DIVISION 700

BRIDGES, CULVERTS, AND RELATED CONSTRUCTION

@ **DIVISION 700**

701.00 CHECKLISTS

701.01 PILES AND PILE DRIVING CHECKLIST

SSHC References	*Section 703 -- Piles and Pile Driving*
	705 -- Precast/Prestressed
Concrete Structural Units	
	1002 -- Portland Cement Concrete
	1004 -- Portland Cement
	1025 -- Steel Wire for Prestressed Concrete Units
Inspection Crew	Project Manager (PM) Construction Technician
Equipment	Saximeter
Material Procedures	Check that all piling is acceptable for driving. Material certifications and/or reports should be given to Project Manager and evaluated before use.
Steel Piling	Steel bearing and sheet piling must be stored on suitable skids [6 inch (150 mm)] ground clearance recommended) and should be kept clean. Don't allow weeds and foreign material in storage sites.
Concrete Piling	Piling must be adequately supported when stored and handled to prevent excess deflection. The surface finish of concrete piling that will be exposed at the completion of driving (bent piles in concrete slab bridges) shall not be damaged or discolored.
Cast-in-Place Concrete Piles Procedures	Check shells immediately before placing any concrete (shape and accumulation of water). Use a drop cord.
Treated Timber	Notify Materials & Research if timber piling appears damaged. The Project Manager or inspector must obtain approval to reject timber piling. Piling certification procedures are found in the *Materials Sampling Guide*.
Pile Driving Procedures	The contractor should build a frame (sometimes called a checkerboard) to hold each pile in the exact position for driving.

Before driving any piles, the inspector should perform the following duties:

1. Verify that piles will be driven exactly as shown in the plan pile layout.

2. Check pile spacing, and record heat numbers (steel pile), code identification (concrete pile) and other pertinent information. Document points and splices.

3. Verify cut-off elevations against a permanent reference.

Confirm that the Project Manager, inspector and contractor understand:

1. How to check penetration depth at any point.

2. How to take and record bearing tests data with saximeter.

3. How to determine the cut-off elevation for individual piles.

SSHC Subsection 703.03, Paragraph 2. allows bearing piling to be driven with a gravity hammer for the first half of the penetration when bearing does not exceed one-third of the design bearing.

Concrete sheet piling shall be driven with a preapproved hammer.

Do not allow pilot holes or preliminary jetting to be greater than 10 ft (3 m).

Gravity hammers used to drive piling to final cut-off elevation shall be preapproved. The fall of gravity hammers shall be regulated so as to avoid damage to the piles. Hammer fall shall not exceed 15 ft (5 m) for wood and steel bearing piles, or 8 ft (2.4 m) for precast concrete piles and shells for cast-in-place piles.

Do not allow hammer fall to damage piles.

Leads are required on all driven piles. Leads shall be held in proper alignment.

Swinging leads are permitted with steam, air or diesel hammers.

Guyed, braced, or fixed leads are required with gravity hammers.

Bearing and Sheet Piles Procedures

1. Frequently check the pile for plumbness or for required batter. Do not allow a variation of more than 1-inch/50 inches (1 mm/50 mm) of pile during driving.

2. Tops shall not be out of line more than 3 inches (75 mm).

3. Adjacent sheets shall be in line within a ½ inch (12 mm) tolerance.

4. The inspector should observe the pile carefully while it is being driven. A sudden increase in the penetration may indicate a broken or collapsed pile.

5. Remove and replace all broken, split, or misplaced piles. If removal is impractical, contact the Construction Division for instructions on the procedure to be followed.

6. Lead with the tongue or ball end of sheet piles to keep the groove or socket clean.

7. The options when a pile is at cut-off elevation, and not at design bearing are:

    a. If less than 10% of the piles in any group fail to reach bearing, the average pile bearing may be adequate to support the structure.

    b. Additional piling may be added to the group.

    c. Extend the piling and drive to obtain design bearing.

    d. Determine a soil set up factor and then drive to cut-off elevation.

    e. Use pile-driving analyzer to determine bearing.

    f. Run a load test to check if bearing capacity is obtained.

Notify the Construction Division when two or three consecutive piling do not attain design bearing.

8. a. Record pile data on the M&R spreadsheet.

b. E-mail a copy of the spreadsheet to M&R (O. Qudus) and to Construction Division (B. Caples).

c. Do not use contractor provided charts for determining bearing.

Soil Setup Factor

1. Two representative piles shall be driven to 2 ft (600 mm) above cut-off elevation (see SSHC 703.07 para 4.f.).
2. The piling at cut-off+2 ft (600 mm), will be rested for 36 hours and then driven to cut-off elevation with a "warm" hammer.
3. The Project Manager will record the penetration for each ten blows of the hammer until cut-off is reached.
4. Record data and call it in to the Construction Division.
5. The factor and a decision on what action to take will be sent back to the Project Manager.
6. Construction Division recommendations shall be recorded under the Remarks Section of the pile driving record.

Bearing Capacity Procedure

1. Determine bearing at or just prior to the pile reaching final penetration.
2. When determining bearing, the inspector shall be certain that all of the following conditions exist:

   a. For single action, the hammer shall have a free fall.
   b. The head of the pile shall be free from crushed or broomed fibers.

   c. The penetration of the pile shall be at a reasonably quick and uniform rate.

   d. There is not excessive bounce of the hammer. Deduct twice the height of the bounce from "H" pile for gravity or stream hammers. No deduction is made for diesel hammers.

e. If the driving is stopped for more than 2 hours, the pile shall be driven at least 1 ft (300 mm) before the bearing capacity is determined.

f. For batter piles driven with gravity hammers, see *SSHC Subsection 703.03*, Paragraph 4 for bearing determination.

3. The energy values for common diesel hammers presently in use are listed in *SSHC Subsection 703.03*, Paragraph 4. If the contractor intends to use a hammer not listed, the Construction Office should be contacted to obtain the appropriate energy value.

4. For bearing capacity computations the mass of the driving cap may be taken from the manufacturer's freight bill or measured. The mass of the pile shall be determined as follows:

Steel "H"

a. Mass per foot (meter) times length at time bearing is determined.

Timber

b. Volume of pile times 44 lb/ft^3 (703 kg/m^3).

Concrete

c. Volume times 150 lb/ft^3 (2400 kg/m^3).

Reference Points

5. The reference point should be an object with a fixed elevation or horizontal distance from the pile. Mark the point where the reference intersects the pile. After the required number of blows, mark another line at reference intersection and the distance between the two lines is penetration. Average penetrations can be computed from several measurements.

