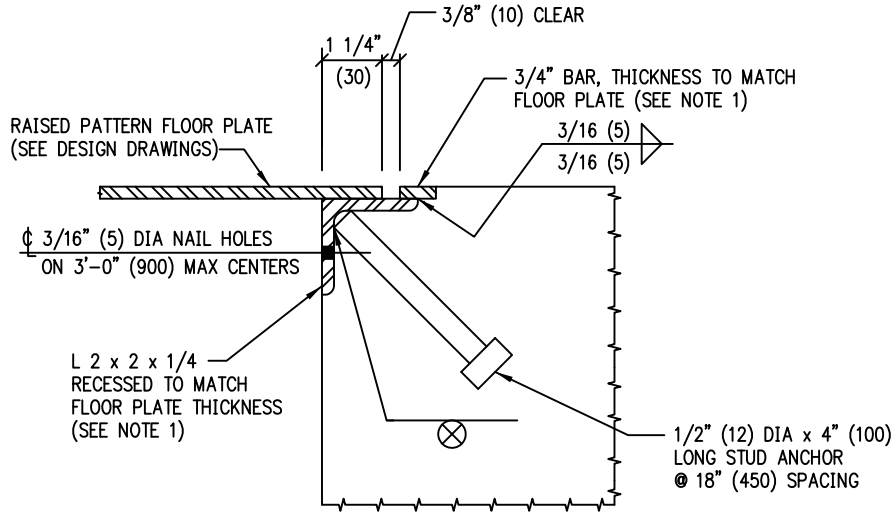
STI03310



BOLTED LEDGER ANGLE FOR 1/4" OR 5/16" RAISED PATTERN FLOOR PLATE
(SEE NOTE 1)



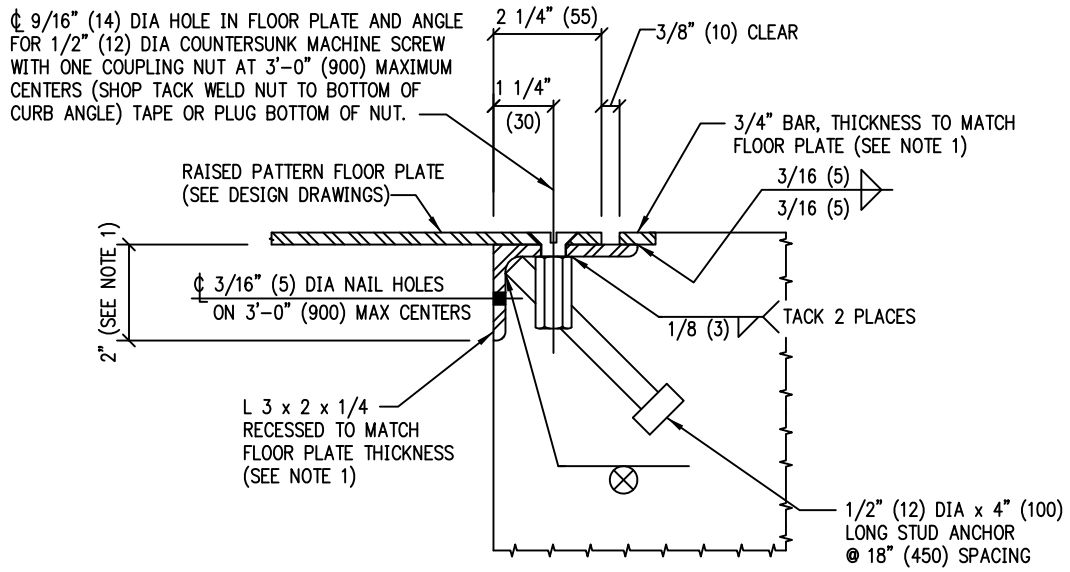
EMBEDDED CURB ANGLE FOR 1/4" OR 5/16" RAISED PATTERN FLOOR PLATE
(SEE NOTE 1)

NOTES:
1. IF APPLICABLE, METRIC EQUIVALENT ANGLES, BARS AND GRATING SHALL BE AS SPECIFIED IN CONTRACT DOCUMENTS.
2. ANGLE ASSEMBLIES SHALL BE FABRICATED AND HOT DIP GALVANIZED AFTER FABRICATION IN ACCORDANCE WITH PIP STS05120.
3. FOR GENERAL NOTES, SEE STI03310-00.

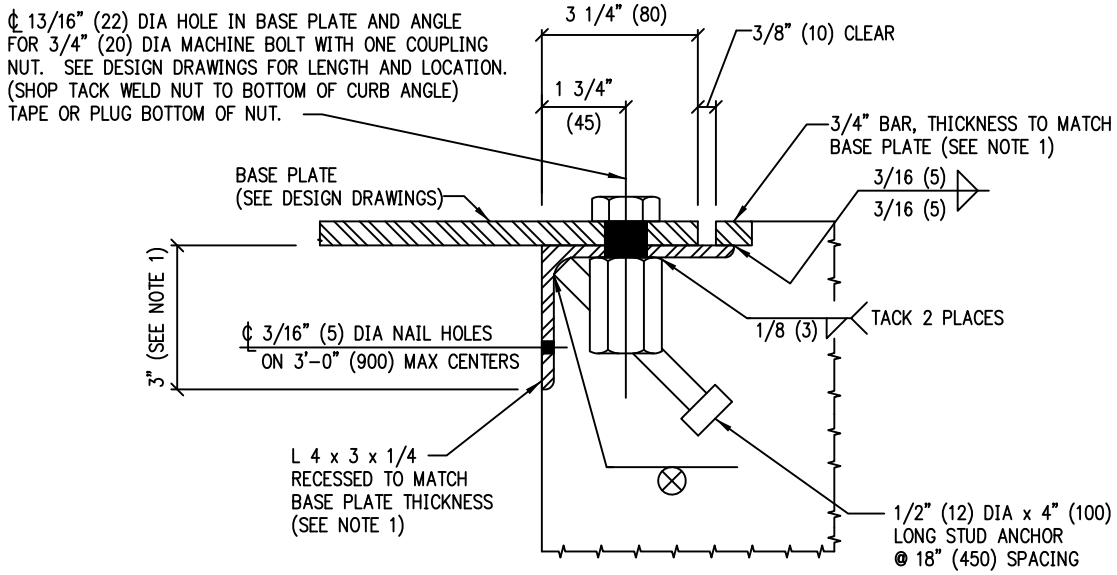
DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

MISCELLANEOUS DETAILS
BOLTED PLATE CURB ANGLES

STI03310-22
ISSUED: OCT 2011
REAFFIRMED: N/A
PAGE 1 OF 1
STI03310



EMBEDDED CURB ANGLE FOR BOLTED 1/4" OR 5/16" RAISED PATTERN FLOOR PLATE
(SEE NOTE 1)



EMBEDDED CURB ANGLE FOR BOLTED PLATE MOUNTED EQUIPMENT
(SEE NOTE 1)

NOTES:
1. IF APPLICABLE, METRIC EQUIVALENT ANGLES, BARS AND GRATING SHALL BE AS SPECIFIED IN CONTRACT DOCUMENTS.
2. ANGLE ASSEMBLIES SHALL BE FABRICATED AND HOT DIP GALVANIZED AFTER FABRICATION IN ACCORDANCE WITH PIP STS05120.
3. CONNECTION BOLTS/SCREWS SHALL BE HOT DIP GALVANIZED AND ATTACHED TO ASSEMBLIES FOR SHIPPING.
3. FOR GENERAL NOTES, SEE STI03310-00.

DIMENSIONS ARE GIVEN IN FEET AND/OR INCHES. METRIC DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
January 2017

Structural

PIP STS02360
Driven Piles Specification

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PUBLISHING HISTORY

April 1995	*Issued*
June 2001	*Complete Revision*
September 2008	*Complete Revision*
January 2017	*Complete Revision*

Not printed with State funds

PIP STS02360
Driven Piles Specification

Table of Contents

Data Sheet

PIP STS02360-D – Pile and Driving Equipment Data Sheet (U.S. Customary Units)
PIP STS02360-DM – Pile and Driving Equipment Data Sheet (SI Units)

1. Scope

This Practice describes the requirements for supplying, transporting, handling, installing, and testing driven load-bearing piles. Pile types covered in this Practice are as follows:

a. Steel pipe piles

b. Concrete-filled thin shell piles

c. Steel H-piles

d. Step taper piles

e. Prestressed/precast concrete piles

f. Timber piles

2. References

Applicable parts of the following Practices, industry codes and standards, and government regulations shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP STS03001 - *Plain and Reinforced Concrete Specification*
- PIP STS02360-D - *Pile and Driving Equipment Data Sheet (U.S. Customary Units)*
- PIP STS02360-DM - *Pile and Driving Equipment Data Sheet (SI Units)*

2.2 Industry Codes and Standards

- American Concrete Institute (ACI)
  - ACI 222R - *Protection of Metals in Concrete Against Corrosion*
  - ACI 543R - *Guide to Design, Manufacture, and Installation of Concrete Piles*
- ASTM International (ASTM)
  - ASTM A6/A6M - *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A53/A53M - *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*
  - ASTM A252 - *Standard Specification for Welded and Seamless Steel Pipe Piles*
  - ASTM A572/A572M - *Standard Specification for High-Strength, Low-Alloy Columbium-Vanadium Structural Steel*
  - ASTM A615/A615M - *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*
  - ASTM D25 - *Standard Specification for Round Timber Piles*

  - ASTM D1143/D1143M - *Standard Test Methods for Deep Foundations Under Static Axial Compressive Load*
  - ASTM D2899 - *Standard Practice for Establishing Allowable Stresses for Round Timber Piles*
  - ASTM D3689 - *Standard Test Methods for Deep Foundations Under Static Axial Tensile Load*
  - ASTM D3966/D3966M - *Standard Test Methods for Deep Foundations Under Lateral Load*

- American Welding Society (AWS)
  - AWS D1.1/D1.1M - *Structural Welding Code - Steel*
- American Wood-Preservers' Association (AWPA)
  - AWPA M4 - *Standard for the Care of Preservative-Treated Wood Products*
  - AWPA T1 - *Use Category System: Processing and Treatment Standard*
  - AWPA U1 - *Use Category System: User Specification for Treated Wood*
- Precast/Prestressed Concrete Institute (PCI)
  - PCI Journal, Volume 38, No.2, March/April 1993 (PCI JR-382) - *Recommended Practice for Design, Manufacture and Installation of Prestressed Concrete Piling*
  - PCI MNL-116 - *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products*

3. Definitions

constructor: Party responsible for supplying all materials, equipment, tools, supervision, and labor for installation of piles in accordance with contract documents. The term constructor shall apply also to constructor's subcontractor(s) and vendor(s).

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets that the purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between the purchaser and the constructor.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of civil works, structures, foundations, materials and appurtenances described in contract documents. Engineer of record shall be licensed as defined by the laws of the locality in which the work is to be constructed, and be qualified to practice in the specialty discipline required for the work described in the contract documents.

fabricator: Party responsible for providing fabricated structural and miscellaneous steel in accordance with contract documents. The term fabricator shall apply also to fabricator's subcontractor(s) and/or vendor(s).

geotechnical engineer: Professional Engineer responsible for performing geotechnical investigation and/or geotechnical consulting during foundation design, construction of civil works, installation of piling and foundations

inspector: Party responsible for verifying quality of all materials, installations, and workmanship furnished by constructor. Inspector shall be qualified by training and experience and hold certifications or documentation of their qualifications. Unless otherwise specified in contract documents, inspector shall be an independent party retained by purchaser.

manufacturer: Party who produces and warrants the performance of piles, and other materials and/or items provided in accordance with contract documents. Piles and other materials and/or items are manufactured in a controlled process using standard codes, specifications, tests and possibly include shop drawings to assist in proper application, installation and/or use. The term manufacturer shall apply also to manufacturer's subcontractor(s) and/or vendor(s).

owner: Party who has authority through ownership, lease, or other legal agreement over the site and facility wherein piles are to be installed.

professional engineer: An engineer, other than engineer of record, licensed as defined by the laws of the locality in which piles are to be installed and qualified to practice in the specialty discipline required for the work described in contract documents

purchaser: Party who awards the contract to constructor, fabricator, manufacturer and/or supplier. Purchaser may be the owner or owner's authorized agent.

4. Requirements

4.1 Quality Control

4.1.1 Data from subsurface investigation(s) furnished by purchaser shall be reviewed by constructor. Such data shall not be construed to represent subsurface conditions at locations other than the specific boring/sounding location indicated. Additional investigations may be performed at constructor's own discretion and expense with approval of the engineer of record provided results are reviewed by the owner's geotechnical engineer.

4.1.2 Intended exposure requirements for piles, e.g., marine, non-marine, freeze-thaw, chemical attack, soil corrosiveness, etc., shall be furnished by engineer of record. Protective coatings or admixtures for piles shall be fit for purposes as required by exposure conditions.

4.1.3 Engineer of record shall be immediately notified in writing of any situations detrimental to proper and timely completion of the work.

4.2 Quality Assurance

4.2.1 An independent testing agency will be retained by purchaser for inspection of all piles and all pile-driving operations.

4.2.2 Testing agency shall furnish inspectors experienced in pile-driving inspection and shall be on site full time during installation of all piles.

4.2.3 Inspector qualifications including a resume of the inspector to be provided by independent testing agency shall be submitted to engineer of record and owner's geotechnical engineer for review and approval not less than 14 days before mobilization.

4.2.4 Testing agency shall document driving in accordance with Section 4.3.9, and shall certify that piles and installation are in accordance with this Practice and the contract documents.

4.2.5 Testing agency shall be responsible for pile concrete testing and sampling.

4.2.6 Testing agency shall notify constructor and engineer of record immediately of any observed deviations from this Practice and contract documents.

4.2.7 Engineer of record, purchaser's inspector and assigned independent testing agencies inspector shall have the right to make additional or independent inspections and tests at any time.

4.2.8 Engineer of record and owner's geotechnical engineer shall be notified not less than 3 working days before installation or testing of piles.

4.2.9 Readily visible marks shall be provided on all piles at 1-ft (300 mm) intervals and marks shall be numbered every 5 ft (1500 mm) starting at the tip.

4.2.10 Engineer of record, owner's geotechnical engineer, purchaser's inspector or assigned independent testing agencies inspector may reject piles that are not in accordance with all requirements of this Practice or contract documents, including piles that are damaged, misplaced, driven improperly, or out of alignment.

4.2.11 Rejected piles shall be corrected as directed by engineer of record or owner's geotechnical engineer. Correction may include extracting the rejected pile and driving a new pile or additional piles. All corrective work shall be performed at no additional cost to purchaser or owner.

4.3 Submittals

4.3.1 Execution Plan Documentation

The following shall be submitted to the engineer of record and owner's geotechnical engineer for review not less than 14 days before commencement of mobilization:

a. Procedure for protection, handling, and storage of piles before installation including dunnage/lifting locations and maximum tolerable sweep for each pile size and length

b. Identification and description of equipment for handling and installing piles

c. Completed *PIP STS02360-D* or *PIP STS02360-DM* as applicable, with manufacturer's hammer specification data and recommended operating procedures, including details of any hammer modifications

d. Pile installation procedures, including any pre-drilling and/or jetting equipment and procedures. A copy of a blank pile driving record proposed for use on the project shall be included.

e. Calibration certificates for pressure gauges, current within 6 months, and manufacturer's calibration of bounce-chamber gauges

f. Pile and pile accessory material certifications

g. Plan of proposed sequence of driving

h. Proposed plan to monitor ground heave for both the ground surface and the newly installed piles

i. Proposed pile acceptance criteria for approval by engineer of record and owner's geotechnical engineer

4.3.2 Prestressed/Precast Concrete Pile

4.3.2.1 The following shall be submitted to engineer of record and owner's geotechnical engineer for review not less than 14 days before commencing manufacturing:

a. All design calculations and manufacturing drawings for piles, including, uplift connections and splices, sealed by constructor's responsible professional engineer

b. A pile driving study including computer analysis of dynamic stresses during pile driving that confirm that tension and compressive stresses during low-resistance and final high-resistance driving are less than allowable stresses for the piles. The range of performance characteristics of constructor's proposed pile driving hammer, cushion blocks and appurtenances using the proposed pile shall be modeled using a proven, generally-available computer program acceptable to the project engineer of record and geotechnical engineer.

c. Concrete mix design and basis for mix

d. Method of curing

e. Sampling and testing procedures

f. Certified test reports that confirm all materials to be used in manufacture of piles, including strands, wire, cement, aggregates, admixtures, and curing are in accordance with this Practice

g. Procedures for tensioning and detensioning, including equipment descriptions and calibration records

h. Shop drawings

4.3.2.2 Prestress loss calculations and the tensioning records in accordance with *PCI MNL-116* shall be submitted to engineer of record and owner's geotechnical engineer within 7 days after tensioning.

4.3.2.3 Concrete cylinder strength test results for each lot of piles, including strengths at time of prestress transfer, when removed from casting bed, and 28 days after pour shall be submitted to engineer of record and owner's geotechnical engineer upon completion of pile manufacturing.

4.3.3 Steel H-Pile

The following shall be submitted to the engineer of record and owner's geotechnical engineer for review not less than 14 days before commencing fabrication:

a. All design calculations and fabrication drawings for piles, including pile shoes, uplift connections and splices, sealed by a qualified, responsible professional engineer

b. A pile driving study including computer analysis of dynamic stresses during pile driving that confirm that the tension and compressive stresses during low-resistance and final high-resistance driving are less than the allowable stresses for the piles. The range of performance characteristics of constructor's proposed pile driving hammer, cushion blocks and appurtenances using the proposed pile shall be modeled using a proven, generally-available computer program acceptable to project engineer of record and geotechnical engineer.

4.3.4 Steel Pipe Pile

The following shall be submitted to engineer of record and owner's geotechnical engineer for review not less than 14 days before commencing fabrication:

a. All design calculations and fabrication drawings for piles, including pile shoes, uplift connections and splices, sealed by the constructor's qualified, responsible professional engineer

b. A pile driving study including computer analysis of dynamic stresses during pile driving that confirm that the tension and compressive stresses during low-resistance and final high-resistance driving are less than the allowable stresses for the piles. The range of performance characteristics of constructor's proposed pile driving hammer, cushion blocks and appurtenances using the proposed pile shall be modeled using a proven, generally-available computer program acceptable to project engineer of record and geotechnical engineer.

4.3.5 Tapered Pile

The following shall be submitted to engineer of record and owner's geotechnical engineer for review not less than 14 days before commencing fabrication:

a. All design calculations and fabrication drawings for piles, including pile shoes, uplift connections and splices, sealed by a qualified, responsible professional engineer

b. A pile driving study including computer analysis of dynamic stresses during pile driving that confirm that the tension and compressive stresses during low-resistance and final high-resistance driving are less than the allowable stresses for the piles. The range of performance characteristics of constructor's proposed pile driving hammer, cushion blocks and appurtenances using the proposed pile shall be modeled using a proven, generally-available computer program acceptable to project engineer of record and geotechnical engineer.

4.3.6 Concrete-Filled Pile

4.3.6.1 The following information shall be submitted to engineer of record and owner's geotechnical engineer for review not less than 14 days before commencement of mobilization:

a. Concrete mix design and basis for mix

b. Sampling and testing procedures

c. Concrete placement procedures

4.3.6.2 Concrete cylinder strength test results for each lot of piles, including strengths at 7 and 28 days after pour shall be submitted to engineer of record and owner's geotechnical engineer.

4.3.7 Timber Pile

The following information shall be submitted to the engineer of record and owner's geotechnical engineer not less than 14 days before installation:

a. Certificate of treatment for each lot of treated timber piles, showing treatment method and type of preservative and minimum net retention of preservative

b. An independent report by an independent inspection agency, attesting that piles have been treated with preservative in accordance with this Practice. This agency shall be experienced with wood preservation and is likely different than the installation inspection agency.

c. A pile driving study including computer analysis of dynamic stresses during pile driving that confirm that tension and compressive stresses during low-resistance and final high-resistance driving are less than allowable stresses for the piles. The range of performance characteristics of constructor's proposed pile driving hammer, cushion blocks and appurtenances using the proposed pile shall be modeled using a proven, generally-available computer program acceptable to project engineer of record and geotechnical engineer.

4.3.8 Pile Load Test

The following submittals shall be provided to engineer of record and owner's geotechnical engineer for review not less than 14 days before commencing the test:

a. Shop drawings of loading apparatus and arrangement of the test and all design calculations, sealed by the constructor's responsible professional engineer

b. Current calibrations of load-cell and jack/jack manometer within one year of the planned completion of test

4.3.9 Pile-Driving Record

4.3.9.1 One copy of the proposed pile-driving record form for pile-driving record keeping shall be submitted to engineer of record and owner's geotechnical engineer for review and approval not less than 14 days prior to beginning installation.

4.3.9.2 During installation, one copy of the completed pile-driving record for each pile shall be submitted to engineer of record and owner's geotechnical engineer within 3 days of completion of driving. Submitted pile-driving record shall be the hand-written field record completed and signed by the inspector in the field and shall be clearly legible.

4.3.9.3 Pile-driving record shall include but not be limited to the following information:

a. Project name, number, and location

b. Drawing number and structure identification

c. Name of constructor, subcontractors, and suppliers

d. Date of pile installation

e. Pile location, number, and design capacity; location of pile in pile group and location or designation of pile group

f. Pile type, size, and length

g. Design and actual pile cut-off and tip elevations

h. Hammer make, model, stroke, weight, normal operating speed, and rated energy

i. Type, dimension, and condition of cushion or capblock

j. Operating pressure for steam/air hammer and bounce chamber pressure for double-acting diesel hammer

k. Actual operating rate or speed (blows/minute) during final driving

l. Other installation equipment including details on use of pile cushion, follower, mandrels, pre-drilling, and water jet

m. Time for start and finish of driving pile

n. Sequence of pile driving for piles in group

o. Penetration under own weight and penetration under own weight plus weight of hammer

p. Driving data in number of blows per foot from initial to final driving and number of blows per 1 inch (25 mm) for the last 12 inches (300 mm)

q. Splice types and locations

r. Upon termination of the driving of open-end pipe piles, record depth from ground surface outside pile to soil surface inside pipe. Record depth of any clean out if used. Note any water in the pipe.

s. Records of re-striking

t. Interruptions (reason, time, duration, tip elevation)

u. Volume of cast-in-place concrete placed

v. Degree of out-of-axial alignment

w. Deviations from contract documents

x. Weather conditions and temperature

y. Notation of any unusual occurrences during installation or of any observed pile damage

z. Signature and title of inspector recording pile-driving data

4.4 Materials

4.4.1 General

4.4.1.1 All constructor-supplied materials and proprietary items, including piles, splice devices, tip protectors, driving shoes, tension or uplift connectors, etc., shall be subject to engineer of record's and owner's geotechnical engineer's approval and shall be installed in accordance with manufacturer's instructions.

4.4.1.2 Concrete shall be in accordance with *PIP STS03001*. Additional requirements for concrete to be used in PCPS piles are presented in Section 4.4.2.

4.4.1.3 Welding

1. Welding shall be in accordance with *AWS D1.1/D1.1M*.
2. Welding filler metal shall be in accordance with *AWS D1.1/D1.1M*, Section 3.3 with electrode strength of 58 ksi (400 MPa) minimum yield strength and 70 ksi (482 MPa) minimum tensile strength.
3. E60XX electrodes may be used for tack welding.
4. Welding procedures and individual welders shall be qualified in accordance with *AWS D1.1/D1.1M*.
5. Qualification records shall be made available to engineer of record and owner's geotechnical engineer for review.

4.4.1.4 Splicing

1. Splices shall provide true alignment of total pile.
2. Splices shall be capable of transmitting all driving forces and all intended service loads.
3. Spliced piles receiving concrete fill shall be watertight after driving to prevent increasing the water/cement ratio and loss of strength. Such piles shall have water and debris removed before concrete fill is placed.

4.4.2 Prestressed/Precast Concrete Piles

4.4.2.1 Design and manufacture of concrete piles shall be in accordance with *PCI JR-382*, *PCI MNL-116*, and *ACI 543R*.

4.4.2.2 For prestressed concrete piles, pile manufacturer's mix design can be used with approval of engineer of record and owner's geotechnical engineer.

4.4.2.3 Pile materials shall be the following types:

a. Concrete shall be minimum 5000 psi (35 MPa) 28-day compressive strength concrete meeting the requirements of *PCI JR-382, PCI MNL-116,* and *ACI 543R*. The maximum aggregate size shall be 3/4 inch (20 mm).

b. Pre-stressing strand shall be in accordance with recommendations of *ACI 543R* for materials, handling, and placement in forms.

c. Deformed reinforcing bars and smooth steel reinforcing shall be in accordance with recommendations of *ACI 543R* for materials, handling, and placement in forms.

d. Embedded metals and strands shall be protected from corrosion as recommended by *ACI 222R*.

4.4.2.4 Transportation, handling, and storage shall be in accordance with *PCI JR-382*. Lift points shall be plainly marked and lift direction shall be shown.

4.4.2.5 Each pile shall be clearly labeled with pile number assigned at the casting yard to correlate quality control data.

4.4.3 Steel H-Piles

4.4.3.1 Pile material shall be in accordance with *ASTM A36/A36M* or *ASTM A572/A572M* Grade 50, HP shapes in accordance with *ASTM A6/A6M*.

4.4.3.2 Splices shall be either of the following types:

a. Full-penetration butt welds using backup plates or back gouging

b. H-pile splicer sleeves, fillet welded to pile web in accordance with contract design drawings, and full-penetration butt-welded to pile flanges. Each flange of upper pile section shall be bevelled, leaving 1/8 inch (3 mm) of metal for weld backing.

4.4.4 Steel Pipe Piles

4.4.4.1 Pipe material shall be welded or seamless steel pipe in accordance with *ASTM A53/A53M*, Grade B, Type E or Type S, or *ASTM A252*, Grade 2.

4.4.4.2 Concrete fill, if required, shall be in accordance with *PIP STS03001* and a minimum of 4000 psi (28 MPa) 28-day compressive strength.

4.4.4.3 Tip closures shall be either of the following types:

a. *ASTM A36/A36M* steel plate welded to beveled pipe end and making a watertight enclosure. Diameter shall not exceed pipe outside diameter.

b. Proprietary weldless drive points with tapered swage and making a watertight joint to pipe. Diameter shall not exceed pipe outside diameter.

4.4.4.4 Drive shoes shall be hardened steel, inside cutting type, within outside diameter of pipe.

4.4.4.5 Splices shall be full-penetration butt welds or proprietary self-sealing, mechanical splices.

4.4.5 Tapered Piles

4.4.5.1 Shell Material

1. Shell material shall be minimum 9-gauge 0.14955-inch (3.75 mm) thickness. Shells may be corrugated or smooth tapers. Shell may change to uniform diameter steel pipe pile as determined by constructor's professional engineer.
2. Welded or seamless steel pipe in accordance with *ASTM A252*, Grade 1 is an alternate shell material.
3. Increase in diameter at each transition shall not exceed 1 inch (25 mm).
4. Shells and joints shall be tight after driving to allow water and debris removal to facilitate placement of concrete fill. This prevents increasing the water/cement ratio and loss of strength.

4.4.5.2 Concrete core shall be in accordance with *PIP STS03001* and constructed with the following materials:

a. Minimum 4000 psi (28 MPa) 28-day compressive strength concrete

b. Reinforcing bars, when required, shall be in accordance with *ASTM A615/A615M* minimum.

4.4.5.3 Tip closures shall conform to mandrel tip, be watertight after pile is driven and be either of the following types:

a. *ASTM A36/A36M* steel plate, seal welded to shell end

b. Shop-formed hemispherical steel, boot welded to shell tip

c. For proprietary thin shell, watertight manufactured type tip closures compatible with manufacturer's shell system

4.4.5.4 Splices shall be either of the following types:

a. For steel pipe, splices in accordance with Section 4.4.4.5

b. For proprietary thin shell, watertight manufactured splice device compatible with manufacturer's shell system

4.4.6 Timber Piles

4.4.6.1 Timber materials shall be in accordance with *ASTM D25* for "clean-peeled" round timber piles, and have minimum allowable design strength of 1200 psi (8.3 MPa) compression parallel to grain in accordance with *ASTM D2899*.

4.4.6.2 Depending on the application specified in contract documents, timber piles shall be of the following species:

a. Piles subject to land or freshwater service: southern pine, ponderosa pine, or Douglas fir

b. Piles subject to marine (brackish or seawater) service: southern pine or Pacific Coast Douglas fir

4.4.6.3 Depending on pile type specified in contract documents, minimum diameters shall be in accordance with the following requirements:

a. Friction piles shall have a butt circumference of 41 inches (1040 mm) minimum (approximately 13-inches (330 mm) diameter) and a minimum tip circumference in accordance with *ASTM D25,* Tables X1.2 and X1.3.

b. End-bearing piles shall have a tip circumference of 25 inches (630 mm) minimum (approximately 8 inches (200 mm) diameter) and a minimum butt circumference in accordance with *ASTM D25,* Table X1.4 and X1.5.

4.4.6.4 Pressure Treatment, Care, and Field Repair

1. Treatment shall be in accordance with *AWPA T1*, *AWPA U1* and Use Category defined in contract documents.
2. All treated piles shall be permanently branded to identify treating company and year of treatment.
3. Care and handling of piles shall be in accordance with *AWPA M4*.
4. Treatment of field cuts caused by handling, cut-offs, installation of uplift connections, and any other daps or holes shall be in accordance with *AWPA M4*.

4.4.6.5 Strapping

1. Strapping shall be high-tensile steel straps, a minimum of 1-1/4 inch (30 mm) wide, having 5100-pounds (22.5 kilonewtons) minimum tensile strength.
2. Strapping shall be secured with crimped seals that develop 80% of strap strength.
3. Two straps shall be installed (after pressure treatment for treated piles), one at 18 inches (450 mm) and the other at 24 inches (600 mm) from butt.

4.5 Execution

4.5.1 General

4.5.1.1 Piling materials, labor, tools, supervision, equipment, and supplies necessary for transporting and installing driven piles shall be provided in accordance with the contract documents and this Practice.

4.5.2 Handling and Storage

4.5.2.1 Piling materials shall be delivered to the job site in good condition.

4.5.2.2 Piling materials shall be handled and stored in a manner that avoids damage to or excessive stresses on these materials.

4.5.2.3 Stored pile materials shall be placed on sufficient dunnage to prevent contact with ground and to keep deflection of stored piles within tolerable limits.

4.5.2.4 Lifting cables, ears, or other connections used in transportation shall be removed to prevent reducing friction capacity as pile is driven. Locations where lifting cables, ears, or connections were attached shall be treated to prevent corrosion and infiltration of water.

4.5.3 Equipment

4.5.3.1 Hammers

1. Piles shall be driven with power impact hammers capable of installing the piles to the specified capacity, resistance, and minimum depth.
2. Vibrating hammers shall not be used without engineer's approval.
3. Piles driven with faulty equipment shall be subject to rejection by engineer of record and owner's geotechnical engineer. Cost of removal or installation of additional piles shall be borne by the constructor.
4. For an air/steam hammer, a calibrated pressure gauge shall be provided.
5. For a double-acting diesel hammer, a calibrated bounce-chamber gauge shall be provided.
6. Gauges on the hammer side of all valves shall be positioned so that gauges can be easily observed by inspecting personnel. Gauges shall not be greater than 100 feet (30 meters) of hose away from the hammer intake.
7. Open-ended (single-acting) diesel hammers shall be equipped with a device to permit inspecting personnel to visually determine hammer stroke at all times during pile driving.
8. Hammers shall not be operated at less than the speed and stroke length specified by the manufacturer.

4.5.3.2 Leads

1. Fixed leads shall be provided.
2. Leads shall be held firmly in position by stiff braces.
3. Axis of the leads, hammer, and pile shall coincide. Swinging or spud type leads shall be used only with approval of engineer of record and owner's geotechnical engineer.

4.5.3.3 Cushioning

1. Hammer cushions or capblocks shall be provided in either of the following configurations:
    a. Aluminum and micarta discs stacked alternately in a steel housing and with a steel plate at the top and bottom of the stack.
    b. One-piece hardwood capblock, with grain parallel to the pile axis and enclosed in a close-fitting steel housing. Satisfactory driving criteria shall be established with this capblock, and a new capblock shall not be used during the final driving of any pile.
2. Cap blocks made from other materials shall be used with approval of engineer of record and owner's geotechnical engineer.
3. Wood chips, small wood blocks, wood shavings, wire rope, or other materials with high-elastic properties shall not be used for capblocks.
4. For prestressed concrete piles, a pile cushion shall be provided that is appropriate for pile and hammer and approved by engineer of record and owner's geotechnical engineer.

4.5.3.4 Mandrel

1. A compatible expanding, internal mandrel shall be used for driving all thin shell and step taper piles.
2. The mandrel shall maintain a positive grip on the pile.

4.5.3.5 Follower

A follower shall be used only with approval of engineer of record and owner's geotechnical engineer.

4.5.4 Installation

4.5.4.1 General

1. Piles shall be driven to the indicated lines, grades, and capacities required by the contract documents.
2. A driving cap or helmet shall be used to prevent damage to pile heads during driving. Loose inserts in cap shall not be permitted.
3. Pile shall be held securely in proper position and alignment while driving.
4. Hammer impacts shall be delivered concentrically and in direct alignment with pile. Forcing pile laterally or bending pile shall be avoided.
5. Piles shall not be driven closer than 20 feet (6 meters) from concrete that has been in place less than 3 days.
6. Piles shall be driven continuously, without interruption, to the final tip elevation.

7. A discontinuous driving operation shall be referred to engineer of record and owner's geotechnical engineer for resolution.
8. Sudden resistance to pile driving by underground obstructions shall be brought to engineer of record and owner's geotechnical engineer's attention for resolution.
9. If required by contract documents, uplift connectors shall be installed.
10. If top of a pile is damaged during driving, damaged portion shall be cut off.
11. A damaged pile shall be brought to the attention of engineer of record and owner's geotechnical engineer for resolution. If required by engineer of record and owner's geotechnical engineer, a new length shall be spliced to the undamaged pile before resumption of driving.
12. Piles in large groups shall be driven from inside toward the outside.
13. Piles shall not be driven beyond depth of penetration required.
14. Piles shall not be driven until the earthwork within the area has been completed to specified grade.
15. If measured driving stresses in piles are deemed excessive by engineer of record and owner's geotechnical engineer, the driving energy transmitted to the pile shall be decreased by reducing the energy output of the hammer or by using additional cushions.

4.5.4.2 Tolerances

1. Pile heads, at cut-off elevation, shall be within 3 inches (75 mm) in any horizontal direction of the position shown in contract documents.
2. Pilings shall be cut off square, true, and level.
3. Cut-off tolerance shall be within 1/4" of required elevations shown in the contract documents.
4. Vertical piles shall be plumb within 2% of pile length.
5. The maximum deviation from required axial alignment of battered piles shall be within 4% of pile length.

4.5.4.3 Pre-drilling

1. Pilot holes shall be drilled when authorized by engineer of record and owner's geotechnical engineer.
2. Pilot holes shall be subject to modification by engineer of record and owner's geotechnical engineer based on the results of initial driving operations and analysis of driving data.
3. Pilot holes shall not be drilled greater than the least dimension of pile minus 2 inches (50 mm).
4. Pre-drilling shall be terminated at least 5 feet (1500 mm) above pile tip elevation.

5. All spoils shall be promptly removed from work area and disposed as directed by the purchaser.

4.5.4.4 Jetting

1. Jetting shall be used when authorized by engineer of record and owner's geotechnical engineer.
2. Jetting procedures shall be submitted for approval by engineer of record and owner's geotechnical engineer.
3. All jet water shall be controlled, treated if necessary, and disposed of in a manner acceptable to engineer of record and owner's geotechnical engineer.

4.5.4.5 Pile Heave

1. Heave and displacement of each pile shall be recorded after all piles in a group have been driven.
2. Piles that heave more than 1/4 inch (6 mm) shall be re-driven to their original elevation.

4.5.4.6 Cutoff

1. Sufficient pile length shall be provided above cut-off elevations so that any portion of pile damaged during driving can be cut off.
2. Piling shall be cut off neatly and squarely at required elevation in accordance with Section 4.5.4.2.3.
3. Cut-off lengths shall be disposed of off the property.

4.5.4.7 Driving Criteria and Capacity Evaluation

1. Pile-driving criteria, specifying the minimum acceptable blows per foot and refusal criteria, shall be in accordance with contract documents.
2. Driving criteria shall be subject to modification by engineer of record and owner's geotechnical engineer based on analysis of initial and ongoing driving results.
3. Any modification of driving criteria shall not result in additional cost to purchaser.
4. Piles shall be driven to minimum tip elevation in accordance with contract documents.
5. Driving shall be continued beyond minimum tip elevation until pile-driving criteria are met or until maximum pile penetration depth is reached.
6. Penetration short of specified minimum tip elevation shall be permitted only if, in the opinion of engineer of record and owner's geotechnical engineer, additional pile driving may damage the pile.
7. If pile-driving criteria are not met, or penetration to minimum tip elevation is not reached, engineer of record and owner's geotechnical engineer shall determine any remediation required.

4.5.4.8 Rejected Piles

1. Piles that are not in accordance with this Practice, including piles that are damaged, broken, misplaced, driven improperly or out of alignment shall be rejected.
2. Rejected piles shall be corrected as directed by engineer of record and owner's geotechnical engineer.
3. Corrective action may include extracting rejected piles and driving new piles or driving additional piles.
4. All corrective work shall not result in additional cost to purchaser.

4.5.4.9 Pipe Piles

1. Piles shall be covered during the interval between driving and placement of concrete.
2. Concrete shall not be placed until effect of ground heave and displacements can no longer be measured.
3. Concrete shall not be placed in a pile that is within 20 ft (6 meters) of another pile that is being driven.
4. Concrete shall not be placed until after piles have been inspected and approved.
5. Concrete shall not be placed until pile is free of all foreign matter and contains not more than 2 inches (50 mm) of water.
6. Concrete shall be placed with a funnel hopper centered directly over the pile. A concrete pump truck with hose may be used in lieu of funnel hopper and tremie pipe.
7. Bottom opening of hopper shall not be larger than one-half diameter of reinforcing steel cage or one-half pile diameter if there is no cage.
8. Concrete shall not be permitted to hit reinforcing steel or side of pile during placement.
9. A tremie pipe shall be substituted for hopper if required to prevent concrete from hitting reinforcement or pile side.
10. If a tremie pipe is used, pipe opening shall be kept submerged under rising top surface of deposited concrete.
11. Concrete shall be placed continuously until pile is full.
12. Piles with a buckle or other deformation that reduces the inside diameter by 10% or more shall be rejected.

4.5.4.10 Precast and Prestressed Concrete Piles

1. For precast and prestressed concrete piles, if anchor/dowel holes have been provided for uplift connection or other purposes, the holes shall be protected to prevent dirt or other substances from contaminating the holes before grouting.
2. The installation of concrete piles should follow recommendations of *ACI 543R.*

4.5.5 Pile Capacity Testing

4.5.5.1 Pile-Driving Analyzer (PDA)

1. If PDA's are required, engineer of record and owner's geotechnical engineer, shall retain and pay for an agency to perform pile-driving analyzer monitoring. Constructor shall promptly provide assistance without cost to agency.
2. Access and assistance shall be provided by constructor to enable testing agency to expeditiously perform required instrumentation and monitoring.
3. Appropriate power sources shall be provided for monitoring as required.
4. Transducers, cables, or equipment associated with dynamic monitoring shall be protected from damage.
5. Personnel to help attach transducers to pile head and manage cables during pile lifting and installation shall be provided by constructor to testing agency. Testing agency shall provide instructions in the details of this work.
6. In accordance with engineer of record and owner's geotechnical engineer's instructions, selected piles shall be re-instrumented and re-tapped for dynamic monitoring not less than 72 hours after end of initial driving.
7. A cold hammer shall not be used for re-tapping. The hammer shall be warmed before re-tapping by applying at least 20 blows to another pile.
8. Dynamic monitoring, including attaching and detaching instrumentation and actual testing, shall be accommodated at no additional cost to purchaser.