Pile Driving Analyzer Procedures

1. Contact the Construction Division to schedule personnel and equipment.

Static Pile Load Test Procedures

1. The Department will furnish the equipment and personnel for conducting the test. The contractor shall unload, erect, dismantle and reload the testing equipment. Payment for this work shall be by the each for each test.

2. If a temporary anchor pile is required. It will be paid for as extra work.

Method of Measurement Procedures

1. If required bearing is obtained at minimum penetration and this is shorter than the order length, the contractor should be encouraged to continue driving until the order length has been driven. Usually he/she will want to drive this extra length to avoid payment deduction. Discontinue driving beyond minimum penetration when:

    a. Practical refusal is reached.

    b. Further driving may result in damage to the pile.

2. If practical refusal is reached before minimum penetration, discontinue driving and notify the District Construction Engineer or the Construction Division and do not cut off the pile without their approval.

3. No payment will be made for pile length driven beyond the order length without PM approval.

4. When steel "H" pile and steel pile shells are driven to the exact cut-off elevation without crimping or damage to the top of the pile, they need not be cut off. Length of pile cut-off (measured as provided in *SSHC Subsection 703.05*) shall be paid at 60% of the piles unit price.

5. It will be necessary to pay for pile cut-off only under the following conditions:

    a. When practical refusal is reached before minimum penetration and the pile cannot be driven or jetted further.

    b. The contractor elects to stop driving after reaching bearing and minimum penetration but before the order length is driven.

6. MASS FOR PRESTRESSED CONCRETE BEARING PILE

For computing bearing capacity required on M&R Pile Bearing spreadsheet.

Pile Type	**Constant Section Mass Per Meter of Pile (Kilogram)**	**(lb)**
I	220	(485)
II	298	(657)
IV	315	(694)

(See Appendix 1. DR97-Pile Driving Record)

Critical Construction Areas	1. Proper placement and length. 2. Permanent reference point. 3. Removal of broken/collapsed piles. 4. Achieving design bearing capacity.
NDR Tests	1. Test pile. 2. Bearing capacity. 3. Pile Driving Analyzer.
Inspector's Records and Forms	1. Pile Record M&R spreadsheet 2. Hammer Data Sheet

701.02 **CONCRETE CONSTRUCTION CHECKLIST**

SSHC References: *Section 704 Concrete Construction*
Section 1002 Portland Cement Concrete
Section 1010 White Opaque Polyethylene Film and Burlap--Polyethylene Sheeting For Curing Concrete
Section 1011 Burlap For Curing Concrete
Section 1014 Joint Sealing Filler
Section 1015 Preformed Joint Filler
Section 1016 Preformed Polychloroprene Elastomeric Joint Seals
Section 1033 Aggregates

Inspection Crew: Lead Inspector

Inspection Equipment: Slump Cone
Air Meter (pressure)
Cylinder Molds and Lids
Rod
Mallet
Strike Off Bar
Ruler

Placement Procedures:

1. Preplacement check of equipment.
2. Check condition and placement of steel.
3. Check Form setting and alignment. Verify location coordinates and orientation.
4. Have contractor wet grade and forms before concrete placement.
5. Test concrete for air content, slump, and make cylinders when mix changes, as a minimum according to Sampling Guide.
6. Watch concrete placement for compliance with specifications. Do not allow free fall greater than 5 ft (1.5 m).
7. Do not use water as a finishing aid; use an approved chemical finishing aid/evaporation retardant.
8. Check curing operation.

Construction Critical Area:

1. Take pictures of any pavement under bridge before work begins.
2. Achievement of concrete consolidation without segregation.
3. The time between loads of concrete.
4. Trucks that segregate concrete or have cement balls must not be used.

NDR Tests:

1. NDR T 23 Making and Curing concrete test specimens.
2. NDR T 119 Slump of Portland Cement Concrete.
3. NDR T 141 Sampling of Fresh Concrete.
4. NDR T 152 Air Content of Freshly Mixed Concrete by the Pressure Method.

701.03 CONCRETE BRIDGE FLOORS CHECKLIST

SSHC References:	*Section 706 Concrete Bridge Floors* *Section 1002 Portland Cement Concrete* *Section 1010 White Opaque Polyethylene Film and Burlap--Polyethylene Sheeting For Curing Concrete* *Section 1011 Burlap For Curing Concrete* *Section 1014 Joint Sealing Filler* *Section 1015 Preformed Joint Filler* *Section 1016 Preformed Polychloroprene Elastomeric Joint Seals* *Section 1033 Aggregates*
Inspection Crew:	Project Manager Placement Inspector Plant Inspector
Inspection Equipment:	Slump Cone Air Meter (pressure) Cylinder Molds and Lids Rod Mallet Strike Off Bar Ruler 10 ft (3 m) straightedge Anemometer Thermometer Hygrometer
Placement Procedures:	1. Preplacement check of equipment. 2. Check condition and placement of steel. Enter in SiteManager the date steel was verified. 3. Check Form setting and alignment. 4. Check slab thickness. 5. Check deck for cleanliness 6. Have contractor wet deck forms and grade under approach slabs before concrete placement.
(Note: It's best to place deck and approach slabs at the same time.)	7. Test concrete for air content and make cylinders when mix changes, as a minimum according to Sampling Guide. 8. Watch concrete placement for compliance with specifications. 9. Do not use water as a finishing aid; use an approved chemical finishing aid/evaporation retardant. 10. Check surface with straightedge. Remove depressions and irregularities. 11. Check tining operation. 12. Check cure operation. 13. Make sure a water service and tanks are available to soak burlap.

Construction Critical Area:

1. Take pictures of any pavement under the deck before work begins.
2. Maintain a uniform roll, of about 4 inches (100 mm), of concrete ahead of the front screed and a minimum of a 2 inch (50 mm) roll ahead of the rear screed.
3. The time between loads of concrete.
4. Trucks that segregate concrete or have cement balls must not be used.
5. Avoiding placement when temperatures and wind velocities may cause plastic shrinkage cracking. (*SSHC Table 706.01*)
6. Vibrate concrete uniformly. Establish good pattern and adjust as necessary.
7. The timing of cure application.

Safety Areas:

NDR Tests:

1. NDR T 23 Making and Curing concrete test specimens.
2. NDR T 119 Slump of Portland Cement Concrete.
3. NDR T 141 Sampling of Fresh Concrete.
4. NDR T 152 Air Content of Freshly Mixed Concrete by the Pressure Method.

701.04 STEEL STRUCTURES CHECKLIST

SSHC References: *See SSHC Table 708.01*

Other References: AWS Standard Specifications. (ANSI/AASHTO/AWS D1.5 Bridge Welding Code)

Inspection Crew: Fabrication Inspector
Project Manager (PM)
Lab Inspector

Inspection Equipment: Skidmore-Wilhem Calibrator

Shop Procedures:

1. Check Fabricators QC Plan.
2. Make sure QC Plan is followed.
3. The mill order list or the Certified Mill Test Reports must be furnished before fabrication begins.
4. Document all actions not in compliance with the QC Plan or Standard AWS procedures.
5. Welding symbols are shown in Section 708.

Field Construction Procedures:

1. Confirm steel was inspected on site and in shop. Enter date in SiteManager.
2. Sample bolts and send to M&R.
3. Heavy hexhead bolts require heavy hexhead nuts and a hardened washer under the element that is turned.
4. Check all bolts, washers, and nuts to make sure there is proper and correct marking on each. (See CM Subsection 704.03)
5. M&R personnel will calibrate the contractor's wrenches but they need at least 7-days advance notice.
6. Before the contractor begins steel erection, the Project Manager will make a final check of span lengths, skew angles, and bearing point elevations.
7. Also, take pictures of pavement under any structure where equipment will be lifting members.
8. Lead sheets [? inch (3 mm) thick] shall be placed between steel and concrete at all bearing points.
9. Rockers, rollers, expansion devices, etc., shall be set according to the temperature at time of installation. (See Plans.)
10. Check matchmarks on all girders, separators, angle braces, etc.
11. Verify that drift pins do not enlarge holes or distort the metal.
12. Stop the contractor from hammering if it appears the metal will be damaged or injured.
13. The Construction Division will be notified of all major misfits and determine what procedures will be allowed.

701.05 CONCRETE BRIDGE DECK REPAIR WITH SILICA FUME CONCRETE

SSHC References:

Section 710 -- Concrete Bridge Deck With Silica Fume Concrete
Section 1002 -- Portland Cement Concrete
Section 1010 -- White Opaque Polyethylene Film and White Burlap—Polyethylene Sheeting For Curing Concrete
Section 1011 -- Burlap For Curing Concrete
Section 1014 -- Joint Sealing Filler
Section 1015 -- Preformed Joint Filler
Section 1016 -- Preformed Polychloroprene Elastomeric Joint Seals
Section 1033 -- Aggregates

Inspection Crew:

Placement Inspector
Plant Inspector

Inspection Equipment:

Slump Cone
Air Meter (pressure)
Cylinder Molds and Lids
Rod
Mallet
Strike Off Bar
Ruler
10 ft (3 m) straightedge
Anemometer
Thermometer
Hygrometer

Placement Procedures:

1. Preplacement check of equipment.
2. Check condition and placement of steel.
3. Check Form setting and alignment.
4. Check slab thickness.
5. Check deck for cleanliness.
6. Have contractor wet deck and forms before concrete placement.
7. Test concrete for air content and make cylinders when mix changes, as a minimum according to Sampling Guide.
8. Watch concrete placement for compliance with specifications.
9. Do not use water as a finishing aid; use an approved chemical finishing aid/evaporation retardant.
10. Check surface with straightedge. Remove depressions and irregularities.
11. Check tining for conformance to specification.
12. Check cure operation.

Construction Critical Area:

1. Check finish machine (template & rails).
2. Check repair areas.
3. Deck shall be uniformly wet, without puddles prior to placement.
4. Bonding grout shall not be allowed to dry out.
5. Maintain a uniform roll, of about 4 inches (100 mm), of concrete ahead of the front screed and a minimum of a 2 inch (50 mm) roll ahead of the rear screed.
6. The time between loads of concrete.
7. Trucks that segregate concrete or have cement balls must not be used.
8. Avoiding placement when temperatures and wind velocities may cause plastic shrinkage cracking (see SSHC Figure 710.01).
9. Fogging system should be operating from time concrete is finished until wet burlap is in place.
10. Check tining operation.
11. The timing of wet burlap application.

Safety Areas:

NDR Tests:

1. NDR T 23 Making and Curing concrete test specimens.
2. NDR T 119 Slump of Portland Cement Concrete.
3. NDR T 141 Sampling of Fresh Concrete.
4. NDR T 152 Air Content of Freshly Mixed Concrete by the Pressure Method.

702.00 EXCAVATION FOR STRUCTURES (*SSHC Section 702*)

702.01 DESCRIPTION

A. All excavation should be done as shown in the plans. Excavation is very dangerous work and appropriate OSHA regulations must always be observed (see SSHC Figure 701.01).

B. Inspector should be present when an area is being backfilled. The inspector should check to see that the backfill materials are as specified. The materials shall be placed as prescribed in the *SSHC Subsection 205.03 or 702.03* as appropriate.

C. Structure excavation includes all excavation, removal of obstruction, bailing, draining, pumping, sheathing, construction and removal of cofferdams, backfilling, compacting and disposal of any excess material necessary to construct the structure in question.

702.02 MATERIAL REQUIREMENTS

A. Unsuitable Material Excavation (*SSHC Subsection 702.05*)

1. When unstable material is encountered it shall be removed and backfilled with approved material. The material shall be measured in cubic yds (meters) before it is placed. Payment for the extra work material and all work involved will be made at 10% of the contact unit price for box culvert concrete (when gravel or rock is used). The inspector should make an inspection of all structure footings as they are being excavated by the contractor.

2. Pier footings should not be constructed on unsuitable material. It is true that if the footing is supported by piles, the rock placed at the bottom of the footing serves a limited structural purpose. We should provide for a solid base to hold the concrete in the forms. However, the contractor is not entitled to a rock surface on which to work at the Department's expense.

702.03 CONSTRUCTION METHODS

A. Culvert Excavation (*SSHC Subsection 702.03*)

1. All culverts should be constructed with a minimum of approximately 12 inches (300 mm) of cover exclusive of surfacing. An accepted method for obtaining specified bedding for these culverts is to require the contractor to furnish a template conforming to the dimensions of the culvert pipe. This template is then used for shaping the trench to the specified depth.

2. The inspector must be knowledgeable of the Occupational Safety and Health Act (OSHA) requirements concerning excavation and trenching. Pipe culvert excavation by OSHA definition would normally be considered a trench.

3. Never allow any part of a pipe culvert to rest on rock or other unyielding materials. When rock is encountered in the bottom of the trench, it shall be removed to a depth of at least 6 inches (150 mm) below the subgrade and back filled with suitable earth or sand.