4.5.5.2 Static Pile Load Test

1. Engineer of record and owner's geotechnical engineer shall retain and pay for an independent agency to perform static pile load testing.
2. Access and assistance shall be provided by constructor to enable testing agency to expeditiously perform required instrumentation and monitoring.
3. Purchaser shall retain a geotechnical engineer to approve, direct, and document load test(s).

4. Neither installation nor testing of reaction piles nor commencement of load testing shall be performed without approval and presence of purchaser's geotechnical engineer.
5. Test and reaction piles shall be provided and installed by constructor at the location specified in contract documents.
6. Requirements for driving test and reaction piles shall be same as those for production piles.
7. Test and reaction piles shall be driven with same equipment to be used to drive production piles.
8. Test and reaction piles that are correctly located and installed and tested without damage and that meet all requirements of this Practice may be used as production piles if approved by engineer of record and owner's geotechnical engineer.
9. Reaction frames and reaction piles shall be designed and installed on approval of engineer of record.
10. Loading tests on piles selected by engineer of record and owner's geotechnical engineer shall be performed in accordance with the following standards for the type of test shown:
    a. Compression - *ASTM D1143/D1143M*
    b. Tension - *ASTM D3689*
    c. Lateral - *ASTM D3966/D3966M*
11. A load-cell and/or jack/manometer system designed for use in field conditions shall be provided. Jack and manometer shall be calibrated together as a system.
12. Manometer measuring the jack pressure shall have a range of 135% minimum to 300% of the specified allowable pile capacity.
13. A single jack shall be used to apply required load unless authorized by engineer of record and owner's geotechnical engineer to use a pair of jacks.
14. An operator experienced in pile load testing and a laborer to operate equipment throughout duration of test shall be provided.
15. Suitable enclosure of test arrangement shall be provided to ensure complete weather protection for reference beams and for personnel conducting the test. Necessary power source, lights, and heating for the enclosure shall also be provided.
16. Compression testing shall begin 5 to 30 days after initial driving of pile or as permitted by engineer of record and owner's geotechnical engineer.
17. Tension testing shall begin 10 to 30 days after initial driving of pile or as permitted by engineer of record and owner's geotechnical engineer.

18. Pile shall not be subject to any loading before starting the test.
19. Pile tests shall be performed in accordance with Quick Load Test Method specified in *ASTM D1143/D1143M* or *ASTM D3689*.
20. Test pile loading and unloading shall be performed in accordance with the following procedure:
    a. Pile shall be loaded in not less than 20 equal increments applied every 10 minutes to a maximum load of 300% of specified pile capacity.
    b. Each load level shall be accurately maintained.
    c. If loading increment becomes too large, the load shall not be released. Load level shall be recorded, the reading shall be taken at this load level, and the next loading increment shall be made correspondingly smaller.
    d. Within each load level, simultaneous readings of movements and load at 3, 6, and 10 minutes after start of loading shall be recorded.
    e. After the maximum test load has been maintained for 10 minutes, pile shall be unloaded in 5 approximately equal decrements of load every 5 minutes. Movements and load for each load level at the end of each 5-minute period shall be recorded.
    f. Movement gauges shall continue to be recorded at 10-minute intervals for at least 30 minutes after completely unloading pile.
21. If requested by engineer of record and owner's geotechnical engineer, a quick pile reloading test shall be performed immediately after first test is completed. Reloading test shall require fewer load increments and will be completed in approximately 2 hours.
22. Evaluation of tests shall be sole responsibility of engineer of record and owner's geotechnical engineer.

	ASSOC. PIP STS02360	DATA SHEET	STS02360-D
	PILE AND DRIVING EQUIPMENT		PAGE 1 OF 1 JANUARY 2017

ISSUED FOR: ☐ PROPOSAL ☐ PURCHASE ☐ AS BUILT

FACILITY NAME/LOCATION: _____

ITEM NAME: _____ PURCHASER/LOCATION: _____

ITEM TAG NO.: _____ JOB NO: _____

SERVICE: _____ PURCHASER ORDER NO.: _____

UNIT: _____ SUPPLIER/LOCATION: _____

P&ID NO.: _____ SUPPLIER ORDER/SERIAL NOS.: _____ / _____

DATA PROVIDED BY: ● PURCHASER ■ SUPPLIER ◆ SUPPLIER IF NOT BY PURCHASER

HAMMER COMPONENTS:

MANUFACTURER: _____ MODEL NO.: _____

HAMMER TYPE: _____ SERIAL NO.: _____

MANUFACTURER'S MAXIMUM RATED ENERGY: _____ FT-LBS

STROKE AT MAXIMUM RATED ENERGY: _____ FT

RANGE IN OPERATING ENERGY: _____ TO _____ FT-LBS

RANGE IN OPERATING STROKE: _____ TO _____ FT

RAM WEIGHT: _____ LBS

MODIFICATIONS: _____

STRIKER PLATE:

WEIGHT: _____ LBS DIAMETER: _____ IN

THICKNESS: _____ IN

HAMMER CUSHION:

MATERIAL #1

NAME: _____

AREA: _____ IN^2

THICKNESS/PLATE: _____ IN

NO. OF PLATES: _____

MATERIAL #2 (FOR COMPOSITE CUSHION)

NAME: _____

AREA: _____ IN^2

THICKNESS/PLATE: _____ IN

NO. OF PLATES: _____

TOTAL THICKNESS OF HAMMER CUSHION: _____ IN

HELMET WEIGHT: _____ LBS

PILE CUSHION:

MATERIAL: _____

AREA: _____ IN^2 THICKNESS/SHEET: _____ IN

NO. OF SHEETS: _____

TOTAL THICKNESS OF PILE CUSHION: _____ IN

PILE:

TYPE: _____

DIAMETER OF CROSS SECTIONAL WIDTH: _____ IN

CROSS SECTIONAL AREA: _____ IN^2 WEIGHT/FT.: _____ LBS

WALL THICKNESS: _____ IN TAPER: _____

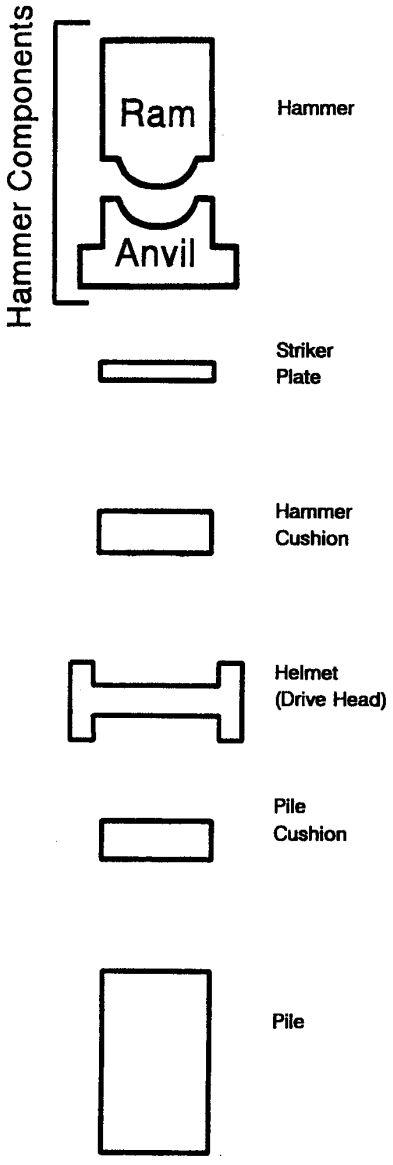
ORDERED LENGTH: _____ FT

DESIGN LOAD: _____ TONS

ULTIMATE PILE CAPACITY: _____ TONS

DESCRIPTION OF SPLICE: _____

DRIVING SHOE/CLOSURE PLATE DESCRIPTION: _____



NO.	DATE	REVISION DESCRIPTION	BY	APVD.

	ASSOC. PIP STS02360	DATA SHEET	STS02360-DM
	PILE AND DRIVING EQUIPMENT (SI UNITS)		PAGE 1 OF 1 JANUARY 2017

ISSUED FOR: ☐ PROPOSAL ☐ PURCHASE ☐ AS BUILT

FACILITY NAME/LOCATION: _____

ITEM NAME: _____ PURCHASER/LOCATION: _____

ITEM TAG NO.: _____ JOB NO: _____

SERVICE: _____ PURCHASER ORDER NO.: _____

UNIT: _____ SUPPLIER/LOCATION: _____

P&ID NO.: _____ SUPPLIER ORDER/SERIAL NOS.: _____ / _____

DATA PROVIDED BY: ● PURCHASER ■ SUPPLIER ◆ SUPPLIER IF NOT BY PURCHASER

HAMMER COMPONENTS:

MANUFACTURER: _____ MODEL NO.: _____

HAMMER TYPE: _____ SERIAL NO.: _____

MANUFACTURER'S MAXIMUM RATED ENERGY: _____ N-m

STROKE AT MAXIMUM RATED ENERGY: _____ m

RANGE IN OPERATING ENERGY: _____ TO _____ N-m

RANGE IN OPERATING STROKE: _____ TO _____ m

RAM WEIGHT: _____ kg

MODIFICATIONS: _____

STRIKER PLATE:

WEIGHT: _____ kg DIAMETER: _____ mm

THICKNESS: _____ mm

HAMMER CUSHION:

MATERIAL #1

NAME: _____

AREA: _____ mm^2

THICKNESS/PLATE: _____ mm

NO. OF PLATES: _____

MATERIAL #2 (FOR COMPOSITE CUSHION)

NAME: _____

AREA: _____ mm^2

THICKNESS/PLATE: _____ mm

NO. OF PLATES: _____

TOTAL THICKNESS OF HAMMER CUSHION: _____ mm

HELMET WEIGHT: _____ kg

PILE CUSHION:

MATERIAL: _____

AREA: _____ mm^2 THICKNESS/SHEET: _____ mm

NO. OF SHEETS: _____

TOTAL THICKNESS OF PILE CUSHION: _____ mm

PILE:

TYPE: _____

DIAMETER OF CROSS SECTIONAL WIDTH: _____ mm

CROSS SECTIONAL AREA: _____ mm^2 WEIGHT/FT.: _____ kg

WALL THICKNESS: _____ mm TAPER: _____

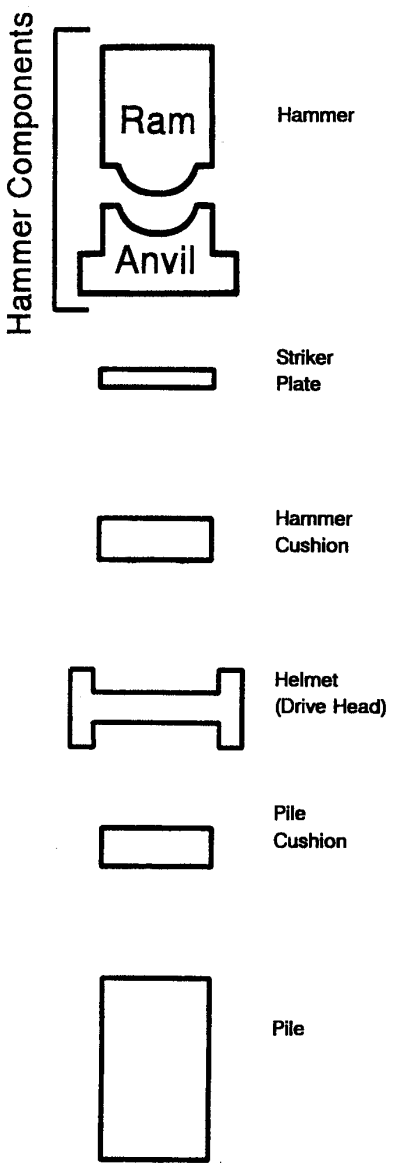
ORDERED LENGTH: _____ m

DESIGN LOAD: _____ TONNES

ULTIMATE PILE CAPACITY: _____ TONNES

DESCRIPTION OF SPLICE: _____

DRIVING SHOE/CLOSURE PLATE DESCRIPTION: _____



NO.	DATE	REVISION DESCRIPTION	BY	APVD.

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
May 2017

Structural

PIP STS03001
Plain and Reinforced Concrete Specification

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PUBLISHING HISTORY

December 1995	*Issued*
July 2001	*Complete Revision*
May 2007	*Complete Revision*
May 2017	*Complete Revision*

Not printed with State funds

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
May 2017

Structural

PIP STS03001
Plain and Reinforced Concrete Specification

Table of Contents

1. Scope

This Practice provides requirements for cast-in-place concrete construction.

This Practice describes technical requirements for furnishing and installing materials and for proportioning, mixing, placing, testing, and curing of plain and reinforced concrete.

This Practice supplements ACI 301-16, *Specifications for Structural Concrete*, and ACI 301M-16, *Specifications for Structural Concrete (Metric)*.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition of references shall be as shown in *ACI 301-16 / ACI 301M-16* Section 1.4 or, if not listed in *ACI 301-16 / ACI 301M-16*, shall be the edition in effect on the date of contract award, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

– PIP STF05121 - *Anchor Fabrication and Installation into Concrete*

2.2 Industry Codes and Standards

- American Concrete Institute (ACI)
  - ACI 117 - *Specification for Tolerances for Concrete Construction and Materials and Commentary*
  - ACI 117M - *Specification for Tolerances for Concrete Construction and Materials and Commentary (Metric)*
  - ACI 237R - *Self-Consolidating Concrete*
  - ACI 301-16 - *Specifications for Structural Concrete*
  - ACI 301M-16 - *Specifications for Structural Concrete (Metric)*
  - ACI 304R - *Guide for Measuring, Mixing, Transporting, and Placing Concrete*
  - ACI 305.1 - *Specification for Hot Weather Concreting*
  - ACI 306.1 - *Standard Specification for Cold Weather Concreting*
  - ACI 350.1 - *Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures*
  - ACI 350.1M - *Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures (Metric)*
  - ACI 350.5 - *Specifications for Environmental Concrete Structures*
  - ACI 350.5M - *Specifications for Environmental Concrete Structures (Metric)*
  - ACI SP-66 - *ACI Detailing Manual*
- ASTM International (ASTM)
  - ASTM A615/A615M - *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*
  - ASTM A1064/A1064M - *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*

- ASTM C33/C33M - *Standard Specification for Concrete Aggregates*
- ASTM C150/C150M - *Standard Specification for Portland Cement*
- ASTM C618 - *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*
- ASTM C920 - *Standard Specification for Elastomeric Joint Sealants*
- ASTM C989/C989M - *Standard Specification for Slag Cement for Use in Concrete and Mortars*
- ASTM C1602/C1602M - *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*
- ASTM C1610/C1610M - *Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique*
- ASTM C1611/C1611M - *Standard Test Method for Slump Flow of Self-Consolidating Concrete*
- ASTM C1621/C1621M - *Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring*
- ASTM C1712 - *Standard Test Method for Rapid Assessment of Static Segregation Resistance of Self-Consolidating Concrete Using Penetration Test*
- ASTM D1751 - *Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)*
- ASTM D5249 - *Standard Specification for Backer Material for Use with Cold- and Hot-Applied Joint Sealants in Portland-Cement Concrete and Asphalt Joints*
- ASTM E1745 - *Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs*

- Concrete Reinforcing Steel Institute (CRSI)
  - *Manual of Standard Practice*
- National Ready Mixed Concrete Association (NRMCA)
  - *Quality Control Manual - Section 3, Certification of Ready Mixed Concrete Production Facilities – Plant Certification Check List*

3. Definitions

constructor: Party responsible for supplying materials, equipment, tools, supervision, and labor for installation of concrete materials in accordance with contract documents. The term constructor shall apply also to constructor's subcontractor(s) and vendor(s).

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets, that purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between purchaser and constructor.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of civil works, structure, foundations, materials, and appurtenances described in contract documents. Engineer of record shall be licensed as defined by laws of the locality in which the work is to be constructed, and be

qualified to practice in the specialty discipline required for the work described in contract documents.

environmental engineering concrete structures: Concrete structures intended for conveying, storing, or treating water, wastewater, or other nonhazardous liquids, and for secondary containment of hazardous materials.

manufacturer: Party who produces and warrants performance of products, materials, and/or items provided in accordance with contract documents. Products, materials, and/or items are manufactured in a controlled process using standard codes, specifications, tests and possibly include shop drawings to assist in proper application, installation and/or use. The term manufacturer shall apply also to manufacturer's subcontractor(s) and/or vendor(s).

mass concrete: Any volume of structural concrete in which a combination of dimensions of the member being cast, the boundary conditions, the characteristics of the concrete mixture, and the ambient conditions can lead to undesirable thermal stresses, cracking, deleterious chemical reactions, or reduction in the long-term strength as a result of elevated concrete temperature due to heat from hydration.

owner: Party who has authority through ownership, lease, or other legal agreement over site, facility, structure or project wherein concrete materials will be used.

purchaser: Party who awards contract to constructor. Purchaser may be owner or owner's authorized agent.

self-consolidating concrete: Fresh concrete that can flow around reinforcement and consolidate within formwork under its own weight without vibration.

supplier: Party responsible for supplying concrete materials in accordance with contract documents.

4. Requirements

4.1 General

4.1.1 Concrete supply and construction shall be in accordance with all requirements of *ACI 301-16 / ACI 301M-16*, except as modified or supplemented in this Practice or by contract documents.

4.1.2 Requirements of federal, state or local agencies that have jurisdiction where concrete is to be placed shall apply.

4.1.3 Any conflicts or inconsistencies between this Practice, design drawings, or other contract documents shall be brought to the attention of purchaser for resolution.

4.1.4 For applications designated as environmental engineering concrete structures in contract documents, concrete supply and construction shall also be in accordance with *ACI 350.5 / ACI 350.5M*.

4.1.5 Any placement of concrete designated in contract documents as mass concrete or any placement of structural concrete with a minimum dimension equal to or greater than 4 ft (1200 mm) shall be considered mass concrete unless otherwise specified in contract documents and shall be in accordance with Section 8 of *ACI 301 / ACI 301M*. For applications designated as environmental engineering

concrete structures in concrete documents, any placement of concrete designated in contract documents as mass concrete shall also be in accordance with Section 8 of *ACI 350.5 / ACI 350.5M*.

4.2 Quality Control

4.2.1 A written quality control program and inspection procedures document shall be submitted to purchaser for approval. These documents shall provide details of how compliance with requirements of this Practice and contract documents shall be achieved.

4.2.2 Samples for testing shall be obtained in accordance with *ACI 301 / ACI 301M*. Rate of sampling shall be in accordance with *ACI 301 / ACI 301M* and the following:

a. For structures and foundations, samples shall be obtained in accordance with the following requirements:

(1) One sample minimum per 100 cubic yards (76 cubic meters) of concrete

(2) One sample minimum for each structure or foundation, except if placing a number of items each smaller than 25 cubic yards (19 cubic meters)

(3) One sample minimum per 25 cubic yards (19 cubic meters) if placing a number of items each smaller than 25 cubic yards (19 cubic meters)

b. For paving and slabs on grade, obtain one sample per 50 cubic yards (38 cubic meters) of concrete.

c. For underground pipe or electrical encasements and fireproofing, obtain one sample at beginning of each day of concreting work.

d. For all other concrete, obtain samples in accordance with Section 4.2.2.a.

e. Additional samples shall be obtained if observations of tests for slump (except for self-consolidating concrete), temperature, or air content indicate nonconformance with contract documents.

f. For self-consolidating concrete only, additional samples shall be obtained if observations of tests for slump flow, T_{50}, Visual Stability Index (VSI), column segregation or passing ability indicate nonconformance with contract documents.