4. The Specifications provide that where unstable subgrades are encountered under pipes or pipe-arch culverts, the unsuitable material shall be removed and the excavated area refilled with gravel, crushed rock, or other suitable material. When crushed rock is used, care should be taken to place the fine rock immediately beneath all metal pipe to prevent abrasion of the spelter coating. When gravel or crushed rock is used in place of unsuitable material, it will be measured in cubic meters before it is placed. Payment for furnishing, hauling and placing this material will be made at 10% of the contract unit price for concrete for box culverts. When box culverts are not included in the contract, the average unit price for box culvert concrete shall be used. (*SSHC Subsection 702.05*)

B. General Structure Backfilling (*SSHC Subsection 702.03*)

1. This operation may involve *SSHC Sections 205, 702, and Table 702.01*. The inspector should insure that all applicable sections are followed. The compaction of backfill material close to structures must given special attention. Mechanical tampers should be operated carefully in such a manner as to obtain the required density without damaging the structure.

2. Before any material is placed, the area to be backfilled should be inspected for trash or perishable matter. The materials to be used for backfill should be given careful consideration. Only those that will produce a dense, well-compacted backfill should be used. Granular materials are desirable as much less effort is needed to compact them than clay.

3. When abutments are tied to an anchor or deadman by means of tie rods, care should be taken in the back filling operation. The backfill should be placed in layers, starting at the anchor or deadman and working toward the abutment. Hand tamping may be required around the tie rods, abutment and anchors.

4. Backfilling must not be started without the permission of the Project Manager and in the case of concrete structures not until test cylinders show a minimum strength of at least 80% of the design strength.

5. Backfill should be brought up evenly to the elevation shown in the plans. Granular material must be placed in not more than 8 inches (200 mm) layers (lifts) and should have sufficient moisture to facilitate compaction. Do not allow dumping of granular material directly from the truck into the excavation if this will result in lifts/layers greater than 8 inches.

6. Special attention should be given to culvert wingwalls and flumes to insure proper compaction to prevent erosion and possible washout. The soil should be brought up even with these walls so the surface water will flow over these walls and not along them. Heavy equipment should be kept 3 feet (1 m) or more away from these wingwalls. Compaction within 3 ft (1 m) of the wingwall shall be with pneumatic hand tampers or small hand operated vibratory plate compactors.

7. Backfill for Bridges - Moisture and density requirements for backfill which is to provide support for subsequent construction will be shown in the plans. Backfill which is not to support later construction shall be compacted to 95% of maximum density without definite moisture limits.

8. Backfill for Culverts - When backfilling pipe culverts, the lifts shall be deposited and compacted alternately on opposite sides of the pipe to avoid lateral displacement. The inspector should also watch for vertical displacement. This may occur when tamping adjacent to the lowest 90 degrees of the pipe and should be checked from the grade stakes as backfilling progresses. The pipe should be tied down if any uplift is noted.

9. Necessary precautions should be taken against washing under the pipe in case of rain. Compacted dikes or temporary earth headwalls at the inlet end will often save removing and relaying the pipe after a heavy rain. All drainage structures in the process of construction should be carefully inspected for washouts at the sides and beneath the structures after rains.

10. Flowable fill is sometimes included in the plans for backfilling culverts. The plans will identify the locations and show the details for using the flowable fill. *SSHC Section 1003* defines Flowable Fill requirements.

C. Concrete Seal Course (*SSHC Subsection 702.03*)

1. When it is impossible to dewater the foundation bed or box culvert footing or if live springs develop within the area, a seal course should be constructed below the elevation of the bottom of the footing. Concrete for seals constructed underwater shall contain 10% excess cement and be placed in accordance with *SSHC Subsection 704.03*. The concrete shall be allowed to harden a minimum of 72 hours after completing the final pour before dewatering and continuing work on the structure. Seepage through inadequate or poorly constructed cofferdams shall not be justification for placing a seal course.

D. Foundations

1. Staking and Checking Locations of Structures - -Check and Double Check

a. All measurements and skew angles must be independently checked. From past practice, "independently checked" meant having a second survey party come in, setup, and completely resurvey (verify) original staking. This method is still the most desirable; however, with our upgrading to total station equipment it is acceptable to either setup off to the side and recheck or "back into" the bridge starting up station after clearing the total station.

b. Stakes used should be substantial and protected from disturbance. Offset stakes for each pier and abutment must be placed outside the area of contemplated work.

c. Any checks suggested by the contractor should be considered, since the site superintendent usually has a good idea of the structure layout in relation to existing features such as trees, old structures, etc. Each stake must be clearly marked to denote its function. Pier numbers must correspond with plan designations.

2. Documentation

   a. A staking diagram for each structure must be recorded in a permanent survey field book. This sketch must show the exact location of each hub and the markings made on each guard stake. IT IS NOT COMPLETE UNLESS IT SHOWS THE MEASUREMENTS MADE AS CHECKS ON THE ACCURACY OF THE STAKING LAYOUT. Names of those in the staking party should be entered as well as the date, design and project numbers, location, type of structure, and any other pertinent information.

E. Common Survey Errors to Avoid

1. Turning the wrong skew angle.

2. Errors in measuring from piers to abutments (This should be detected by an overall check from abutment to abutment.)

3. The centerline of the bridge is not always on centerline of the road (This is quite common on interstate bridges.) A bridge with a sidewalk may not be centered on its pier(s).

F. Encountering Old Substructures (*SSHC Subsection 104.06*)

1. *SSHC Section 203* describes the removal requirements when structures interfere with the new work. Existing substructures are usually shown on the plans. If the designer intended to miss some of these old substructures and the contractor later encounters them, payment will be made to the contractor by change order to remove that portion in conflict. Payment will "NOT" be made if plans indicate the new substructure would hit the old structure. See *SSHC Subsection 104.06* for a list of approved unforeseen obstructions.

G. Bridge Deck Removal

1. Contractors generally can be expected to be able to remove the deck without damaging the girders. However, the contractor must use some caution. The contractor cannot use the same force directly over a girder as would be applied over the “free/open” space between girders.

2. Sometimes a contractor will start the removal work properly with heavy blows only in the “free” space. However, either from impatience, changes to the equipment operator or for some other reason, we have seen the contractor at some point begin to apply too much force directly over the girders. This is very bad because the girders are damaged.

3. Forewarn the contractor and monitor their operation to make sure girders are not damaged. This is covered in the contract but is still important to monitor in the field.

703.00 PILING AND PILE DRIVING (*SSHC Section 703*)

A. The Department's Geotechnical Section in the Materials and Research Division provides guidance and geotechnical designs for our projects. Some county bridge projects are completely designed by consultants including pile foundations. When a consultant design fails, i.e., bearing cannot be achieved, the consultant that designed the bridge should be the first point of contact to determine how to correct a failed design.