4.2.3 For each concrete sample obtained, the following tests shall be conducted in accordance with *ACI 301 / ACI 301M*:

a. Compressive strength

b. Slump (except for self-consolidating concrete)

c. Temperature

d. Air content

4.2.4 For each concrete sample obtained for self-consolidating concrete, the following tests shall also be conducted:

a. Slump flow in accordance with *ASTM C1611/C1611M*

b. T_{50} and Visual Stability Index (VSI) in accordance with Appendix of *ASTM C1611/C1611M*

c. Column segregation in accordance with *ASTM C1610/C1610M* or *ASTM C1712*

d. Passing ability in accordance with *ASTM C1621/C1621M*

4.2.5 Test cylinder sets shall be dated and numbered consecutively.

4.2.6 Concrete quality control test reports shall be provided to purchaser weekly unless otherwise specified in contract documents. Data in test report shall include, but not be limited to, the following:

a. Location of concrete on the job and associated design drawing numbers and structure/foundation identification

b. Specified compressive strength (f ′c)

c. Date placed

d. Proportions of concrete mix or mix identification

e. 7- and 28-day compressive strength and compressive strength for any other duration as specified in contract documents

f. Slump (except for self-consolidating concrete), air and concrete temperatures at time of placement, time of day concrete was batched, and time of day concrete was placed

g. For self-consolidating concrete only, slump flow, T_{50}, Visual Stability Index (VSI), column segregation and passing ability

h. Air content

i. Name of inspector making cylinders and cylinder number

4.2.7 Constructor shall notify testing agency when concrete is to be placed.

4.2.8 Ready mixed concrete suppliers shall be certified in accordance with one of the following:

a. Certification by holding a current NRMCA Certificate of Conformance for Concrete Production Facilities

b. Certification from an independent testing agency stating conformance with NRMCA Certification of Ready Mixed Concrete Production Facilities

c. Certification from Department of Transportation or governing authority for the project site location

The certification shall be current for duration of concrete supply.

4.3 Quality Assurance

4.3.1 Unless otherwise specified in contract documents, the purchaser shall be responsible for furnishing a testing agency to act as the "owner's testing agency" as defined by *ACI 301 / ACI 301M*.

4.3.2 The purchaser shall have the right to make inspections at any time at the source of supply of materials, at the place of preparation of materials, at the mixing plant if ready mixed concrete is used, and during execution of all concrete work.

4.4 Submittals

4.4.1 The items listed in Table 2 shall be submitted for engineer of record review and approval of items in the Approval Column. Work shall not proceed without approval.

4.4.2 Additional documentation which is not listed in Table 2 shall be submitted to purchaser if required by contract documents.

4.5 Materials

4.5.1 General

4.5.1.1 Materials shall be in accordance with this Practice and contract documents unless otherwise approved in writing by purchaser.

4.5.1.2 Materials and application thereof shall be in accordance with applicable federal, state and local volatile organic compound regulations.

4.5.2 Cementitious Materials

4.5.2.1 Portland cement shall be in accordance with *ASTM C150/C150M*, Type I or Type II unless otherwise specified in contract documents.

4.5.2.2 Only one brand of cement shall be used.

4.5.2.3 Fly ash may be used in accordance with *ACI 301 / ACI 301M* and shall be in accordance with *ASTM C618*, Class F unless otherwise specified in contract documents. Class C fly ash may be used if Class F is not available.

4.5.2.4 Ground Granular Blast Furnace Slag (GGBFS) in accordance with *ASTM C989/C989M* may be used if available.

4.5.2.5 Cementitious materials used for mass concrete applications shall be in accordance with *ACI 301 / ACI 301M* Section 8.2.1.1. For applications designated as environmental engineering concrete structures in contract documents, cementitious materials used for mass concrete applications shall also be in accordance with *ACI 350.5 / ACI 350.5M* Section 8.2.1.1.

4.5.3 Admixtures

4.5.3.1 All admixtures shall require engineer of record's authorization for use.

4.5.3.2 Only one manufacturer for each admixture shall be used. Admixtures used together shall be from same manufacturer or documentation of compatibility from manufacturers shall be submitted for approval prior to use.

4.5.3.3 Calcium chloride and admixtures containing soluble chlorides shall not be permitted.

4.5.3.4 For applications designated as environmental engineering concrete structures in contract documents, admixtures used for mass concrete applications shall be in accordance with *ACI 350.5 / ACI 350.5M* Section 8.2.1.2.

4.5.4 Aggregate

4.5.4.1 Aggregate shall be in accordance with *ASTM C33/C33M*.

4.5.4.2 Aggregate shall be obtained from a single source.

4.5.4.3 Aggregates proposed for use shall be tested in accordance with Appendix of *ASTM C33/C33M*, or a record of satisfactory performance shall be submitted to engineer of record for approval.

4.5.4.4 Fine and coarse aggregate shall meet the restrictions on reactive materials in accordance *ASTM C33/C33M*.

4.5.5 Reinforcement

4.5.5.1 Reinforcing bars shall be deformed billet steel in accordance with *ASTM A615/A615M*, Grade 60 (420) unless otherwise specified in contract documents.

4.5.5.2 Reinforcing shall be uncoated unless otherwise specified in contract documents.

4.5.5.3 Welded wire reinforcement shall be plain wire in accordance with *ASTM A1064/A1064M*. Wire shall be of sufficient size to fabricate in sheets. Rolls of welded wire reinforcement shall not be used.

4.5.5.4 Tie wire shall be black annealed wire, 16 gage (1.29 mm) minimum.

4.5.6 Water

Water used for mixing water, ice, curing, or any other function relating to placement of concrete shall be potable or meet the requirements of *ASTM C1602/C1602M*.

4.5.7 Accessories

Accessories shall meet the requirements of *ACI 301 / ACI 301M*.

4.5.8 Joints

4.5.8.1 Joint filler shall be in accordance with *ASTM D1751* unless otherwise specified in contract documents.

4.5.8.2 Backer rod for joint sealant shall be in accordance with *ASTM D5249*. Diameter shall be 1.5 times the width of the joint unless otherwise specified in contract documents.

4.5.8.3 Joint sealant shall be in accordance with *ASTM C920*, unless otherwise specified in contract documents.

4.5.9 Anchorage

Anchorage shall be in accordance with *PIP STF05121*, unless otherwise specified in contract documents.

4.5.10 Vapor Barrier

Below floor vapor barrier shall be in accordance with *ASTM E1745*, Class A, and minimum 10 mil (250 μm) thickness unless otherwise specified in contract documents.

4.6 Execution

4.6.1 General

4.6.1.1 Storage, handling, measuring, mixing, transporting, and placing of concrete materials shall follow the methods and means outlined in *ACI 304R* and comply with manufacturer's written recommendations for handling, storage, and protection.

4.6.1.2 Execution for self-consolidating concrete shall follow the methods and means outlined in *ACI 237R*.

4.6.2 Formwork

4.6.2.1 Unless otherwise specified in contract documents, 3/4-inch (20-mm) chamfer strips shall be provided at all corners on permanently exposed surfaces.

4.6.2.2 Form-release agents shall not be applied if concrete surfaces shall receive special finishes or where the agent may affect applied coverings. Alternately, inside surfaces of untreated formwork shall be soaked with clean water and kept moist before placing concrete.

4.6.2.3 Form removal shall be in accordance with *ACI 301 / ACI 301M* and the following:

a. For structures for which forms do not provide vertical support or lateral stability (e.g., footings, piers, columns, walls, or sides of beams), the forms may be removed 48 hours after completion of placement if concrete is sufficiently hard to prevent damage by form removal, and if curing starts immediately.

b. Unless otherwise specified in contract documents, forms for self-supporting members may be removed if concrete compressive strength is at least 80 percent of the specified 28-day compressive strength. Refer to *ACI 301 / ACI 301M*, Section 2.3.4, for determining compressive strength of concrete for removal of formwork.

c. Unless otherwise approved by the purchaser, forms shall not be left permanently in place.

4.6.2.4 Form accessories that remain embedded in the concrete (e.g., ties and hangers) shall be a commercially manufactured type.

4.6.2.5 Formed concrete surfaces shall be constructed in accordance with the tolerances shown in *ACI 117 / ACI 117M*.

4.6.2.6 Formwork for columns and walls shall be provided with adequate cleanout openings to permit inspection and easy cleaning after reinforcement has been placed.

4.6.2.7 All side and bottom surfaces of concrete for structures that will be exposed shall be formed. Unless otherwise approved by engineer of record, vertical surfaces of concrete for subgrade structures and pavements shall be formed at least to a depth of 12 inches (300 mm) below grade. Concrete below this level may be placed against earth.

4.6.2.8 Formwork design calculations and drawings shall be sealed by engineer of record for the formwork.

4.6.3 Joints

4.6.3.1 All joints shall be located and constructed in accordance with contract documents. Any variation from the location specified shall be approved by engineer of record.

4.6.3.2 Control joints to be cut with a saw shall be cut as soon as concrete is hard enough to prevent surface raveling and aggregate dislodging, and within 8 hours after concrete placement.

a. Control joints shall be cut in accordance with saw manufacturer's written recommendations.

b. Sawing sequence shall be based on concrete placement time and size of slab.

4.6.3.3 Control joints in slab toppings shall be located directly above and in line with the control joints in underlying concrete slab.

4.6.3.4 Isolation joints shall be placed where pavement adjoins vertical surfaces (e.g., walls, columns, catch basins, manholes, and equipment foundations). Isolation joints shall be located in accordance with contract documents.

4.6.3.5 Dowels at expansion joints shall be properly aligned to prevent any restraint on expansion movement at the joint.

4.6.3.6 The surface of joints shall be cleaned of scale and laitance and thoroughly wetted, but free of standing water, before placing adjoining concrete.

4.6.4 Waterstops

Waterstops shall be installed in accordance with contract documents and manufacturer's written recommendations.

4.6.5 Reinforcing and Embedments

4.6.5.1 Detailing and Fabrication

1. Reinforcement placing drawings and bending schedules shall be prepared in accordance with *ACI SP-66* and *CRSI Manual of Standard Practice* and submitted to engineer of record for review and approval.

2. Reinforcement placing drawings and bending schedules shall show number, grade, size, length, mark, location, and bending diagrams for reinforcing bars.
3. Splices in reinforcement shall be detailed, fabricated, and located only as shown on the design drawings.
4. Fabrication drawings shall indicate the related PO number, release number, and design drawing number.
5. Reinforcement shall be tagged with weather-resistant metal tags.
6. Each bundle of fabricated bars shall be tagged. The tags shall indicate reinforcement placing drawing number, release number, mark number, grade, bar quantity, and bar size.
7. Each bundle of stock-length straight bars shall be tagged to indicate bar quantity, grade, bar size, and bar length.
8. Fabrication tolerances shall comply with the requirements of *ACI 117 / ACI 117M*.

4.6.5.2 Installation

1. Embedded aluminum items shall not be permitted.
2. Anchors, inserts, sleeves, drains, curb and seat angles, nosing, and other embedded items shall be installed before placing concrete. Welding of these items to the reinforcing bars shall not be permitted.
3. Embedded portion of anchor rods shall be wrapped with non-bonding tape for the required length and location specified in contract documents if applicable.
4. Anchor threads above the top of concrete elevation specified on the design drawings shall be covered with duct tape or other suitable means to keep the threads clean and to prevent any damage during placement of concrete.
5. Anchor sleeves shall be filled with a nonbonding moldable material or an elastomeric moldable non-hardening material unless otherwise specified in concrete documents. Anchor sleeves shall be capped or plugged to keep out water, concrete, and debris until sleeves are filled with a nonbonding moldable material or an elastomeric moldable non-hardening material, or for sleeves specified in contract documents to be filled with grout (by others).
6. Grout pockets for anchors and shear keys to be grouted in place (by others) shall be capped or plugged to keep out water, concrete, and debris until pockets are filled with grout.
7. Reinforcing bars shall be spliced in accordance with design drawings only. Unless otherwise approved by engineer of record, welded or mechanical splices shall not be permitted.

4.6.5.3 Tolerances

Embedments shall be installed in accordance with tolerances shown in Table 1, unless otherwise specified in contract documents. The term "anchor group" used in Table 1 is defined as the set of anchors for a single fabricated steel shipping piece, or a single piece of equipment or skid.

Table 1 – Tolerances for Embedments

Measurement	Tolerance
Anchor projection	+ or – 1/4 inch (6 mm)
Center of anchor group	+ or – 1/4 inch (6 mm)
Center to center of any two anchors within a group	+ or – 1/8 inch (3 mm)
Center to center between anchor groups	+ or – 1/4 inch (6 mm)
Anchor plumbness	1/8 inch in 3 feet (4 mm in 1 meter)
Plate inserts in columns, walls, and beams horizontal and vertical location	+ or – 1/4 inch (6 mm)
Shapes and plate inserts in floor slabs	+ or – 1/4 inch (6 mm) horizontal + or – 1/16 inch (2 mm) elevation

4.6.6 Proportioning and Mixing

4.6.6.1 Concrete minimum 28-day compressive strength, f ′c, shall be 5,000 psi (28 MPa) unless otherwise specified for Exposure Class in accordance with *ACI 301 / ACI 301M* or other requirements in this Practice or other contract documents.

4.6.6.2 Maximum water-cementitious materials ratio shall be 0.4 for environmental engineering concrete structures or concrete designated to be Exposure Class C2 or Exposure Class F3, 0.45 for concrete designated to be Exposure Class F2 or Exposure Class S2 or S3, and 0.5 for all other concrete, unless otherwise specified in contract documents.

4.6.6.3 High early strength concrete or other types of high performance concrete shall meet the requirements specified in contract documents.

4.6.6.4 Fly ash content shall not exceed 25% by weight of cementitious material, unless approved by engineer of record.

4.6.6.5 Unless otherwise specified in contract documents, nominal maximum size of coarse aggregate in concrete shall be in accordance with *ACI 301 / ACI 301M*.

4.6.6.6 Concrete mixtures shall comply with the most restrictive requirements of *ACI 301 / ACI 301M* Section 4.2.2.7 for the exposure category and class specified by engineer of record in contract documents.

4.6.6.7 Unless otherwise specified in the contract documents, concrete shall be air entrained in accordance with *ACI 301 / ACI 301M* Section 4.2.2.7.b based on the freezing and thawing exposure class specified in contract

documents with the exception of trowel-finished concrete which shall not be air entrained.

4.6.6.8 Self-consolidating concrete shall be proportioned to meet slump flow in accordance with *ASTM C1611/C1611M*, T_{50} in accordance with Appendix of *ASTM C1611/C1611M*, and passing ability in accordance with *ASTM C1621/C1621M*, as specified in contract documents for each specific application. Visual stability index (VSI) shall have a rating of 0 (highly stable) or 1 (stable) in accordance with Appendix of *ASTM C1611/C1611M*. Column segregation shall be less than 10% in accordance with *ASTM C1610/C1610M* or *ASTM C1712*.

4.6.6.9 Admixtures shall be added at batch plant unless otherwise directed or approved by engineer of record.

4.6.6.10 Concrete envelopes for underground electrical ducts and cover slabs for direct-buried cables shall have a minimum 28-day compressive strength, f ′c, of 3,000 psi (21 MPa) and be colored red by adding 10 pounds of red oxide powder per cubic yard (6 kilograms per cubic meter) of concrete unless otherwise specified in contract documents.

4.6.6.11 Concrete envelopes for underground instrument air-line ducts shall have a minimum 28-day compressive strength, f ′c, of 3,000 psi (21 MPa) and be colored yellow by adding 10 pounds of yellow oxide powder per cubic yard (6 kilograms per cubic meter) of concrete unless otherwise specified in contract documents.

4.6.6.12 On-site mixed concrete shall not be permitted unless otherwise approved by purchaser.

4.6.7 Placing Concrete

4.6.7.1 Inspection and authorization shall be obtained from purchaser before placing concrete.

4.6.7.2 Concrete that has achieved initial set or has been contaminated by foreign matter shall not be deposited in the structure.

4.6.7.3 Re-tempering or addition of water after concrete is first mixed shall not be permitted.

4.6.7.4 The addition of ice at construction site shall be permitted only if it has been considered in the mix design. The concrete manufacturer shall provide written instructions on required amount of ice and mixing procedure.

4.6.7.5 Materials and equipment for protection, finishing and curing shall be operational at placement site before placement begins.

4.6.7.6 Slabs shall be placed in alternating panels.

4.6.7.7 The interval between concrete deliveries shall be such that no more than 20 minutes interruption elapse during placement of a single foundation or slab, unless approved by engineer of record.

4.6.7.8 Discharge of concrete shall be completed within 45 minutes after introduction of mixing water to cement and aggregates or introduction of

the cement to the aggregates. This time may be extended up to 90 minutes with approval of engineer of record.

4.6.8 Curing and Protection

4.6.8.1 Concrete shall be cured and protected in accordance with *ACI 301 / ACI 301M* unless otherwise specified in this Practice or in contract documents.

4.6.8.2 Concrete not in contact with forms may utilize any of the methods indicated in *ACI 301 / ACI 301M* for the preservation of moisture.

4.6.8.3 Liquid membrane curing compounds shall not be used on surfaces that shall receive bonded treatments, tiles, paint or other adhered finishes, epoxy toppings, or additional concrete unless otherwise specified in contract documents.

4.6.8.4 Curing and protection of concrete for environmental engineering concrete structures shall comply with the following:

a. The provisions of *ACI 350.5 / ACI 350.5M*.

b. Temperature differential between freshly placed and previously placed concrete elements shall be maintained at 18°F (10°C) or less until a minimum compressive strength of 3,500 psi (24 MPa) is achieved.

4.6.8.5 Curing and protection of mass concrete shall be in accordance with *ACI 301 / ACI 301M* Section 8.3.1. For applications designated as environmental engineering concrete structures in contract documents, curing and protection of mass concrete shall also be in accordance with *ACI 350.5 / ACI 350.5M* Section 8.3.2.

4.6.9 Loading of Self-Supporting Members

No superimposed load shall be applied to self-supporting members before 28-day verification of specified compressive strength, unless specified 28-day compressive strength has been verified by field-cured cylinders and approved by engineer of record.

4.6.10 Surface Finishing and Tolerances

4.6.10.1 Surface finish and correlating tolerance requirements shall be in accordance with *ACI 301 / ACI 301M* and *ACI 117 / ACI 117M* and as specified in contract documents.

4.6.10.2 Equipment bases shall be finished with a floated finish. Stairs, steps, ramps, and walks shall be finished with a broom finish.

4.6.11 Repair of Surface Defects

4.6.11.1 Tie holes, honeycombs, and other concrete surface defects shall be repaired promptly after form removal at a time and in a manner that shall not delay, interfere with, or impair the proper curing of the fresh concrete unless otherwise specified or approved by engineer of record.

4.6.11.2 Engineer of record shall be notified before proceeding with repair if the defect is any of the following:

a. Depth is greater than 3 inches (75 mm) at the maximum point and surface area is greater than 150 square inches (100,000 square mm).

b. Depth is greater than 1/4 the thickness of the member and greater than 6 inches (150 mm) in any other direction.

c. Reinforcing steel is exposed.

4.6.11.3 Prepackaged grouts and patching compounds or a patching mortar similar to the concrete mix without coarse aggregate may be used with approval of engineer of record.

4.6.11.4 Out-of-tolerance slabs shall be repaired by grinding down high points and/or raising low points by using a self-leveling compound or repair topping approved by engineer of record and installed in accordance with manufacturer's recommendation.

4.6.11.5 Critical slab areas, identified in contract documents shall be replaced if out-of-tolerance. A demolition and replacement plan for the slab areas shall be submitted to engineer of record for review and approval before proceeding.

4.6.12 Hot and Cold Weather Concreting

4.6.12.1 If the combination of temperature, humidity, and wind velocity is expected to cause a rate of evaporation equal to or greater than 0.2 pounds per square foot per hour (1 kilogram per square meter per hour), the provisions of *ACI 305.1* shall be followed.

4.6.12.2 Cold weather concreting shall meet the requirements of *ACI 306.1* for minimum temperatures specified therein.

4.6.13 Architectural and Prestressed Concrete

Architectural and prestressed concrete requirements that are in addition to *ACI 301 / ACI 301M* and this Practice shall be in accordance with contract documents.

4.6.14 Tightness Testing of Environmental Engineering Concrete Structures

If specifically required in the contract documents, tightness testing of environmental engineering concrete structures shall be performed in accordance with *ACI 350.1 / ACI 350.1M*.