703.01 EQUIPMENT

A. Diesel Hammers

1. Generally, single acting diesel hammers are the mainstay of contractors for pile driving. Occasionally however, a contractor will request the use of an "air" or "hydraulic" operated hammer. In addition there are a few "double acting" hammers in use. A wave equation analysis will be required for approval of these hammers.

2. One manufacturer of hammers uses one size hammer barrel and places different sized rams inside. Therefore, the MKT "DE" series hammers need to be field verified for ram mass (weight). A check is accomplished by having the contractor stand the hammer upright (in the driving position) and measuring down from top of the barrel to top of the ram. Verify the ram mass (weight) shown on the Hammer Data sheet as follows:

Ram Mass (kg)	Ram Distance (meter)	Ram Mass (tons)	Ram Distance (ft)
907	1.9	1	6.25
1270	1.2	1.4	4.0
1497	0.7	1.65	2.3
1814	180 mm	2.0	0.6

B. Bearing and Penetration

1. Penetration Requirements

a. Design pile length is a calculated value based on design bearing and soil conditions. One factor which enters into the calculation is the potential for scour. Obviously, any soil which is eroded during a flood event represents a loss in bearing capacity and foundation stability. **For this reason "minimum penetration" is extremely important.**

b. A depth of expected scour is typically shown on the Bridge Geology sheet in the plans. In general, streams with large drainage areas and sand or gravel stream beds are quite susceptible to scour while streams with small drainage areas and heavy clay stream beds are less susceptible to scour.

c. When doubt exists concerning the amount of probable scour or minimum pile penetration required, the Construction Division should be consulted. If greater penetration is required, it will be achieved either by boring holes to receive the piles or by jetting. If penetration achieved is satisfactory, piles will be cut off.

C. Dynamic Pile Analyzer

1. The Materials & Research Division has a pile analyzer available for driving evaluations. The pile analyzer will evaluate the bearing, based on energy delivered to a pile as it is being driven.

2. There are two situations where the analyzer should be used:

   Case 1. Contract documents require pile to be driven with the analyzer.

   Case 2. Pile do not achieve bearing and there are unresolvable questions or conditions observed during driving.

703.02 CONSTRUCTION METHODS

A. Pile Driving Constraints

1. Piles shall not be driven within 50 ft (15 m) of freshly placed concrete. Normally piles may not be driven near new concrete until three days after the concrete was placed.

B. Splicing Pile--Welding Steel Pile

1. *SSHC Section 708* requires that all welds conform to the Structural Welding Code ANSI/AASHTO/AWS DI.5 of the American Welding Society.

2. Only Shielded Metal Arc Welding (SMAW) will be permitted for welding steel piles.

3. The welding electrode must be on the NDR Approved Products List.

C. Steel Pile Cutoffs

1. If the contractor feels the cutoff is long enough that they may use it on some future project, the Heat number should be placed on the cutoff and a number to indicate the project it came from.

D. Pile Groups/Categories

1. Selecting the type of pile to be used and estimating its necessary length are fairly difficult tasks that require good judgment.

2. Piles can be divided into two major groups, depending on their length and the mechanisms of load transfer to the soil:

   a. Point Bearing Piles

      (1) If bedrock is within a reasonable depth, then piles can be extended to the rock and achieve the ultimate bearing capacity.

   b. Friction Piles

(1) The ultimate bearing capacity is achieved through the skin friction. The length of friction piles depends on the shear strength of the soil, the applied load and pile size. In clayey soils, the resistance to applied load is caused by adhesion.

(2) Piles are also divided into two different categories depending on their interaction with the soil:

c. Displacement Pile:

(1) The effect of displacement pile on the soil is, it increases the lateral ground stress. It displaces cohesion-less soils, remolds and weakens cohesive soils temporarily. If displacement piles are used for cohesive soil, setup time in sensitive clays may be up to six months.

(2) Typical types of displacement piles are closed end steel pipe pile and concrete pile.

d. Non-displacement Pile:

(1) Opposite of the displacement pile, it minimizes disturbance to the soil.

(2) Typical types of non-displacement piles are open-end steel pile and steel H pile. It should be mentioned open steel pipe is not suited for friction piles in coarse granular soils.

(3) It has low driving resistance and this makes field capacity verification difficult, which result in excessive pile length.

Weights of Prestressed Concrete Bearing Piling

For computing bearing capacity required on M&R Pile Record spreadsheet

Pile Type	**Constant Section Wt. per Lin. Ft. (Pounds)**	**Tapered Section Total Weight (Pounds)**
I	148	None
II	200	None
III	173	None
IV	212	None
V	124	1740
VI	169	2500
VII	221	2950

This table is based on and is for use only with Standard Plan 1720-C-R2.

Steel Pipe Pile Data

	ARMCO		Union Metal
Size O.D. (ins)	12	12¾	12 (Nominal)
Wall T. (ins.)	.188	.188	7 Ga.
Wt. per Lin. Ft. (lbs.)	23.72	25.16	25.3
Conc. per Lin. Ft. (C.Y.)	.0273	.0309	.0255

Union Metal 30’ tapered Sec. Type F Total Wt. 589 Lbs. Conc. 0.55 Cu. Yd.

Size O.D. (ins)	14	14 (Nominal)
Wall T. (ins.)	.188	7 Ga.
Wt. per Lin. Ft. (lbs.)	27.66	29.5
Conc. per Lin. Ft. (C.Y.)	.0375	.0350

Union Metal 40’ tapered Sec. Type F Total Wt. 895 Lbs. Conc. 0.95 Cu. Yd.

For Raymond step tapered pile, contact Geotechnical Section, Materials & Research.

Driving Sequence of Piles

The driving sequence of piles in a pier or bent can be important. The driving sequence can affect the way piles drive as well as the influence the new construction has on adjacent structures. This is especially true for displacement piles. For non-displacement piles, the driving sequence is generally not as critical.

The driving sequence of displacement pile groups should be from the center of the group outward or from one side to the other side. The preferred driving sequence of the displacement pile group shown in Figure 24.16 would be (a) by the pile number shown, (sequence 1), (b) by driving each row starting in the center and working outward (sequence 2), or (c) by driving each row starting on one side of the group and working to the other side (sequence 3).

Figure 703.01 Driving Sequence of Displacement Pile Groups (after Passe, 1994)

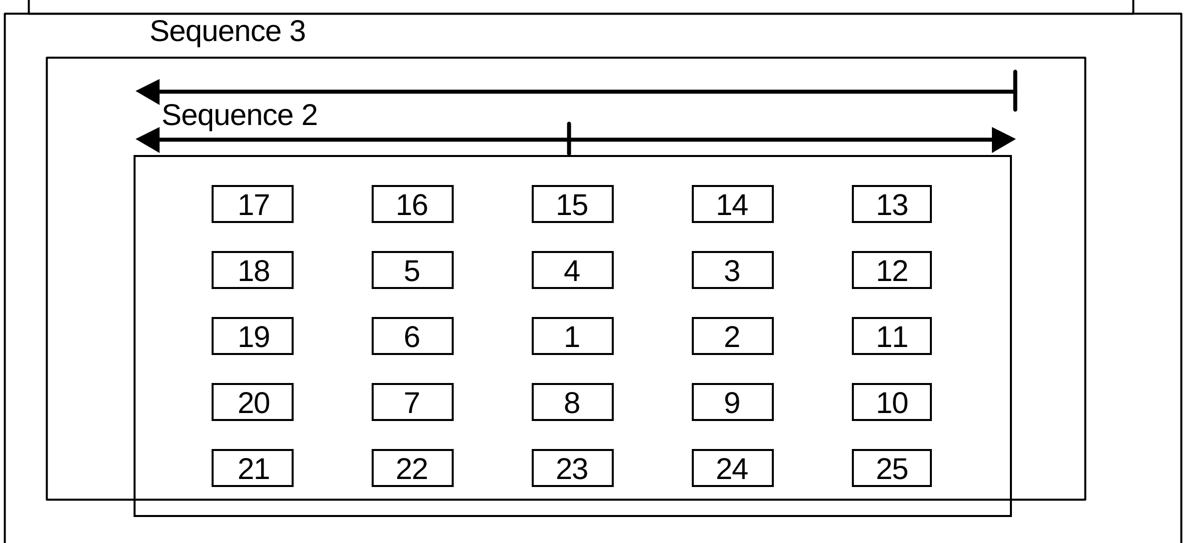


Figure 703.01

The following guidelines for Single Acting Diesel Hammer are provided to assist you. If there is a need for a different type of hammer inspection guideline, please contact the Geotechnical Section.

It is very important to field check the hammer systems provided by the contractor to the hammer data sheets after they are approved by the Geotechnical Section. Prior to pile driving, please verify cap weight and size and condition of the hammer cushion material as shown on the hammer data sheets.

E. Inspection of Piles Prior to and During Installation

1. The inspection will be different for each type of pile. Shop plans are required for sheet piles, but usually are not required for H-piles, concrete-piles or pipe-piles.

2. When MSE walls are being constructed, at times the soil conditions may require additional considerations. A note is sometimes included on our plans that states the MSE Wall Must Be Built Before Piles Are Driven. This note is usually applicable when the embankment behind the MSE wall is constructed as a fill. The note also usually specifies that the MSE wall cannot be constructed until the embankment has reached 95+% of its anticipated settlement. The concern here is that the granular backfill material will settle further and the embankment is also able to settle some additional amount due to the granular backfill load. The combined effect on the piling is to cause a downward load on the piling that will reduce the piling's capacity to resist the live and dead loads from the roadway.

3. Battered piles are driven at 1 ft. offset per 12 ft. of length or 3.33 ft. offset in 40 ft.

F. Precast Concrete Piles

1. The following is a list of items for prestressed concrete piles to be inspected at the construction site:

   a. The piles should be of the specified length and section. The inspector must be assured that a minimum concrete strength has been obtained. If the piles are to be spliced on the site, the splices should meet the specified requirements (type, alignment, etc.).

   b. Piles should be inspected for cracks or spalling. There should be no evidence that any pile has been damaged during shipping to the site, or during unloading of piles at the site. Lifting hooks are generally cast into the piling at pick-up points. Piles should be unloaded by properly sized and tensioned slings attached to each lifting hook.

   c. The piles should be stored properly. When piles are being placed in storage, they should be stored above ground on adequate blocking in a manner which keeps them straight and prevents undue bending stresses.

   d. The contractor should lift the piles into the leads properly and safely. Cables looped around the pile are satisfactory for lifting. Chain slings should never be permitted. Cables should be of sufficient strength and be in good condition. Frayed cables are unacceptable and should be replaced. For shorter piles, a single pick-up point may be acceptable. The pick-up point locations should be as specified by the casting yard. For longer piles, two or more pick-up points at designated locations may be required.

e. The pile should be free to twist and move laterally in the helmet.

f. Piles should have no noticeable cracks when placed in leads or during installation. Spalling of the concrete at the top or near splices should not be evident.

g. Steel H-Piles

1. The following should be inspected at the construction site:

   a. The piles being driven must be oriented with flanges in the correct direction as shown on the plans. Because the lateral resistance to bending of H-piles is considerably more in the direction perpendicular to flanges, the correct orientation of H-piles is very important.

   b. The piles should be of the specified steel grade, length, or section/weight.

   c. Pile points, if required for pile toe protection, should be as specified.

   d. Splices should be either proprietary splices or full penetration groove welds as specified. The top and bottom pile sections should be in good alignment before splicing.

   e. Pile point attachments and splices must be welded properly.

   f. There should be no observable pile damage, including deformations at the pile head.

G. Steel Pipe Piles

1. The following should be inspected at the construction site:

   a. The piles should be of specified steel grade, length, or minimum section/weight (wall thickness) and either seamless or spiral welded as specified.

   b. Piles should be driven either open-ended or closed-ended. Closed-ended pipe piles should have bottom closure plates or conical points of the correct size (diameter and thickness) and be welded on properly, as specified. Open-end pipe piles should have cutting shoes that are welded on properly.

   c. The top and bottom pile sections should be in good alignment before splicing. Splices or full penetration groove welds should be installed as specified.

   d. There should be no observable pile damage, including deformations at the pile head. After installation, closed-end pipes should be visually inspected for damage or water prior to filling with concrete.

H. Steel Sheet Piles

1. The sheet piles must meet thickness, section models, steel grade, length and width requirements as shown in our plans.

2. Sheet pile length should be measured so that analysis of obstructions to driving can be properly accomplished.

3. Sheet piles should be driven plumb or at the angle shown in the plans.

I. Inspection of Driving Equipment

A typical driving system consists of crane, leads, hammer, hammer cushion, helmet, and in the case of concrete piles, a pile cushion. Each component of the drive system has a specific function and plays an important role in the pile installation. The project plans and specifications may specify or restrict certain items of driving equipment. The Geotechnical Section will approve the contractor's driving equipment and determine conformity with the plans and specifications. The inspector must be sure the equipment used is what was approved.