Table 2 – Supplier Data Requirements

	Type of Submittal		When Required					Remarks
	For Approval	For Record	Weekly	14 Days Before Placement	14 Days Before Fabrication	With RFQ Submittal	Other	
Supplier's QA Program	X					X		
Batch Plant and Truck Mixer Certification		X		X				
Mix Designs	X			X				
Trial Batch Qualification Test Results	X			X				
Cement Certifications		X		X				
Mineral Additive Certifications		X		X				If applicable
Fine and Coarse Aggregate Certifications		X		X				
Admixture Data Sheets and Certifications		X		X				
Material Suppliers, Sources, and Certifications		X		X				
Manufacturer Spec's, Certifications and Installation Instructions		X		X				
Proposed Curing Methods	X					X		
Reinforcing Bending Schedule and Placing Drawings	X				X			
Certified Mill Test Reports for each bar size and heat number		X		X				If requested
Coating Inspection Reports		X	X					If applicable
Concrete Delivery Ticket		X					With delivery	
Compression Test Reports		X	X					
Compression Breaks 500 psi (3.5 MPa) or more below required		X					Same day	Engineer of record needs to review and provide disposition of low strength concrete results
Water Testing Reports		X		X				If applicable
Mass Concrete Thermal Control Plan	X			X				Required for each mass concrete placement

COMPLETE REVISION
July 2008

Process Industry Practices
Structural

PIP STS03600
Nonshrink Cementitious Grout Specification

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PRINTING HISTORY

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Process Industry Practices
Structural

PIP STS03600
Nonshrink Cementitious Grout Specification

Table of Contents

1. Introduction

1.1 Purpose

This Practice provides the requirements for "non-shrink" cementitious grout materials and installation.

1.2 Scope

This Practice describes the requirements for supplying, testing, and installing "non-shrink" cementitious grout materials.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles will be used herein where appropriate.

2.1 Industry Codes and Standards

- ASTM International (ASTM)
  - ASTM C109/C109M- *Standard Test Method for Compressive Strength of Hydraulic-Cement Mortars (Using 2-in. [50-mm] Cube Specimens)*
  - ASTM C827 – *Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures*
  - ASTM C1090 – *Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout*
  - ASTM C1107/C1107M - *Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink)*

2.2 Government Regulations

Federal standards and instructions of the U. S. Occupational Safety and Health Administration (OSHA), including any additional requirements by state or local agencies that have jurisdiction where the grout is to be installed, shall apply, including the following:

- Code of Federal Regulations, *OSHA Part 1910*

3. Definitions

constructor: The party responsible for supplying the materials, equipment, tools, supervision, and labor for the installation of the grout in accordance with the contract documents. Unless otherwise noted, the term constructor shall apply also to the constructor's subcontractor(s) and vendor(s).

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets, that the purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made

part of the legal contract agreement or purchase order between the purchaser and the constructor

grout manufacturer: The party who produces and warrants the performance of the grout provided in accordance with the contract documents. The grout is manufactured in a controlled process using standard codes, specifications, tests and possibly includes shop drawings to assist in proper application, installation and/or use. Unless otherwise noted, the term grout manufacturer shall apply also to the grout manufacturer's subcontractor(s) and/or vendor(s).

owner: The party who has authority through ownership, lease, or other legal agreement over the site wherein the grout will be used

purchaser: The party who awards the contract to the constructor. The purchaser may be the owner or the owner's authorized agent.

4. Requirements

4.1 General

4.1.1 The constructor shall furnish all equipment, materials, labor, and supervision and shall perform all operations necessary for the formwork, proper mixing, placing, finishing, and curing of "nonshrink" cementitious grout, hereafter referred to as grout, where indicated by the contract documents.

4.1.2 Any conflicts or inconsistencies between this Practice, the design drawings, the grout manufacturer's specifications and recommendations, and other contract documents shall be brought to the attention of the purchaser for resolution before the work begins.

4.2 Field Quality Control of Grout

4.2.1 The constructor shall be solely responsible for the quality control of all constructor-provided materials, installations, and workmanship, including those items or installations provided by any of the constructor's subcontractors or vendors.

4.2.2 Notwithstanding the constructor's responsibility for quality, the grout manufacturer shall provide a technical representative who shall be on-site to review the grouting set-up procedures and the grouting manufacturer's instructions with those who will actually be doing the grouting. The technical representative shall remain at the grouting site as long and as often as required to ensure that the grout manufacturer's installation instructions are being followed. This requirement may be waived by the purchaser or as otherwise specified in the contract documents.

4.2.3 The purchaser reserves the right to make inspections at any time during mixing of the materials and during execution of all grout work.

4.3 Testing

4.3.1 After initial prequalification, grout shall be sampled and tested if required by the contract documents.

4.3.2 Three sets of three test cubes shall be made in the field each day that grout is mixed and placed.

4.3.3 Test cubes shall be in accordance with *ASTM C109/C109M*.

4.3.4 One set of test cubes shall be transported to the testing laboratory after the initial set and tested at 24 hours.

4.3.5 Cubes that remain at the site shall be tested as follows:

a. The remaining cubes shall be cured in the field for 3 days in the same way as the placed grout is cured.

b. At the end of 3 days, the cubes shall be transported to the testing laboratory for compressive strength testing.

c. One cube set shall be tested at 7 days and the other cube set at 28 days.

4.3.6 Compressive strength of cubes shall be tested in accordance with *ASTM C109/C109M* and shall meet the requirements of *ASTM C1107/ C1107M*.

4.4 Submittals

4.4.1 Unless noted otherwise in the contract documents, the grout manufacturer's literature, material safety data sheets, and certified test data for the grout shall be submitted to the purchaser. The literature and certified test data shall include the product's compressive strength, adhesive properties, dimensional stability, flowability, consistency, and other requirements in accordance with this Practice.

4.4.2 A minimum of fifteen days before installation, a written quality control program, describing in detail how compliance with this Practice shall be ensured, shall be submitted to the purchaser for review and approval. The program shall include procedures for all forming, handling, mixing, placement, locating joints, including joint details, curing, testing, and inspection.

4.4.3 If testing is required by the contract documents, the constructor shall submit to the purchaser copies of all inspection and test reports. Reports shall contain the date of grout placement, grout type, identification of foundation of grout placement, design compressive strength, air temperature at time of grout placement, foundation temperature at time of grout placement, and compressive break strengths.

4.5 Safety

4.5.1 The constructor shall be responsible for compliance with the safety requirements specified in the contract documents and by the grout manufacturer.

4.5.2 Grout Material Safety Data Sheets (MSDSs) shall be available, and associated hazards shall be reviewed with all grouting personnel.

4.5.3 Goggles or face shields, protective gloves, and aprons shall be worn by those personnel mixing and placing the grout.

4.5.4 Dust masks or respirators (in accordance with MSDS requirements) shall be worn by those personnel exposed to the grout or aggregate prior to mixing.

4.5.5 Soap and water shall be available for periodic hand cleaning, should the need arise.

4.6 Materials

4.6.1 All materials shall be provided in accordance with the contract documents and this Practice.

4.6.2 Grout Materials

4.6.2.1 All grout materials shall be proportioned products, in accordance with *ASTM C1107/C1107M.*

4.6.2.2 Grout materials shall be packaged in accordance with *ASTM C1107/C1107M.*

4.6.2.3 Grout materials shall require only the addition of potable water, and shall not contain metallic substances, aluminum powder, measurable amounts of water soluble chlorides, or other substances that may be potentially harmful to concrete or steel reinforcement.

4.6.2.4 Compressive strength shall be in accordance with *ASTM C1107/C1107M* (minimum 28-day compressive strength, 5000 psi (34 Mpa)).

4.6.2.5 Cementitious grouts shall not shrink and shall expand no more than 4.0 percent when tested in accordance with *ASTM C827* (before set) and no more than 0.3 percent when tested in accordance with *ASTM C1090* (after set).

4.6.2.6 All manufactured grout materials shall be delivered to the job site in original unopened packages and shall be stored in accordance with the grout manufacturer's recommendations.

4.6.2.7 All materials and tools shall be stored in a clean, dry, and organized manner.

4.6.2.8 Unless specified in the contract documents, admixtures shall not be added to the grout without approval of the purchaser and the grout manufacturer.

4.6.3 Mixing Water

Mixing water shall be potable and free of oils, acids, alkalines, organics, and other deleterious materials.

4.7 Preparation for Grouting

4.7.1 Foundation preparation shall be in accordance with the grout manufacturer's written instructions and the following. If there is a conflict between the manufacturer's instructions and the following, the manufacturer's instructions shall take precedence.

a. New concrete foundations shall be cured for 7 days minimum before surface preparation unless otherwise approved by purchaser.

b. In the areas that will be covered by grout, the foundation shall be prepared by chipping away all laitance (poor quality concrete) and oil-soaked or damaged concrete down to exposed fractured coarse aggregate. Concrete must be removed in this chipping process down to a depth to permit 1 inch (25 mm) minimum grout (or the grout thickness specified in contract documents) between the concrete and the bottom of of the base or sole plate. Scarifying the surface with a needle gun or bushing tool or sandblasting to remove laitance from the foundation is unacceptable. Concrete chipping and removal shall not be performed with heavy tools, such as jackhammers, as they could damage the structural integrity of the foundation. A chipping hammer with a chisel bit is the preferred tool for this purpose.

c. When the surface chipping is complete, the foundation shall be thoroughly swept and air-blown free of all dust with clean, dry, oil-free air.

d. The foundation must be kept free of contamination by oil, dirt, water, etc., after it has been prepared for grouting. Protective sheeting (such as sheets of clean polyethylene) shall be used to cover the prepared surfaces when work is not in progress.

4.7.2 Grout Forms

a. Grout forms shall be built of materials of adequate strength and securely anchored and sealed to withstand the liquid head and forces developed by the grout during placement.

b. Forms shall not be attached to the foundation using power nailing.

c. Grout forms shall be sealed to prevent grout leakage. Bitumastic or room temperature vulcanizable (RTV) silicone rubber can be used for this purpose.

d. Unless otherwise shown in the contract documents, grout forms shall have minimum 3/4-inch (19 mm), 45° chamfer strips at all exposed grout corners.

4.7.3 All metal surfaces of base plates and equipment bases which are to be in direct contact with the grout shall be free of oil, grease, and other foreign substances.

4.7.4 A bond breaker in accordance with the grout manufacturer's recommendations shall be applied to the surface of the formwork in contact with the grout.

4.7.5 Joints in grout shall be located in accordance with the contract documents or as recommended by the grout manufacturer. Unless otherwise shown in the contract documents, expansion joints shall be made from 1-inch (25 mm) thick closed-cell neoprene foam rubber (polystyrene may also be used). These shall be glued in position prior to the grout placement with silicone rubber (RTV) or elastic epoxy seam sealant (liquid rubber).

4.8 Installation of Grout

4.8.1 Grout shall be stored, mixed, placed, and cured in accordance with the grout manufacturer's written requirements and at temperature ranges that are consistent with the grout manufacturer's recommendations. The constructor

shall be responsible for reading, understanding, and complying with the grout manufacturer's instructions.

4.8.2 Grout shall be dry packed, flowed, or pumped into place in accordance with the grout manufacturer's written instructions for the specific grout being installed. Dry packing shall be used only where there is adequate accessibility.

Comment: For some grouts, particular installation methods are restricted or prohibited by the grout manufacturer. Therefore, manufacturer's written instructions shall be strictly followed.

4.8.3 Grouting shall be performed with ambient temperatures and mix temperatures between 40°F (4°C) and 90°F (32°C) unless otherwise permitted by the grout manufacturer. Comply with the manufacturer's special requirements for grouting done outside of this temperature range.

4.8.4 Concrete surfaces in contact with the grout shall be saturated surface dry (saturated with clean water before grout placement with the surface of the concrete damp but free from standing water).

4.8.5 All grout shall be placed in only one direction to prevent trapping air.

4.8.6 Grout shall be applied in the thickness specified in the contract documents.

4.8.7 Grouting shall be quick and continuous to avoid segregation, bleeding, or premature initial set.

4.8.8 Retempering of grout by adding water after stiffening is not permitted.

4.8.9 Where forms are not used, the grout shall be cut back to the lower edge of the baseplate after it has reached its initial set. The cutback shall be at a 45° angle, unless otherwise indicated in the contract documents.

4.8.10 If grout is placed through grout holes, the grout shall be placed into one hole continuously until the grout has passed a second hole. A liquid head pressure shall be maintained at the first access hole until a head pressure has been established at the next hole. Grout placement shall continue from the next hole in a similar fashion.

4.8.11 All voids in anchor bolt sleeves (except for rotating equipment) shall be cleared of all foreign material and completely filled with grout, unless shown otherwise on the drawings. Anchor bolt sleeves for rotating equipment, or other equipment shown on drawings, shall be filled with a non-bonding moldable material prior to grout placement.

4.8.12 If grouting around sliding surfaces, (e.g. reactor skirts, exchanger supports, etc.), grout shall be placed in such a manner that does not inhibit movement between sliding surfaces.

4.8.13 All voids that remain after removal of temporary shims shall be filled with the same grout material.

4.9 Curing

The following shall be adhered to unless the grout manufacturer specifies otherwise:

4.9.1 Forms shall remain in place for 24 hours minimum after completion of grouting.

4.9.2 Moisture loss must be prevented by keeping the exposed surfaces wet for 7 days minimum or by application of a curing compound.

4.9.3 Moist curing can be achieved by applying wet rags or burlap to the exposed surfaces. The wet rags or burlap shall be covered with plastic to prevent excessive evaporation. The wet rags or burlap shall be rewetted as necessary to maintain moistness.

4.9.3 Temperature of the grouted base and concrete foundation shall be maintained between 40°F (4°C) and 90°F (32°C) for 3 days minimum after the initial set.

4.9.4 Equipment shall not be placed in service before the grout has attained 80 percent of the specified 28-day design compressive strength.

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
August 2018

Structural

PIP STS05120
Structural and Miscellaneous Steel Fabrication Specification

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PRINTING HISTORY

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January 1999	*Revision*	*August 2018*	*Complete Revision*
January 2000	*Technical Correction*		

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PIP STS05120
Structural and Miscellaneous Steel Fabrication Specification

Table of Contents

1. Scope

This Practice provides requirements for materials, connections, detailing, fabricating, galvanizing, and delivery of structural and miscellaneous steel. Structural and miscellaneous steel are as defined in *ANSI/AISC 303-16* - Code of Standard Practice for Steel Buildings and Bridges.

This Practice does not include requirements that may be applicable for structures that require special seismic detailing.

2. References

Applicable parts of the following Practices, industry codes and standards, and government regulations shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP STS05130 - *Structural and Miscellaneous Steel Erection Specification*

2.2 Industry Codes and Standards

- American Institute of Steel Construction (AISC)
  - ANSI/AISC 303-16 - *Code of Standard Practice for Steel Buildings and Bridges*
  - AISC 325 - *Steel Construction Manual*
  - AISC 326 - *Detailing for Steel Construction*
  - ANSI/AISC 360-16 - *Specification for Structural Steel Buildings*
- ASTM International (ASTM)
  - ASTM A6/A6M - *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A53/A53M - *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*
  - ASTM A106/A106M - *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
  - ASTM A108 - *Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished*
  - ASTM A123/A123M - *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*
  - ASTM A143/A143M - *Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*
  - ASTM A307 - *Standard Specification for Carbon Steel Bolts and Studs, and Threaded Rod 60,000 PSI Tensile Strength*

  - ASTM A384/A384M - *Standard Practice for Safeguarding Against Warpage and Distortion during Hot-Dip Galvanizing of Steel Assemblies*
  - ASTM A385/A385M - *Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)*
  - ASTM A500/A500M - *Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes*
  - ASTM A563 - *Standard Specification for Carbon and Alloy Steel Nuts*
  - ASTM A563M - *Standard Specification for Carbon and Alloy Steel Nuts (Metric)*
  - ASTM A572/A572M - *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*
  - ASTM A759 - *Standard Specification for Carbon Steel Crane Rails*
  - ASTM A780/A780M - *Standard Specification for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*
  - ASTM A786/A786M - *Standard Specification for Hot-Rolled Carbon, Low-Alloy, High-Strength Low-Alloy, and Alloy Steel Floor Plates*
  - ASTM A992/A992M - *Standard Specification for Structural Steel Shapes*
  - ASTM A1011/A1011M - *Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength*
  - ASTM B695 - *Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel*
  - ASTM E376 - *Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods*
  - ASTM F436/F436M - *Standard Specification for Hardened Steel Washers Inch and Metric Dimensions*
  - ASTM F606/F606M - *Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets*
  - ASTM F959/F959M - *Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, Inch and Metric Series*
  - ASTM F1136/1136M - *Standard Specification for Zinc/Aluminum Corrosion Protective Coatings for Fasteners*
  - ASTM F2329/F2329M - *Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners*
  - ASTM F3125/F3125M - *Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions*
- American Welding Society (AWS)
  - AWS D1.1/D1.1M - *Structural Welding Code - Steel*

  - AWS D14.1/D14.1M - *Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment*
  - AWS QC1 - *Standard for AWS Certification of Welding Inspectors*
- National Association of Architectural Metals Manufacturers (NAAMM)
  - NAAMM MBG 531 - *Metal Bar Grating Manual*
- Research Council on Structural Connections (RCSC)
  - RCSC *Specification for Structural Joints Using High-Strength Bolts*
- Steel Deck Institute (SDI)
  - SDI *Design Manual for Composite Decks, Form Decks and Roof Decks*
- Steel Joist Institute (SJI)
  - SJI *Standard Specifications and Load Tables*

2.3 Government Regulations

Requirements by state or local agencies that have jurisdiction where the structural and miscellaneous steel is to be erected, shall apply.

- US Department of Labor, Occupational Safety and Health Administration (OSHA)
  - OSHA 29 CFR Part 1910
  - OSHA 29 CFR Part 1926

3. Definitions

contract documents: Any and all documents, including codes, studies, design documents, specifications, sketches, practices, and data sheets, that purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between purchaser and fabricator.

design documents: The design drawings, or where the parties have agreed in the contract documents to provide digital model(s), the design model. A combination of drawings and digital models also may be provided.

design drawings: The graphic and pictorial portions of the contract documents showing the design, location and dimensions of the work. These documents generally include, but are not necessarily limited to, plans, elevations, sections, details, schedules, diagrams and notes.

design model: A dimensionally accurate 3D digital model of the structure that conveys the structural steel requirements given in Section 3.1 of *ANSI/AISC 303-16* for the building or structure.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of the civil works, structure, foundations, materials, and appurtenances described in contract documents. Engineer of record shall be licensed as defined by laws of the locality in which the work is to be constructed, and be qualified to practice in specialty discipline required for the work described in contract documents. Also known as structural engineer of record in *AISC Code of Standard Practice*.

erection drawings: Field-installation or member-placement drawings that are prepared by the fabricator to show the location and attachment of the individual structural steel shipping pieces.

fabricator: Party responsible for providing fabricated structural and miscellaneous steel in accordance with contract documents. The term fabricator shall apply also to fabricator's subcontractor(s) and/or vendor(s).

inspector: Party responsible for verifying quality of all materials, installations, and workmanship furnished by fabricator. Inspector shall be qualified by training and experience and hold certifications or documentation of their qualifications. Unless otherwise specified in contract documents, inspector shall be retained by fabricator.

manufacturer: Party who produces and warrants performance of products, materials, and/or items provided in accordance with contract documents. Products, materials, and/or items are manufactured in a controlled process using standard codes, specifications, tests and possibly include shop drawings to assist in proper application, installation and/or use. The term manufacturer shall apply also to manufacturer's subcontractor(s) and/or vendor(s).

miscellaneous steel: Steel items other than structural steel that are typically attached to elements of the structural frame including but not limited to stairs, ladders, cages, guards, handrails, toe plate, floor plate, grating, steel decking, steel joists, crane rails and steel items embedded in concrete that are not intended to support structural steel.

owner: Party who owns facility wherein the structural and miscellaneous steel will be used.

professional engineer: An engineer, other than engineer of record licensed as defined by laws of the locality in which the steel is to be erected, and qualified to practice in specialty discipline required for the work described in contract documents.

purchaser: Party who awards contract to fabricator. Purchaser may be owner or owner's authorized agent.

shop drawings: Drawings of the individual structural steel shipping pieces that are to be produced in the fabrication shop.

structural steel: Elements of the structural frame that are shown and sized in the structural design documents, essential to support the design loads. See *ANSI/AISC 303-16*, Section 2.1 for a list of items defined as structural steel.

4. Requirements

4.1 Quality Control

4.1.1 Fabricator shall participate in the AISC Certification Program and be designated an AISC Certified Plant, Category BU (formerly known as Category STD).

4.1.2 Fabricator shall be solely responsible for quality control of all materials and workmanship.

4.1.3 Each piece of mill material shall be legibly marked with the heat number, size of section, length and mill identification marks in accordance with

ASTM A6/A6M, plus fabrication mill order number. Alternate material tracking procedures may be used if approved by purchaser.

4.1.4 For material other than *ASTM A36/A36M*, the appropriate specification number, grade, heat number and fabrication mill order number shall be transferred to the remnant. Alternate material tracking procedures may be used if approved by purchaser.

4.1.5 Mill material with specified minimum yield strength higher than 36 ksi (250 MPa) shall be marked with the color designated in *ASTM A6/A6M*. Alternate material tracking procedures may be used if approved by purchaser.

4.1.6 A written Material Handling Procedure, Quality Control Program, and Inspection Procedures document shall be provided. This document shall provide details of how compliance with requirements in this Practice and contract documents shall be achieved.

4.1.7 Purchaser has the right to inspect all materials and workmanship and shall have unrestricted entry to fabricator's shop at all times while work is being performed.

4.1.8 The purchaser may reject improper, inferior, defective, or unsuitable materials and workmanship.

4.1.9 All materials and workmanship rejected shall be repaired or replaced as directed by purchaser.

4.1.10 Bolted connections shall be inspected in accordance with the RCSC *Specification for Structural Joints Using High-Strength Bolts*.

4.1.11 Welding procedures and individual welders shall be qualified in accordance with requirements of *AWS D1.1/D1.1M* and when applicable *AWS D14.1/D14.1M*.

4.1.12 Welding procedures previously qualified for purchaser may be used without requalification. However, purchaser reserves the right to require requalification of any questionable procedure before the start of fabrication.

4.1.13 All welding shall be inspected in accordance with *AWS D1.1/D1.1M* and when applicable *AWS D14.1/D14.1M*. Inspectors shall be qualified and certified as AWS Certified Welding Inspectors in accordance with the provisions of *AWS D1.1/D1.1M* or *AWS QC1* or shall be trained by and working under the supervision of an AWS Certified Welding Inspector.

4.1.14 Welding of rigging and under the hook lifting devices shall be inspected in accordance with *AWS D14.1*. Inspectors shall be qualified and certified as AWS Certified Welding Inspectors in accordance with the provisions of *AWS D14.1* or *AWS QC1*.

4.1.15 Nondestructive testing of welded joints shall be performed in accordance with *ANSI/AISC 360-16* Chapter N. *ANSI/AISC 360-16* requirements for buildings shall also apply to nonbuilding structures. Unless otherwise specified, structures shall be considered as Risk Category III and groove welds shall be considered as being subject to transversely applied tension loading.

Comment: Chapter N refers to and is consistent with inspection requirements of *AWS D1.1/D1.1M*. However, *AWS*

D1.1/D1.1M specifies HOW nondestructive testing is to be performed, but does not specify the extent of nondestructive testing required. *ANSI/AISC 360-16* Chapter N clarifies this. However, there are different requirements for different structures. To apply Chapter N, fabricator needs to know the risk category of the structure and whether a particular weld carries direct tension. The language included here provides defaults typical for petrochemical projects which can be modified in contract documents.

4.1.16 Certified mill test reports for each heat of structural steel and each lot of high strength bolts shall be available for review by purchaser.

4.1.17 Purchaser may require a quantity of representative samples of bolt assemblies to be used for testing. Testing in accordance with *ASTM F606/F606M* shall be at purchaser's expense.

4.1.18 Purchaser reserves the right to inspect and reject all galvanized steel in accordance with *ASTM A123/A123M* and *ASTM E376*.

4.2 Submittals

4.2.1 The following items shall be submitted to engineer of record for approval. Work shall not proceed without approval:

a. Checked erection and shop drawings

b. Checked engineering calculations for each fabricator-designed connection

c. Quality Control Program and Inspection Procedures

d. Welding Procedure Specification (WPS)

e. Procedure Qualification Records (PQR)

f. Welder(s) qualification records

4.2.2 Final erection drawings, shop drawings, and field bolt lists shall be sent to the persons responsible for managing construction at their field office before shipment of steel.

4.2.3 A shipping list (including total weight of release and weight of shipment), a bolt list, and final erection drawings shall accompany the first shipment of each release.

4.2.4 As a minimum, the following documents shall be submitted to purchaser for record purposes:

a. Final erection and shop drawings

b. Records of Quality Control inspection test reports requested by purchaser

c. Final engineering calculations for each fabricator-designed connection sealed and signed by the responsible Professional Engineer

d. Records of calibration or recalibration performed on the tools or equipment used during the work, if requested by purchaser

4.2.5 Erection and Shop Drawings

a. Shop drawings and erection drawings shall be prepared in accordance with the AISC documents listed in Section 2.2.

b. Erection drawings shall reference the corresponding design documents; shop drawings shall reference the corresponding erection drawings.

c. Shop drawings shall clearly show the specification and grade of steel to be used.

d. Erection and shop drawings shall be grouped in sets and identified separately for each building, structure, or yard area.

e. Erection drawings shall clearly show the mark number and position for each member. Mark number system shall be agreed upon in advance with purchaser.

f. Erection drawings shall clearly identify pretensioned and slip critical high strength bolted connections.

g. Purchaser's purchase order number shall be shown on all erection and shop drawings.

h. Shop drawings shall state the welding electrode to be used.

i. Surface preparation and shop applied coatings, including areas to be masked, shall be noted on the shop drawings.

j. A bolt list and list of other fasteners showing the number, grade, size, and length of field bolts and other fasteners for each connection shall be provided. These lists may be shown on either the shop drawings or separate sheets.

k. In the event that drawing revisions are necessary, the shop drawings shall clearly be clouded showing all changes of the latest revisions.

l. Shop drawings and erection drawings shall be prepared using a three-dimensional steel modeling and detailing software system. All miscellaneous steel such as handrail, guards, stairs, and ladders shall be included in the same three-dimensional model as main structural steel and detailed using the same system.

4.3 Performance

4.3.1 All work shall be in accordance with the *ANSI/AISC 303-16, ANSI/AISC 360-16,* applicable portions of *OSHA 29 CFR Part 1910* and *Part 1926,* and any other applicable federal, state or local regulations.

4.3.2 If local specifications, codes, or standards exist for the materials, section properties, design, and test methods covered by this Practice which yield equivalent quality and performance, they may be substituted only with prior written approval by purchaser.

4.4 Products and Materials

4.4.1 Structural wide flange shapes and WT shapes made from wide flange shapes shall be *ASTM A992/A992M*, unless otherwise specified in contract documents.

4.4.2 Structural channels, angles, and other shapes shall be *ASTM A36/A36M*, *ASTM A992/A992M*, or *ASTM A572/A572M* Grade 50, as specified in contract documents.

4.4.3 Plates and bars shall be *ASTM A36/A36M*, or *ASTM A572/A572M* Grade 50, as specified in contract documents.

4.4.4 Pipe shall be *ASTM A53/A53M* Type E or S, Grade B or *ASTM A106/A106M* Grade B.

4.4.5 Structural tubing (hollow structural sections) shall be *ASTM A500/A500M* Grade C, unless otherwise specified in contract documents.

4.4.6 High strength bolt assemblies, except twist-off type bolt assemblies, shall be as follows:

a. Bolt - *ASTM F3125/F3125M*, Grade A325 (Grade A325M), Type 1 or *ASTM F3125/F3125M*, Grade A490 (Grade A490M), Type 1, as specified in contract documents

b. Washer - *ASTM F436 / ASTM F436M*

c. Direct Tension Indicator (DTI) washers - *ASTM F959 / ASTM F959M*, if specified in contract documents

e. Heavy Hex Nut - *ASTM A563 / ASTM A563M* Grade DH

4.4.7 If twist-off type high strength bolt assemblies are specified in contract documents, they shall be *ASTM F3125/F3125M*, Grade F1852, Type 1, or Grade F2280, Type 1, as specified in contract documents.

4.4.8 Standard bolt assemblies shall be as follows:

a. Bolt - *ASTM A307* Grade A Heavy Hex

b. Washer - *ASTM F436 / ASTM F436M*

c. Heavy Hex Nut - *ASTM A563 / ASTM A563M* Grade A

4.4.9 Headed studs shall be *ASTM A108* Grade 1010 through 1020, *AWS D1.1/D1.1M* Section 7, Type B.

4.4.10 Welding filler metal shall be *AWS D1.1/D1.1M* Section 3.3 (including Table 3.1), low hydrogen, with an electrode strength of 58 ksi (400 MPa) minimum yield strength and 70 ksi (480 MPa) minimum tensile strength. (For example, use E70XX for SMAW, F7XX-EXXX for SAW, ER70S-X for GMAW, and E7XT-X for FCAW.)

4.4.11 Crane rails shall be as follows:

a. Rails 60 to 84 lb/yd (29.8 to 41.7 kg/m) - *ASTM A1*

b. Rails 104 to 175 lb/yd (51.6 to 86.8 kg/m) - *ASTM A759*

4.4.12 Checkered floor plate shall be *ASTM A786/A786M* Pattern 4 or 5, commercial quality grade, fabricated from an applicable ASTM material with a minimum yield strength of 36 ksi (250 MPa).

4.4.13 Welded steel bar grating and grating stair treads shall be *ASTM A1011/A1011M*, Commercial Steel (Type B), galvanized in accordance with *ASTM A123/A123M* and *NAAMM MBG 531*. Top surface of bearing bars shall be ~~plain, unless~~ serrated ~~is specified~~. Grating stair treads shall have abrasive or checkered plate nosing.

4.4.14 Steel deck shall be in accordance with the SDI *Design Manual for Composite Decks, Form Decks and Roof Decks*.

4.4.15 Steel joists shall be in accordance with *SJI Standard Specifications and Load Tables.*

4.5 Connections

4.5.1 General

All connections shall be engineer-designed, fabricator-selected, or fabricator-designed as specified in contract documents.

Comment: One of these options will be specified in contract documents for each connection. Connections may be grouped by type and a combination of these options may be specified for the various connection types used in a project.

4.5.2 Engineer-Designed Connections

4.5.2.1 Engineer-designed connections will be fully designed and detailed in design documents, and shall be furnished as shown.

4.5.2.2 Engineer-designed connections shall be only those connections fully detailed in design documents, showing all fastener sizes, arrangement, dimensions, quantities and grades, and all connection material and weld types, sizes, and lengths for each individual member or part to be joined. This information shall be shown on shop drawings.

4.5.2.3 A request to deviate from the specific details of any engineer-designed connection shall be in writing, with written approval of engineer of record. Approval of this submittal constitutes acceptance by engineer of record of design responsibility for the structural adequacy of the changed detail. Such changed details shall also be clearly shown on shop drawings.

4.5.3 Fabricator-Selected Connections

4.5.3.1 Fabricator-selected connections shall be those for which engineer of record has authority and responsibility for the design adequacy and fabricator has authority and responsibility for the detailing.

4.5.3.2 Fabricator-selected connections shall be simple connections (shear only, or negligible bending moment). These connections shall be detailed by selecting standard details from the accepted standards listed in Section 2.2 and shall meet all other requirements in contract documents.

4.5.3.3 The approval by engineer of record of shop drawings detailing fabricator-selected connections constitutes acceptance by engineer of record of design responsibility for the structural adequacy, but not the detailing, of the approved fabricator-selected connections.

4.5.4 Fabricator-Designed Connections

4.5.4.1 Fabricator-designed connections shall be designed and detailed to equal or exceed the required strength shown in design documents or as provided in contract documents.

4.5.4.2 A professional engineer shall design or supervise the design of all fabricator-designed connections and be responsible for the structural adequacy.

4.5.4.3 Fabricator-designed connections shall meet all requirements of contract documents.

4.5.4.4 In all cases, the design shall consider the entire joint (including beams, girders, columns, and bracing) and shall take into account all applicable limit states, including bolt shear, combined bolt tension and shear, prying action, local bending, coped beam capacities, block shear, web buckling, etc.

4.5.4.5 Stiffeners for column webs, column flanges, and for elements of other members involved shall be designed and furnished as required.

4.5.4.6 Checked engineering calculations for each fabricator-designed connection shall be sealed and signed by the responsible professional engineer who designed or supervised the design of the connections.

4.5.4.7 If required by contract documents, all shop drawings containing fabricator-designed connections shall be sealed and signed by the responsible professional engineer.

4.5.4.8 Review of shop drawings detailing fabricator-designed connections and engineering calculation sheets by engineer of record does not relieve fabricator of responsibility for both the structural adequacy and detailing of connections designed by fabricator.

4.5.5 Bolted Connections

4.5.5.1 Design, detailing, and fabrication of bolted connections shall be in accordance with either AISC's Allowable Strength Design (ASD) or Load and Resistance Factor Design (LRFD) method, as noted in contract documents.

4.5.5.2 Connection design shall be in accordance with the RCSC *Specification for Structural Joints Using High-Strength Bolts, AISC 325,* and *AISC 326.*

4.5.5.3 The minimum available strength of all bolted, or mixed bolted and welded, framed beam connections shall be the member end reaction shown in design documents.

4.5.5.4 Unless otherwise specified in design documents, 3/4 inch (M20) diameter *ASTM F3125/F3125M*, Grade A325 (Grade A325M) high-strength bolts shall be used in all bolted structural connections.

4.5.5.5 *ASTM F3125/F3125M*, Grade A325 (Grade A325M) bolts larger than 3/4-inch (M20) diameter shall not be used without specific written approval of engineer of record.

4.5.5.6 *ASTM A307* bolts, 5/8-inch (16 mm) or smaller diameter shall be permitted for ladder, stair tread, purlin, girt, door frame, and guard and handrail connections.

4.5.5.7 *ASTM A307* bolts larger than 5/8-inch (16 mm) shall not be permitted.

4.5.5.8 The minimum number of bolts in a framed beam connection shall be two bolts.

4.5.5.9 High-strength bolted connections shall be bearing type A325-N with threads included in the shear plane.

4.5.5.10 Slip-critical type connections A325-SC shall be used if noted in contract documents.

4.5.5.11 Unless otherwise specified in design documents or permitted by the following paragraphs, all bolt holes shall be standard holes as defined by *ANSI/AISC 360-16*.

4.5.5.12 For framed beam bearing connections, horizontal short-slotted holes as defined by *ANSI/AISC 360*-16 may be used in the outstanding leg of clip angles if approved by engineer of record.

4.5.5.13 For framed beam slip-critical connections, oversized or horizontal short-slotted as defined by *ANSI/AISC 360-16* holes may be used in the outstanding leg of clip angles if approved by engineer of record.

4.5.5.14 Unless otherwise approved by engineer of record, the long direction of the slot shall be perpendicular to the load direction.

4.5.5.15 Slotted or oversized hole dimensions shall be in accordance with Table J3.3 of the *ANSI/AISC 360-16*.

4.5.5.16 Hardened washers shall be provided under all bolt heads and/or nuts adjacent to any ply with oversized or slotted holes.

4.5.5.17 For standard holes, a minimum of one hardened washer shall be supplied with each bolt.

4.5.5.18 If used, direct tension indicator washers shall be in accordance with *ASTM F959 / ASTM F959M* and shall be installed according to the washer manufacturer's published specifications.

4.5.5.19 All bolt lengths shall be determined in accordance with the Commentary on *RCSC Specification for Structural Joints Using High-Strength Bolts*, Table C-2.2.

4.5.5.20 A minimum of 5% extra quantities of each bolt size and length, including nuts and washers, shall be provided for field erection.

4.5.5.21 Mechanically galvanized bolts or nuts shall not be interchanged with hot dipped galvanized nuts or bolts, respectively.

4.5.5.22 All column splices shall be field bolted and shall be in accordance with *AISC 326*, Appendix C.

4.5.5.23 All nuts for high-strength bolts shall be wax-dipped to reduce torque during installation.

4.5.5.24 Each bolt component shall be clearly marked with the component manufacturer's identification.

4.5.6 Welded Connections

4.5.6.1 Design, detailing, and fabrication of welded connections shall be in accordance with either AISC's Allowable Strength Design (ASD) or Load and Resistance Factor Design (LRFD) method, as specified in contract documents.

4.5.6.2 Welded connection design shall be in accordance with *ANSI/AISC 360*, *AISC 325*, and *AISC 326*. Welding for monorails, lifting lugs and other below the hook devices required for lifting or rigging shall conform to *AWS D14.1/14.1M*.

4.5.6.3 The minimum available strength of all welded framed beam connections shall be the member end reaction specified in design documents.

4.5.6.4 Minimum fillet weld size shall be AISC minimum or 3/16 inch (5 mm), whichever is larger, for structural welds.

4.5.6.5 Seal welds shall be 1/8 inch (3 mm) minimum fillet weld.

4.5.6.6 Welds shall be continuous, unless otherwise specified in design documents or approved by engineer of record.

4.5.6.7 Erection clips for field welded connections shall be provided.

4.5.6.8 All run-off bars and extension tabs shall be removed unless otherwise noted.

4.5.7 Shop and Field Connections

4.5.7.1 Unless otherwise specified in design documents, all field, galvanized, or coated connections shall be bolted and all shop connections shall be either bolted or welded.

4.5.7.2 To ensure electrical continuity if shop applying non-conductive coatings (i.e., epoxies), all contact surfaces shall be masked unless otherwise noted in contract documents.

4.5.7.3 All locations of no-paint or areas requiring full masking or strip masking shall be noted on the shop drawings.

4.5.7.4 Provide additional bolts or connection devices where required to comply with *OSHA 29 CFR Part 1926, Subpart R – Steel Erection*.

4.5.8 Bracing Connections

4.5.8.1 Connections for pre-assembled bracing and truss members shall be designed for the required strength specified in design documents, but not less than 50% of the available tensile strength of the member, unless otherwise specified in design documents.

4.5.8.2 The available tensile strength of the member shall be calculated using the gross cross section of the member.

4.5.8.3 A minimum of two bolts per connection shall be provided.

4.5.8.4 All cross bracing shall be bolted at intersections with one bolt minimum for angles and two bolts minimum for tees.

4.5.8.5 All bracing connections, including gusset plates, shall be designed in accordance with the *ANSI/AISC 360-16* and *AISC 325*.

4.5.8.6 All gusset and stiffener plates shall be 3/8 inch (10 mm) minimum thickness.

4.5.8.7 Unless otherwise specified in design documents, all vertical bracing and knee bracing shall have gusset plates on column centerlines.

4.5.8.8 Unless otherwise specified in design documents, the following working points shall be used:

a. For vertical bracing at the intersection of a column, beam, and brace, the gusset plate shall be connected to both beam and column. The work point shall be the point at which the beam and column centerlines intersect.

b. For the connection of V-braces to nominal beams 10 inches (250 mm) or smaller, the working point shall be the intersection of the horizontal centerline of the beam and the centerline of the bay.

c. For the connection of V-braces to nominal beams 12 inches (300 mm) or larger, the working point shall be the intersection of a horizontal line 5 inches (125 mm) below the top flange if the brace is above the beam, or 5 inches (125 mm) above the bottom flange if the brace is below the beam, and the centerline of the bay.

4.5.9 Connections for Concrete Fireproofed Members

4.5.9.1 Connections for members fireproofed with concrete shall be detailed to minimize blockouts in shop applied fireproofing.

4.5.9.2 Gusset plates for vertical or horizontal bracing members and single-plate shear connections for beams shall extend outside fireproofing a sufficient length to make the connection with the fireproofing in place.

4.6 Fabrication

4.6.1 All fabrication shall be in accordance with *ANSI/AISC 303-16* and *ANSI/AISC 360-16*, unless otherwise specified in contract documents, state or local laws, or building codes.

4.6.2 All welding shall be in accordance with *AWS D1.1/D1.1M* and contract documents.

4.6.3 Shop splices, substitutions of member sizes, or changes in details or dimensions shall not be permitted without written authorization from engineer of record.