1. <u>The following checklist will be useful in the inspection of driving equipment before driving</u>:

    a. The pile driving hammer should be the specified type/size.

        (1) The inspector should make sure for <u>single acting air/steam or hydraulic hammers</u> that the contractor uses the proper size external power source and that, for adjustable stroke hammers, the stroke necessary for the required energy be obtained. For <u>double acting or differential air/steam or hydraulic hammers</u>, the contractor must again obtain the proper size external power source and the operating pressure and volume must meet the hammer manufacturer's specification.

    b. The hammer cushion being used should be checked to confirm it is of the approved material type, size and thickness.

        (1) The main function of the hammer cushion is to protect the hammer itself from fatigue and high frequency accelerations which would result from steel to steel impact with the helmet and/or pile. The hammer cushion should have the proper material and same shape/area to snugly fit inside the helmet (drive cap). If the cushion diameter is too small, the cushion will break or badly deform during hammer blows and become ineffective. The hammer cushion must not be excessively deformed or compressed. Some air/steam hammers rely upon a certain total thickness (of cushion plus striker plate) for proper valve timing. Hammers with incorrect hammer cushion thickness may not operate, or will have improper kinetic energy at impact. Since it is difficult to inspect this item once the driving operation begins, it should be checked before the contractor starts pile driving on a project as well as periodically during production driving on larger projects.

c. The helmet (drive cap) should properly fit the pile.

(1) The purpose of the helmet is to hold the pile head in alignment and transfer the impact concentrically from the hammer to the pile. The helmet also houses the hammer cushion, and must accommodate the pile cushion thickness for concrete piles. The helmet should fit loosely to avoid transmission of torsion or bending forces, but not so loosely as to prevent the proper alignment of hammer and pile. Helmets should ideally be of roughly similar size to the pile diameter. Although generally discouraged, spacers may be used to adapt an oversize helmet, provided the pile will still be held concentrically wit the hammer. A properly fitting helmet is important for all pile types, but is particularly critical for precast concrete piles. <u>A poorly fitting helmet often results in pile head damage</u>. Check and record the helmet weight for conformance to wave equation analysis or for future wave equation analysis. Larger weights will reduce the energy transfer to the pile.

d. The pile cushion should be of correct type material and thickness for concrete piles.

(1) <u>The purpose of the pile cushion is to reduce high compression stresses, to evenly distribute the applied forces to protect the concrete pile head from damage, and to reduce the tension stresses in easy driving</u>. Pile cushions for concrete piles should have the required thickness determined from a wave equation analysis but not less than 4 inches (100 mm). A new plywood, hardwood, or composite wood pile cushion, which is not water soaked, should be <u>used for every pile</u>. The cushion material should be checked periodically for damage and replaced before excessive <u>compression (more than half the original thickness)</u>, burning or charring occurs. Wood cushions may take only about 1,000 to 2,000 blows before they deteriorate. During hard driving, more than one cushion may be necessary for a single pile. Longer piles or piles driven with larger hammers may require thicker pile cushions.

e. Predrilling, jetting or spudding equipment, if specified or permitted, should be available for use and meet the requirements. <u>The depth of predrilling, jetting or spudding should be very carefully controlled so that it does not exceed the allowable limits, usually 10 feet (1 m). Predrilling, jetting, or spudding below the allowed depths will generally result in a reduced pile capacity, and the pile acceptance may become questionable.</u>

f. A lead system must be used.

(1) <u>The leads perform the very important function of holding the hammer and pile in good alignment with each other</u>. Poor alignment reduces energy transfer as some energy is then imparted into horizontal motion. Poor alignment also generally results in higher bending stresses and higher local contact stresses which can cause pile damage. This is particularly important at end of driving when driving resistance is highest and driving stresses are generally increased.

J. Inspection of Driving Equipment During Installation

1. The main purpose of inspection is to assure that piles are installed so that they meet the driving criteria and the pile remains undamaged. The driving criteria is often defined as a minimum driving resistance as measured by the blow count in blows per inch. The driving criteria is to assure that piles have the desired capacity. However, the driving resistance is also dependent upon the performance of the pile driving hammer. The driving resistance will generally be lower when the hammer imparts higher energy and force to the pile, and the driving resistance will be higher if the hammer imparts lower energy and force to the pile. High driving resistances can be due either to soil resistance or to a poorly performing hammer. Thus, for the inspector to assure that the minimum driving criteria has been met and, therefore, the capacity is adequate, the inspector must evaluate if the hammer is performing properly.

2. Each hammer has its own operating characteristics; the inspector should not blindly assume that the hammer on the project is in good working condition. In fact, two different types of hammers with identical energy rating will not drive the same pile in the same soil with the same driving resistance. In fact, two supposedly identical hammers (same make and model) may not have similar driving capability due to several factors including differing friction losses, valve timing, air supply hose type-length-condition, duel type and intake amount, and other maintenance status items. The inspector should become familiar with the proper operation of the hammer(s) used on site. The inspector may wish to contact the hammer manufacturer or supplier who generally will welcome the opportunity to supply further information.

K. Single Acting Diesel Hammers

1. Determine/confirm that the hammer is the correct make and model. Check for and record any identifying labels as to hammer make, model and serial number.

2. Make sure all exhaust ports are open with all plugs removed.

3. Inspect the recoil dampener for condition and thickness. If excessively worn or improper thickness (consult manufacturer) it should be replaced. If the recoil dampener is too thin, the stroke will be reduced. If it is too thick, or if cylinder does not rest on dampener between blows, the ram could blow out the hammer top and become a safety hazard.

4. Check that lubrication of all grease nipples is regularly made. Most manufacturers recommend the impact block be greased every half-hour of operation.

5. As the ram is visible between blows, check the ram for signs of uniform lubrication and ram rotation. Poor lubrication will increase friction and reduce energy to the pile.

6. Determine the hammer stroke, especially at end of driving or beginning of restrike. A "jump stick" attached to the cylinder is a safety hazard and should not be used. The stroke can be determined by a saximeter which measures the time between blows and then calculates the stroke. The hammer stroke can also be calculated from this formula if the number of blows per minute (bpm) is manually recorded.

$$h\ [\text{meters}] = (4400/[\text{bpm}^2]) - 0.90$$

   a. The calculated stroke may require correction for batter or inclined piles. The inspector should always observe the ram rings and visually estimate the stroke using the manufacturer's chart.