4.6.4 All beams, except cantilevers, shall be fabricated with natural mill camber in the up position.

4.6.5 All re-entrant corners shall be shaped, notched-free, to a radius.

4.6.6 If performing shop assembly work, the tolerances shall not exceed those specified in *ANSI/AISC 303-16*.

4.6.7 All pieces shall be clearly marked with a permanent identifying erection mark number. Method and location of marking shall be proven by past performance to survive galvanizing, shipping, handling, and outdoor storage and be approved by purchaser.

4.6.8 Before surface preparation, all sharp corners, burrs (including bolt hole burrs), weld spatter, slag, weld flux, loose mill scale and other foreign matter shall be removed.

4.6.9 Platforms, stairways, guards, and handrails shall be shop assembled in the largest units suitable for handling and shipping. Ladder cages shall be shop assembled on ladders.

4.6.10 The method for fastening grating shall be as specified in the contract documents. A minimum of two fasteners per panel shall be used at each support, with a minimum of four per panel. The fasteners shall be supplied with 5% extra to cover losses.

4.6.11 Grating/checkered plate openings shown in design documents shall be cut and banded in the shop unless otherwise noted in design documents.

4.6.12 Joints perpendicular to the span of grating and checkered plate flooring shall be permitted only over support members.

4.6.13 Checkered plate shall have 1/2 inch (12 mm) diameter drain holes provided for each 20 square feet (2 square meters) of area, with a minimum of one hole per panel.

4.7 Galvanizing / Corrosion Protective Coating

4.7.1 General

4.7.1.1 Unless otherwise noted in contract documents, all materials, except crane rails and *ASTM F3125/F3125M*, Grade A490 (Grade A490M) bolts and corresponding nuts and washers, shall be galvanized.

4.7.1.2 Galvanizing of steel shapes, plates, and hardware shall be in accordance with the following ASTM specifications:

a. Steel shapes and plates - *ASTM A123/A123M*

b. *ASTM F3125/F3125M* , Grade A325 (Grade A325M) bolts and corresponding nuts and washers - *ASTM B695* or *ASTM F2329/F2329M*

c. *ASTM A36/A36M* threaded bar or *ASTM A307* bolts and corresponding nuts and washers - *ASTM B695* or *ASTM F2329/F2329M*

4.7.1.3 Unless otherwise noted in contract documents, *ASTM F3125/F3125M*, Grade A490 (Grade A490M) bolts and corresponding nuts and washers shall be coated with Zinc/Aluminum corrosion protective coating in accordance with *ASTM F1136/F1136M*, Grade 3.

4.7.2 Fabrication

4.7.2.1 It shall be fabricator's responsibility to safeguard against embrittlement and warpage in accordance with *ASTM A143/A143M* and *ASTM A384/A384M*.

4.7.2.2 Fabrication details shall be in accordance with *ASTM A385/A385M* to allow for the creation of high quality zinc coatings.

4.7.2.3 If practical, cutting, drilling and welding shall be performed before galvanizing.

4.7.2.4 Weld slag shall be removed before galvanizing.

4.7.2.5 The edges of tightly contacting surfaces shall be completely seal welded.

4.7.2.6 Vent holes shall be provided for piping or tubular assemblies as required by *ASTM A385/A385M*.

4.7.2.7 Potential problems that require a modification in design shall be brought to the attention of purchaser before proceeding.

4.7.3 Galvanizing of Steel Hardware

4.7.3.1 Nuts shall be tapped oversize in accordance with *ASTM A563 / ASTM A563M*.

4.7.3.2 Nut threads shall be retapped after hot-dip galvanizing to provide proper fit.

4.7.3.3 Direct tension indicators, if used, shall be mechanically galvanized by the indicator manufacturer in accordance with Class 50 of *ASTM B695*.

4.7.4 Repair

4.7.4.1 Any damage to galvanizing shall be repaired in accordance with *ASTM A780/A780M* and as described below unless otherwise specified in contract documents.

4.7.4.2 Before repair of damaged galvanized coating, exposed substrate metal shall be cleaned to bright metal and free of all visual rust, oil, or grease. Any nonadhering galvanizing shall be removed to the extent that the surrounding galvanizing is integral and adherent.

4.7.4.3 If surface defects exceed 2% of a member's area, the defects shall be repaired by redipping the member in the zinc bath.

4.7.4.4 Cold repair using an organic zinc rich coating shall be permitted if the following conditions exist:

a. Total damaged area is less than 1% of the total coated area of the member being repaired

b. No single repair is greater than 2 square inches (1300 mm^2)

c. No single repair is greater than 12 inches (300 mm) long.

4.7.4.5 For coating applied for a cold repair, the dry film thickness shall be 2 to 3 mils (0.05 mm to 0.08 mm) and contain a minimum of 65% zinc dust by weight.

4.7.4.6 Hot repairs shall be made in the shop if any of the following conditions exist:

a. Total damaged area is greater than 1% but less than 2% of the total coated area of the member being repaired

b. Any single repair is at least 2 square inches (1300 mm^2) in area

c. Any single repair is 12 inches (300 mm) long or more

4.7.4.7 Hot repair shall be made using zinc alloy rod or powder manufactured for the repair of galvanized steel.

4.7.4.8 Flux, heavy ash, or heavy dross inclusions shall be removed by brushing, grinding, or filing as required.

4.7.4.9 Galvanized steel which has been rejected shall be stripped, regalvanized, and submitted again for inspection.

4.7.4.10 Correction of excessive warpage that exceeds *ASTM A6/A6M* criteria shall be performed by press straightening if possible.

4.7.4.11 The application of localized heating to straighten shall be approved by engineer of record.

4.7.4.12 If galvanized tension control bolts are used, all bare steel surfaces (i.e., bolt ends) shall be repair galvanized in accordance with this section.

4.8 Handling, Shipping, and Delivery

4.8.1 Delivery of steel shall be in the order needed for erection. The delivery sequence for the fabricated steel, unless otherwise noted in contract documents or arranged by purchaser, shall be as follows:

a. Loose base plates

b. Steel embedded in concrete

c. Erection bolts

d. First tier columns and framing for all its levels (including stairs, grating, and handrail)

e. Second tier columns and its framing, etc.

4.8.2 All bolts, washers, and nuts shall be packaged and delivered in rigid (not cardboard), weatherproof containers.

4.8.3 Railcars and/or trucks shall be loaded and cribbed so they can be readily unloaded by others.

4.8.4 Railcars and/or trucks shall be loaded in such a manner that continuous drainage is ensured.

4.8.5 All steel and its coatings shall be protected from any damage caused by handling, storage, or shipping before receipt by purchaser.

4.8.6 Adequate protection shall be provided for threads on sag rods and any other threaded components to prevent damage during shipping and handling.

4.8.7 All materials and documentation shall be delivered to the job site in good condition.

4.8.8 All materials and documentation will be inspected by purchaser upon receipt to determine that all items included in the bill of materials have been supplied, to ensure that all documentation has been received, and to check for any damage.

4.8.9 Purchaser reserves the right to reject all damaged or below quality material or documentation.

PROCESS INDUSTRY PRACTICES

COMPLETE REVISION
August 2018

Structural

PIP STS05130
Structural and Miscellaneous Steel Erection Specification

PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

This Practice is subject to revision at any time.

PRINTING HISTORY

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December 1998	*Revision*	*August 2018*	*Complete Revision*
February 2002	*Technical Correction*		

Not printed with State funds

PIP STS05130
Structural and Miscellaneous Steel Erection Specification

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Drawing

1. Scope

This Practice provides requirements for receipt, handling, erection, assembly, and field inspection of structural and miscellaneous steel. Structural and miscellaneous steel are as defined in *ANSI/AISC 303-16* - Code of Standard Practice for Steel Buildings and Bridges.

2. References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Process Industry Practices (PIP)

- PIP STS03600 - *Nonshrink Cementitious Grout Specification*
- PIP STS03601 - *Epoxy Grout Specification*
- PIP STS05120 - *Structural and Miscellaneous Steel Fabrication Specification*

2.2 Industry Codes and Standards

- American Institute of Steel Construction (AISC)
  - ANSI/AISC 303-16 - *Code of Standard Practice for Steel Buildings and Bridges*
  - AISC 325 - *Steel Construction Manual*
  - ANSI/AISC 360-16 - Specification for Structural Steel Buildings
- American Society of Safety Engineers (ASSE)
  - ASSE A10.13 - *Safety Requirements for Steel Erection – American National Standard for Construction and Demolition Operations*
- ASTM International (ASTM)
  - ASTM A36/A36M - *Standard Specification for Carbon Structural Steel*
  - ASTM A307 - *Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength*
  - ASTM F3125/F3125M - *Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions*
- American Welding Society (AWS)
  - AWS D1.1/D1.1M - *Structural Welding Code – Steel*
  - AWS QC1 - *Specification for AWS Certification of Welding Inspectors*
- Research Council on Structural Connections (RCSC)
  - RCSC *Specification for Structural Joints Using High-Strength Bolts*
- Steel Deck Institute (SDI)
  - SDI *Design Manual for Composite Decks, Form Decks and Roof Decks*
- Steel Joist Institute (SJI)
  - SJI *Standard Specifications and Load Tables*

2.3 Government Regulations

Requirements by state or local agencies that have jurisdiction where the structural and miscellaneous steel is to be erected, shall apply.

- U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)
  - *OSHA 29 CFR Part 1910*
  - *OSHA 29 CFR Part 1926*

3. Definitions

contract documents: Any and all documents, including codes, studies, design documents, specifications, sketches, practices, and data sheets, that purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between purchaser and erector.

design documents: The design drawings, or where the parties have agreed in the contract documents to provide digital model(s), the design model. A combination of drawings and digital models also may be provided.

design drawings: The graphic and pictorial portions of the contract documents showing the design, location and dimensions of the work. These documents generally include, but are not necessarily limited to, plans, elevations, sections, details, schedules, diagrams and notes.

design model: A dimensionally accurate 3D digital model of the structure that conveys the structural steel requirements given in Section 3.1 of *ANSI/AISC 303-16* for the building or structure.

engineer of record: Purchaser's authorized representative with overall authority and responsibility for engineering design, quality, and performance of civil works, structure, foundations, materials, and appurtenances described in contract documents. Engineer of record shall be licensed as defined by laws of the locality in which the work is to be constructed, and be qualified to practice in the specialty discipline required for the work described in contract documents. Also known as structural engineer of record in *AISC Code of Standard Practice*.

erection drawings: Field-installation or member-placement drawings that are prepared by the fabricator to show the location and attachment of the individual structural steel shipping pieces.

erector: Party responsible for erecting structural and miscellaneous steel in accordance with contract documents. The term erector shall apply also to erector's subcontractor(s) and/or vendor(s).

inspector: Party responsible for verifying quality of all materials, installations, and workmanship furnished by erector. Inspector shall be qualified by training and experience and hold certifications or documentation of their qualifications. Unless otherwise specified in contract documents, inspector shall be retained by erector.

manufacturer: Party who produces and warrants performance of products, materials, and/or items provided in accordance with contract documents. Products, materials, and/or items are manufactured in a controlled process using standard codes, specifications, tests and possibly include shop drawings to assist in proper application, installation and/or use. The term manufacturer shall apply also to manufacturer's subcontractor(s) and/or vendor(s).

miscellaneous steel: Steel items other than structural steel that are typically attached to elements of the structural frame including but not limited to stairs, ladders, cages, guards, handrails, toe plate, floor plate, grating, steel decking, steel joists, crane rails and steel items embedded in concrete that are not intended to support structural steel.

owner: Party who owns facility wherein the structural and miscellaneous steel will be used.

professional engineer: An engineer, other than engineer of record licensed as defined by laws of the locality in which the steel is to be erected, and qualified to practice in the specialty discipline required for the work described in contract documents.

purchaser: Party who awards contract to erector. Purchaser may be owner or owner's authorized agent.

shop drawings: Drawings of the individual structural steel shipping pieces that are to be produced in the fabrication shop.

structural steel: Elements of the structural frame that are shown and sized in the structural design documents, essential to support the design loads. See *ANSI/AISC 303-16*, Section 2.1 for a list of items defined as structural steel.

4. Requirements

4.1 General

4.1.1 Quality Control

4.1.1.1 Erector shall participate in the AISC Certification Program and be designated an AISC Certified Erector, Category ACSE.

4.1.1.2 Erector shall be solely responsible for quality control of all installations, workmanship, and erector-supplied materials.

4.1.1.3 Provide a written Quality Control Program and Inspection Procedures document that includes details of how compliance with requirements of this Practice and shop and erection drawings will be achieved.

4.1.1.4 Maintain a complete up-to-date set of erection drawings at jobsite.

4.1.1.5 Bolted connections shall be installed and inspected in accordance with RCSC *Specification for Structural Joints Using High-Strength Bolts*.

4.1.1.6 Welding procedures and individual welders shall be qualified in accordance with the requirements of *AWS D1.1/D1.1M*.

4.1.1.7 All welding shall be inspected in accordance with *AWS D1.1/D1.1M*. Inspectors shall be qualified and certified as AWS Certified Welding Inspectors in accordance with the provisions of *AWS D1.1/D1.1M* or *AWS QC1* or shall be trained by and working under the supervision of an AWS Certified Welding Inspector.

4.1.1.8 Inspector shall inspect all materials, installations, and workmanship to ensure conformance with all requirements of this Practice and contract documents.

4.1.1.9 Purchaser shall have the right to inspect all materials, installations, and workmanship and shall have an unrestricted right of access to work areas.

4.1.1.10 Purchaser may reject any improper, inferior, defective, or unsuitable materials, installations, and workmanship.

4.1.1.11 Rejected materials, installations, and workmanship shall be repaired or replaced in accordance with purchaser's instructions at no cost to purchaser.

4.1.1.12 Inspection tools and tool calibration records for tools used shall be maintained and available for examination by purchaser.

4.1.1.13 Nondestructive testing of welded joints shall be performed in accordance with *ANSI/AISC 360-16*, Chapter N. *ANSI/AISC 360-16* requirements for buildings shall also apply to nonbuilding structures. Unless otherwise specified, structures shall be considered as Risk Category III and groove welds shall be considered as being subject to transversely applied tension loading.

Comment: Chapter N refers to and is consistent with inspection requirements of *AWS D1.1/D1.1M*. However, *AWS D1.1/D1.1M* specifies HOW nondestructive testing is to be performed, but does not specify the extent of nondestructive testing required. *ANSI/AISC 360-16 Chapter N* clarifies this. However, there are different requirements for different structures. To apply *Chapter N*, fabricator needs to know the risk category of the structure and whether a particular weld carries direct tension. The language included here provides defaults typical for petrochemical projects which can be modified in contract documents.

4.1.2 Submittals

4.1.2.1 The following items shall be submitted to engineer of record for approval. Work shall not proceed without approval.

a. Safety program

b. Quality control program and inspection procedures

c. Welding Procedure Specification (WPS)

d. Procedure Qualification Records (PQR)

e. Welder(s) qualification records

f. Assembly lift plan(s) as required by purchaser or *OSHA 29 CFR Part 1926 Subpart R*

4.1.2.2 If requested, the following documents shall be submitted to purchaser for recording purposes:

a. Quality control inspections and test results

b. Calibration or recalibration performed on tools or equipment used during the work

4.1.3 Performance Requirements

4.1.3.1 Safety

1. A written safety program shall be provided that addresses safety measures that will be used during steel erection work.
2. Safety program shall be in accordance with:
   a. Contract documents
   b. *ANSI/AISC 303-16*
   c. Applicable portions of *OSHA 29 CFR Part 1910* and *Part 1926*
   d. Any other applicable federal, state, or local requirements

4.1.3.2 Assembly Lift Plan

Erector shall be responsible for assuring all preassemblies not specifically shown or noted in contract documents to be preassembled before lifting will maintain structural integrity during lifting.

1. Provide a written assembly lift plan to purchaser, prepared by a professional engineer, for assemblies larger than 50 feet (15 meters) in one direction, larger than 2,000 square feet (186 square meters) in the plan area, greater than 50 tons (45 metric tons), or as otherwise specified in contract documents.
2. Assembly lift plan shall demonstrate that proposed lift will be performed safely and that assemblies being lifted will remain free from distortion or undue bending, and maintain structural integrity during the lift.
3. Assembly lift plan shall contain detailed data on extent of lifted assembly, its weights, structural calculations that prove structural stability of assembled components during lifting operations, verification of capacity capabilities for any cranes utilized in the lift, location and positioning of cranes, and a description of rigging to be utilized.
4. Review of assembly lift plan by purchaser does not relieve erector's responsibility for safe erection and/or lifting of any component, structural assembly, or any other item.

4.2 Products and Materials

Unless otherwise specified, all materials shall be in accordance with *PIP STS05120*.

4.3 Execution

4.3.1 Receiving, Inspection, and Storage

4.3.1.1 All materials shall be received, unloaded, stored, and otherwise handled in a manner that prevents distortion, deterioration, damage, or staining.

4.3.1.2 Keep all materials free of dirt, grease, and other foreign matter.

4.3.1.3 Unless otherwise specified, inspect all materials immediately after receipt to ensure that the materials are not damaged, that all items on

the packing list have been supplied, and that all documentation has been received.

4.3.1.4 If any damage is discovered, or any parts, components, or documentation are missing or otherwise defective, immediately report the occurrence in writing to purchaser.

4.3.2 Erection

4.3.2.1 Erect structural and miscellaneous steel in accordance with:

a. Contract documents

b. *ANSI/AISC 303-16*

c. *OSHA 29 CFR Part 1910* and *Part 1926*

d. Applicable state, municipal, or local regulations or codes

4.3.2.2 Erect steel joists in accordance with:

a. Requirements of Steel Joist Institute (SJI)

b. Joist manufacturer's written instructions

c. *OSHA 29 CFR 1926 Subpart R*

4.3.2.3 Erect steel deck in accordance with:

a. Requirements of Steel Deck Institute (SDI)

b. Deck manufacturer's written instructions

c. *OSHA 29 CFR 1926 Subpart R*

4.3.2.4 Install ladder safety gates, ladder safety systems and personal fall arrest systems in accordance with:

a. Contract documents

b. Manufacturer's written instructions

c. *OSHA 29 CFR Part 1910*

4.3.2.5 Immediately report to purchaser in writing any circumstances discovered that affect progress, performance, or completion of work activities. These may include, but are not limited to, discrepancies between the erection/shop drawings and the delivered steel members, incorrectly fabricated steel members, or incomplete or unacceptable work of other contractors affecting the work.

4.3.2.6 Report any damage caused during erection to purchaser in writing. Complete corrective measures as directed by purchaser at no cost to purchaser.

4.3.2.7 Do not place temporary erection loads or permanent loads on any incomplete portions of the structure being erected unless it can be demonstrated by analysis that the contemplated action is safe.

4.3.2.8 Restrain or remove loose timbers, metal sheeting, bolt buckets, tools, debris, and temporary scaffolding from work areas.

4.3.2.9 Lift painted or galvanized structural members with a nonabrasive choker.

4.3.2.10 Maintain a daily record, by piece number, of all material erected.

4.3.2.11 Before commencing work, check foundations and other connection points to confirm their location, orientation, elevation, and condition.

4.3.2.12 Where connecting to existing structures, protect existing structure from weather.

4.3.3 Structural Stability

4.3.3.1 During construction, erector shall be responsible for maintaining structure in a stable condition; ensuring that no part shall be overstressed during construction activities. It shall be erector's responsibility to specify, install and locate all temporary bracing and/or guy cables to maintain the partly-assembled structure in a stable condition under a combination of probable construction and wind loads. This responsibility shall also extend to temporary bracing required to ensure safe and stable conditions of partially completed structural assemblies.

4.3.3.2 Structure shall be plumbed, leveled, and braced before any final bolted or welded connections are made and before grouting of base plates.

4.3.4 Setting Base Plates

4.3.4.1 Clean top of bearing surfaces and bottom of base plates.

4.3.4.2 Provide temporary shims or wedges where required.

4.3.4.3 Set and shim column base plates to correct positions, elevations, and locations as shown on erection drawings.

4.3.4.4 If setting nuts are used, loosen them after installing shims or wedges and before grouting.

4.3.4.5 Unless otherwise specified in contract documents, grout base plates in accordance with *PIP STS03600* or *PIP STS03601* as applicable. Fill shear key openings with grout. Fill anchor sleeves with grout only if specified in contract documents. Chamfer or cut off exposed edges of grout at 45 degrees after grout has acquired its initial set in accordance with *PIP STS03600* or *PIP STS03601* as applicable.

4.3.4.6 After grout has reached design strength, remove temporary shims or wedges and grout void space.

4.3.4.7 If required in contract documents, fully tighten anchors to specified tension.

4.3.4.8 Anchors shall be fully tightened to specified tension only after base plates have been grouted and grout has sufficiently set in accordance with manufacturer's recommendations.

4.3.5 Bolted Connections

4.3.5.1 If structural joints are made using high-strength bolt assemblies, materials, methods of installation, tension control, types of wrenches to be used, and inspection methods shall be in accordance with RCSC *Specification for Structural Joints Using High-Strength Bolts* and contract documents.

4.3.5.2 If used, direct tension indicator (DTI) washers shall be installed in accordance with DTI washer manufacturer's written instructions.

4.3.5.3 All bolts shall be as noted on shop drawings, erection drawings, or other contract documents.

4.3.5.4 Mechanically galvanized bolts and nuts shall not be intermixed with hot-dip galvanized nuts and bolts.

4.3.5.5 If *ASTM A307* bolt assemblies are used for connecting miscellaneous steel (i.e., guard and handrails, fixed ladders and cages, etc.) to structural steel members, bolts shall be tightened to a snug-tight condition.

4.3.5.6 *ASTM F3125/F3125M*, Grade A490 (Grade A490M) bolts and galvanized *ASTM F3125/F3125M*, Grade A325 (Grade A325M) bolts shall not be reused.

4.3.5.7 Bolts that have been pretensioned shall be color coded, die punched, or otherwise marked on the ends indicating that bolts have been properly tensioned and are ready for inspection.

4.3.6 Welded Connections

4.3.6.1 All welding shall be in accordance with *AWS D1.1/D1.1M* and contract documents.

4.3.6.2 Unless approved otherwise by the purchaser, all welds shall be continuous.

4.3.6.3 Minimum fillet weld size shall be AISC minimum or 3/16 inch (5 mm), whichever is larger, for structural welds.

4.3.6.4 Seal welds shall be 1/8-inch (3-mm) minimum fillet weld.

4.3.6.5 Welds to connection plates embedded in concrete shall be deposited in a sequence that minimizes distortion of the embedment to plus or minus 1/8 inch (3 mm) of flat or true.

4.3.6.6 If contract documents require welding to existing facilities that were constructed before 1963 and/or using steel other than *ASTM A36/A36M*, erector shall follow welding procedures provided by engineer of record.

4.3.7 Correction of Errors

4.3.7.1 Fit-up bolts and drift pins shall not be used to bring improperly fabricated members and parts into place (springing).

4.3.7.2 Drift pins shall not be driven with such a force as to damage adjacent metal areas.

4.3.7.3 Holes in connections that misfit by more than 1/16 inch (1 mm) shall be corrected as directed by engineer of record.

4.3.7.4 Enlargement of holes shall be made only when approved by engineer of record, and made by reaming or drilling only. Flame cutting, burning, gouging, chipping, or drift punching shall not be permitted.

4.3.7.5 Unless approved by engineer of record, packing, shimming, filling, or wedging shall not be permitted to correct faulty work.

4.3.7.6 One filler plate up to 1/8-inch (3-mm) thickness may be used in spaces between members to be bolted. Engineer of record's approval shall be required for filler plate requirements greater than 1/8 inch (3 mm).

4.3.8 Steel Joists

4.3.8.1 Field welding or bolting joists to supporting steel framework shall be in accordance with *SJI specifications* for type of joists used, erection/shop drawings, and other contract documents.

4.3.8.2 Modifications or repairs to steel joists shall not be performed without prior written approval of engineer of record.

4.3.8.3 Use of power-driven or powder-actuated fasteners in diagonal and bottom chord members of joists shall not be permitted.

4.3.9 Floor Plate and Grating

4.3.9.1 Install all field-cut floor plate or grating openings requiring toe plate protection or banding in accordance with detail *STS05130-01*.

4.3.9.2 Fasten grating and floor plate in accordance with contract documents. Use a minimum of four fasteners per panel.

4.3.10 Metal Decking for Floors and Roofs

4.3.10.1 Install floor and roof deck in accordance with deck manufacturer's written installation instructions and contract documents.

4.3.10.2 Repair all sags, deformations, holes, and other irregularities.

4.3.10.3 If damage has occurred to shop-applied coatings on metal decking, field touch-up shall be in accordance with decking manufacturer's recommendations.

4.3.11 Shear Connectors

4.3.11.1 Weld all shear stud attachments in strict accordance with stud manufacturer's recommendations for welding procedure and welding equipment.

4.3.11.2 If two or more stud welding guns are operated from the same power source, interlock guns so that only one gun can be operated at a time to ensure that the power source has fully recovered from making one weld before another weld is started.

4.3.11.3 Remove all ceramic insulators from base of studs after welding.

4.3.12 Coating Repairs

4.3.12.1 Repair all erection damage to hot-dip galvanized coatings in accordance with *PIP STS05120*.

4.3.12.2 Repair all erection damage to shop-applied paint coatings in accordance with purchaser's coating specification.

4.3.12.3 Paint all galvanized bolt assemblies tightened against shop-applied paint.

4.3.12.4 Where twist-off bolt assemblies are used, coat ends of bolts to match the steel coating system.

FIELD LOCATED AND FIELD FABRICATED GRATING OPENINGS

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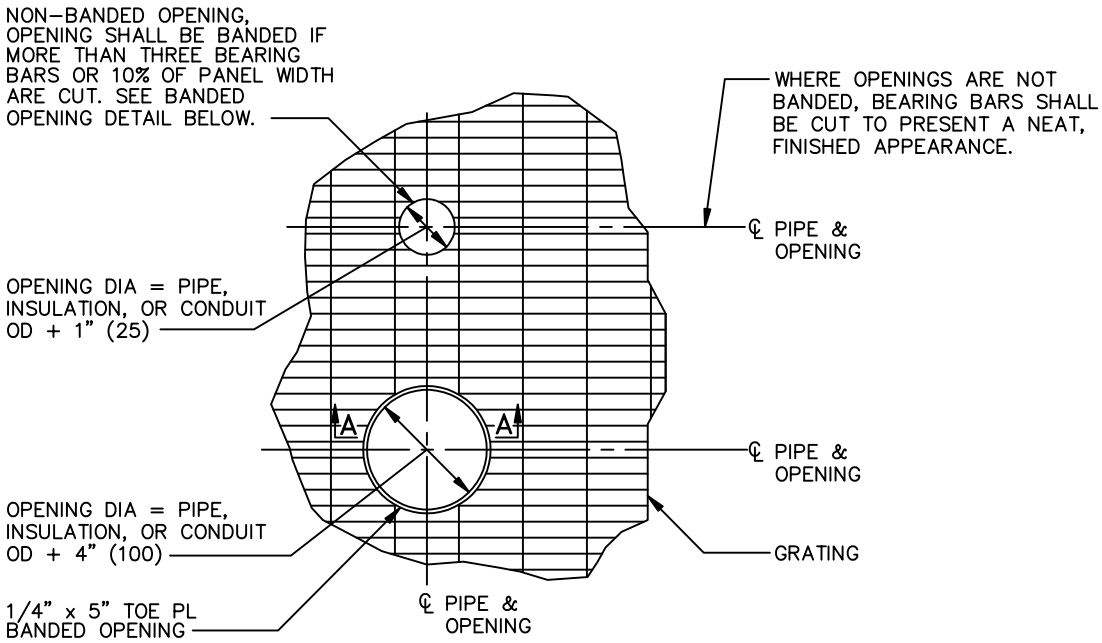

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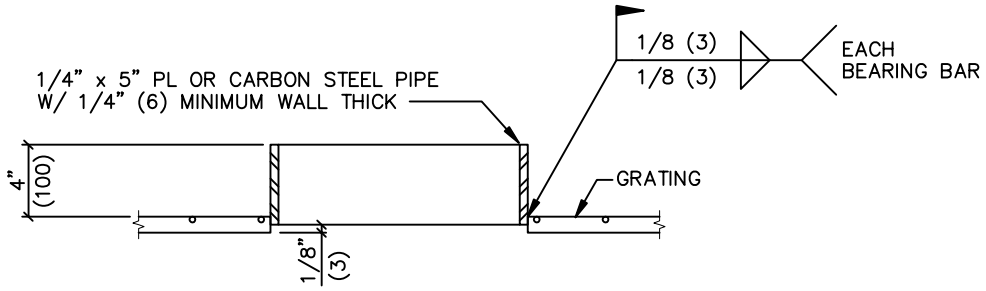

SECTION A-A

FIELD LOCATED AND FIELD FABRICATED GRATING OPENINGS

(FOR FIELD LOCATED OPENINGS > 12" (300) DIA OR RECTANGULAR OPENINGS, CONTACT ENGINEER OF RECORD)

Item 540
Metal Beam Guard Fence

1. DESCRIPTION

Furnish, install, replace, or adjust metal beam guard fence consisting of metal beam rail elements, hardware, blocks, and support posts.

2. MATERIALS

Provide samples of metal beam rail elements, terminal sections, bolts, and nuts for compliance testing according to Tex-708-I and Tex-713-I to verify physical and chemical properties meet AASHTO M 180 when directed.

Obtain materials at the locations shown on the plans when the plans designate that the Department will furnish materials.

2.1. **Metal Beam Rail Elements**. Furnish new metal beam rail elements, transitions, anchor sections, and terminals that meet the requirements of Table 1 and are from a manufacturer on the Department's MPL of rail element manufacturers.

Type I or II is required, unless otherwise shown on the plans. Base metal for metal beam rail elements must not contain more than 0.04% phosphorous or more than 0.05% sulfur.

Warped or deformed rail elements will be rejected.

Table 1
Rail Element Requirements

Specification	AASHTO M 180
Class	A— Base metal nominal thickness 0.105 in. B— Base metal nominal thickness 0.135 in.
Type	I— Zinc-coated 1.80 oz. per square foot minimum single-spot. II— Zinc-coated 3.60 oz. per square foot minimum single-spot. IV— Weathering Steel (required when shown on the plans).
Shape	W-Beam Thrie Beam W-Beam to Thrie Beam Transition
Markings	Permanently mark each metal beam rail element with the information required in AASHTO M 180. In addition, permanently mark all curved sections of metal beam rail element with the radius of the curved section in the format "R=XX ft." Markings must be on the back of the metal beam rail section away from traffic and visible after erection.

2.2. **Posts**. Furnish new round timber, rectangular timber, or rolled steel section posts in accordance with details shown on the plans and the following requirements:

2.2.1. **Timber Posts**. Meet the requirements of DMS-7200, "Timber Posts and Blocks for Metal Beam Guard Fence." Purchase from a manufacturer or supplier on the Department's MPL of timber treating plants and suppliers.

2.2.2. **Steel Posts**. Provide rolled sections conforming to the material requirements of ASTM A36. Drill or punch posts for standard rail attachment as shown on the plans. Galvanize according to Item 445, "Galvanizing." Low-fill culvert posts may be fabricated as galvanized "blanks" with the rail hole and the final height field fabricated. Treat all exposed post surfaces caused by the field fabrication in accordance with Section 445.3.5., "Repairs."

2.3. **Blocks**. Furnish new rectangular timber or composite blocks in accordance with details shown on the plans and the following requirements:

2.3.1. **Timber**. Meet the requirements of DMS-7200, "Timber Posts and Blocks for Metal Beam Guard Fence." Purchase from a manufacturer or supplier on the Department's MPL of timber treating plants and suppliers.

2.3.2. **Composite**. Meet the requirements of DMS-7210, "Composite Material Posts and Blocks for Metal Beam Guard Fence." Purchase from a manufacturer on the Department's MPL of composite material blocks and posts.

2.4. **Fittings**. Furnish new fittings (bolts, nuts, and washers) according to the details shown on the plans and galvanized according to Item 445, "Galvanizing."

2.5. **Terminal Connectors**. Furnish new terminal connectors, where required, meeting the material and galvanizing requirements specified for metal beam rail elements.

2.6. **Concrete**. Furnish concrete for terminal anchor posts meeting the requirements for Class A concrete as required in Item 421, "Hydraulic Cement Concrete."

2.7. **Curb**. If indicated in the details, furnish the curb shown with metal beam guard fence transition as required by Item 529, "Concrete Curb, Gutter, and Combined Curb and Gutter."

2.8. **Terminal Anchor Posts**. Furnish new terminal anchor posts from steel conforming to the material requirements of ASTM A36. Fabricate posts according to Item 441, "Steel Structures." Galvanize terminal anchor posts after fabrication according to Item 445, "Galvanizing."

2.9. **Driveway Terminal Anchor Posts**. Furnish new terminal anchor posts from steel conforming to the material requirements of ASTM A36. Fabricate posts according to Item 441, "Steel Structures." Galvanize terminal anchor posts after fabrication according to Item 445, "Galvanizing."

2.10. **Downstream Anchor Posts**. Furnish new terminal anchor posts consisting of new rectangular timber and new steel foundation tubes according to details shown on the plans.

2.11. **Downstream Anchor Hardware**. Furnish new hardware (brackets, plates, struts, cable, etc.) according to the details shown on the plans and galvanized according to Item 445, "Galvanizing."

2.12. **Controlled Released Terminal (CRT) Posts**. Furnish new CRT posts according to the details shown on the plans and conforming to the requirements of DMS-7200, "Timber Posts and Blocks for Metal Beam Guard Fence." Purchase from a manufacturer or supplier on the Department's MPL of timber treating plants and suppliers.

3. CONSTRUCTION

Install posts and rail elements according to details shown on the plans.

3.1. **Posts**. Install posts by either drilling or driving.

3.1.1. **Drilling**. Drill holes and set posts plumb and firm to the line and grade shown. Backfill posts by thoroughly compacting material to the density of adjacent undisturbed material.

3.1.2. **Driving**. Drive posts plumb with approved power hammers (steam, compressed air, vibratory, or diesel) or gravity hammers to the line and grade shown while preventing damage to the post. Use pilot holes when required and approved. Determine the size and depth of pilot holes based on results of the first few posts driven. Thoroughly tamp loosened soil around the post, fill voids with suitable material, and thoroughly compact to the density of adjacent undisturbed material.

3.2. **Rail Elements**. Erect metal beam rail elements to produce a smooth, continuous rail paralleling the line and grade of the roadway surface or as shown on the plans. Bolt rail elements end-to-end and lap splices in the direction of traffic. Field-drill or punch holes in rail elements for special details, only when approved.

3.3. **Short Radius**. Special rail fabrication with a required radius must be as shown on the plans.

3.4. **Terminal Anchor Posts**. Embed terminal anchor posts in concrete, unless otherwise shown on the plans.

3.5. **Galvanizing Repair**. Repair all parts of galvanized steel posts, washers, bolts, and rail elements after erection where galvanizing has become scratched, chipped, or otherwise damaged. Repair in accordance with Section 445.3.5., "Repairs."

3.6. **Guardrail Adjustment**. Work includes vertical adjustment, horizontal shift, and overlap of the rail element to meet the detail shown on the plans.

3.7. **Curb**. If indicated in the details, construct the curb shown with metal beam guard fence transition as required by Item 529, "Concrete Curb, Gutter, and Combined Curb and Gutter."

3.8. **Driveway Terminal Anchor Posts**. Embed terminal anchor posts in concrete, unless otherwise shown on the plans.

4. MEASUREMENT

4.1. **Guard Fence**. Measurement will be by the foot of fence. Fence will be measured on the face of the rail in place, from center-to-center of end splice locations.

4.2. **Terminal Anchor Sections**. Measurement will be by each section, complete in place, consisting of a terminal anchor post and one 25-ft. section of rail element.

4.3. **Transitions**. Transitions for rail connection will be measured by each transition.

4.4. **Short Radius**. Measurement will be by the foot to the nearest whole foot along the face of the rail in place, from beginning of radius (first CRT post) to the end of radius.

4.5. **Driveway Terminal Anchor Section**. Measurement will be by each section, complete in place, consisting of a driveway terminal anchor post and one 6-ft. section of rail element.

4.6. **Downstream Anchor Terminal**. Measurement will be by each section, complete in place, consisting of one W-Beam end section, 2 downstream anchor posts, and one rail section.

4.7. **Long Span System**. Measurement will be by the foot of fence. Fence will be measured on the face of the rail, in place, between the first CRT and last CRT posts in the system.

5. PAYMENT

The work performed and material furnished in accordance with this Item and measured as provided under "Measurement" will be paid at the unit price bid for "Metal W-Beam Guard Fence" of the post type specified; "Metal Thrie Beam Guard Fence" of the post type specified; "Terminal Anchor Section"; "Metal Beam Guard Fence Transition" of the type specified; "Metal W-Beam Guard Fence Adjustment"; "Metal Thrie Beam Guard Fence Adjustment"; "Terminal Anchor Section Adjustment"; "Transition Adjustment"; "Short Radius"; "Driveway Terminal Anchor Section; "Downstream Anchor Terminal"; or "Metal Beam Guard Fence (Long Span System)." When weathering steel is required, Type IV will be specified.

Samples furnished to the Department for testing purposes, special backfill materials, and concrete curbs will not be paid directly but are subsidiary to this Item.

5.1. **Guard Fence**. The price bid for "Metal W-Beam Guard Fence" or "Metal Thrie Beam Guard Fence" is full compensation for materials, hauling, erection, setting posts in concrete, blocks, driving posts, excavating, backfilling, equipment, labor, tools, and incidentals.

5.2. **Terminal Anchor Section**. When a separate bid item is specified, the price bid for "Terminal Anchor Section" is full compensation for furnishing the rail element, anchor assembly, terminal anchor post, and foundations; installing the rail element anchor assembly and the terminal anchor post and foundations; excavation and backfilling; and equipment, labor, tools, and incidentals.

5.3. **Transition**. The price bid for "Metal Beam Guard Fence Transition" is full compensation for furnishing nested sections of Thrie Beam; nested sections of W-Beam; Thrie Beam to W-Beam transitional rail piece, posts, concrete, curb, and connections to W-Beam guard fence and bridge rails; Thrie Beam terminal connectors; excavation and backfilling; and equipment, labor, tools, and incidentals.

5.4. **Guardrail Adjustment**. The price bid for "Metal W-Beam Guard Fence Adjustment," "Metal Thrie Beam Guard Fence Adjustment," "Terminal Anchor Section Adjustment," and "Transition Adjustment" is full compensation for furnishing materials not supplied by the Department, drilling holes in posts, hauling, erection, blocks, excavation, backfill, cleaning, salvaging materials, setting rail element anchor assembly and terminal anchor post, removal of rail element, concrete, curb, equipment, labor, tools, and incidentals.

5.5. **Short Radius**. The price bid for "Short Radius" is full compensation for furnishing special rail fabricated metal beam guard fence, CRT posts, steel posts, sand barrels, end terminal, cable anchor, materials, hauling, erection, blocks, driving posts, excavating, backfilling, equipment, labor, tools, and incidentals.

5.6. **Driveway Terminal Anchor Section**. The price bid for "Driveway Terminal Anchor Section" is full compensation for furnishing the rail element, driveway anchor assembly, driveway terminal anchor post, and foundations; installing the rail element anchor assembly and the driveway terminal anchor post and foundations; excavation and backfilling; and equipment, labor, tools, and incidentals.

5.7. **Downstream Anchor Terminal**. The price bid for "Downstream Anchor Terminal" is full compensation for furnishing the rail element, W-Beam end section, guardrail anchor bracket, shelf angle bracket, channel strut, downstream anchor posts, breakaway cable terminal (BCT) cable anchor assembly, and foundations; installing the BCT cable anchor assembly and the downstream anchor post and foundations; excavation and backfilling; and equipment, labor, tools, and incidentals.

5.8. **Long Span System**. The price bid for "Metal Beam Guard Fence (Long Span System)" is full compensation for furnishing the rail element, CRT posts, materials, hauling, erection, blocks, driving posts, excavating, backfilling, equipment, labor, tools, and incidentals.