7. As the driving resistance increases, the stroke should also increase. At the end of driving, if the ram fails to achieve the correct stroke (part of the driving criteria from a wave equation analysis), the cause could be lack of fuel. Most hammers have adjustable fuel pumps. Some have distinct fuel settings, others are continuously variable, and some use a pressure pump. Make sure the pump is on the correct fuel setting or pressure necessary to develop the required stroke. The fuel and fuel line should be free of dirt or other contaminants. A clogged or defective fuel injector will also reduce the stroke and should be replaced if needed.

8. Low strokes could be due to poor compression caused by worn or defective piston or anvil rings. Check compression by raising the ram, and with the fuel turned off, allowing the ram to fall. The ram should bounce several times if the piston and anvil rings are satisfactory.

9. Watch for signs of preignition. When a hammer preignites, the fuel burns before impact, requiring extra energy to compress gas and leaving less energy to transfer to the pile. In long sustained periods of driving, or if the wrong fuel with a low flash point is used, the hammer could overheat and preignite. When preignition occurs, less energy is transferred and the driving resistance rises, giving a false indication of high pile capacity. If piles driven with a cold hammer drive deeper or with less hammer blows, or if the driving resistances decrease after short breaks, preignition could be the cause and should be investigated. Dynamic testing is the preferable method to check for preignition.

10. For some diesel hammers, the total thickness of hammer cushion and striker plate must match the hammer manufacturer's recommendation and the hammer cushion cavity in the helmet for proper fuel injection and hammer operation. This total thickness must be maintained.

11. Make sure the helmet stays properly seated on the pile and that the hammer and pile maintain alignment during operation.

12. The hammer hoist line should always be slack, with the hammer's weight fully carried by the pile. Excessive tension in the hammer hoist line is a safety hazard and will reduce energy to the pile. Leads should always be used.

13. Some manufacturers void their warranty if the hammer is consistently operated above 100 blows per 250 mm of penetration beyond short periods, such as those required when toe bearing piles are driven to rock. Therefore, in prolonged hard driving situations, it may be more desirable to use a larger hammer or stiffer pile section.

14. Common problems and problem indicators for single acting diesel hammers are presented in the following table.

COMMON PROBLEMS AND PROBLEM INDICATORS FOR SINGLE ACTING DIESEL HAMMERS (from Williams Earth Sciences, 1995)

Common Problems	Indicators
Water in fuel.	Hollow sound, white smoke.
Fuel lines clogged.	No smoke or little gray smoke.
Fuel pump malfunctioning.	Inconsistent ram strokes, little gray smoke or black smoke.
Fuel injectors malfunctioning.	Inconsistent ram strokes, little gray smoke or black smoke.
Oil low.	Blows per minute rate is lower than specified.
Oil pump malfunctioning.	Blows per minute rate is lower than specified.
Water in combustion chamber.	Hollow sound, white smoke.
Piston rings worn.	Low strokes.
Tripping device broken.	Pawl or pin used to lift piston does not engage piston. Pawl engages but does not lift piston.
Overheating.	Paint and oil on cooling fins start to burn/sound changes.

L. Field Driving Problem

In the following table, there is a list of common field problems and possible solutions.

COMMON PILE INSTALLATION PROBLEMS & POSSIBLE SOLUTIONS	
Problem	**Possible Solutions**
Piles encountering refusal driving resistance (blow count) above minimum pile penetration requirements.	Have wave equation analysis performed and check the pile has sufficient drivability and that the driving system is matched to the pile. If the pile and driving system are suitably matched, check driving system operation for compliance with manufacturer's guidelines. If no obvious problems are found, dynamic measurements should be made to determine if the problem is driving system or soil behavior related. Driving system problems could include preignition, preadmission, low hammer efficiency, or soft cushion. Soil problems could include greater soil strength than anticipated, temporarily increased soil resistance with later relaxation (required restrike to check), large soil quakes, or high soil damping.
Piles driving significantly deeper than estimated pile penetration depths.	Soil resistance at the time of driving probably is lower than anticipated or driving system performance is better than anticipated. Have wave equation analysis performed to assess ultimate pile capacity based on the blow count at the time of driving. Perform restrike tests after an appropriate waiting period to evaluate soil strength changes with time. If the ultimate capacity based on restrike blow count is still low, check drive system performance and restrike capacity with dynamic measurements. If drive system performance is as assumed and restrike capacity low, the soil conditions are weaker than anticipated. Foundation piles will probably need to be driven deeper than originally estimated or additional piles will be required to support the load. Contact the structural engineer/designer for recommended change.
Abrupt change or decrease in driving resistance (blow count) for bearing piles.	If borings do not indicate weathered profile above bedrock/bearing layer, then pile toe damage is likely. Have wave equation analysis performed and evaluate pile toe stress. If calculated toe stress is high and blow counts are low, a reduced hammer energy (stroke) and higher blow count could be used to achieve capacity with a lower toe stress. If calculated toe stress is high at high blow counts, a different hammer or pile section may be required. For piles that allow internal inspection, reflect light to the pile toe and tape the length inside the pile for indications of toe damage. For piles that cannot be internally inspected, dynamic measurements could be made to evaluate problem or pile extraction could be considered for confirmation of a damage problem.
Driving resistance (blow count) significantly lower than expected during driving.	Review soil borings. If soil borings do not indicate soft layers, pile may be damaged below grade. Have wave equation analysis performed and investigate both tensile stresses along pile and compressive stresses at tie. If calculated stresses are within allowable limits, investigate possibility of obstructions/uneven toe contact on hard layer or other reasons for pile toe damage. If pile was spliced, re-evaluate splice detail and field splicing procedures for possible splice failure.
Vertical (heave) or lateral movement of previously installed piles when driving new piles.	Pile movements likely due to soil displacement from adjacent pile driving. Contact geotechnical engineer for recommended action. Possible solutions include redriving of installed piles, change in sequence of pile installation, or predrilling of pile locations to reduce ground movements. Lateral pile movements could also result from adjacent slope failure in applicable conditions.

COMMON PILE INSTALLATION PROBLEMS & POSSIBLE SOLUTIONS	
Problem	**Possible Solutions**
Piles driving out of alignment tolerance.	Piles may be moving out of alignment tolerance due to hammer-pile alignment control or due to soil conditions. If due to poor hammer-pile alignment control, a pile gate, template or fixed lead system may improve the ability to maintain alignment tolerance. Soil conditions such as near surface obstructions (see subsequent section) or steeply sloping bedrock having minimal overburden material (pile point detail is important) may prevent tolerance from being met even with good alignment control. In these cases, survey the as-built condition and contact the Geotechnical engineer for recommended action.
Piles driving out of location tolerance.	Piles may be moving out of location tolerance due to hammer-pile alignment control or due to soil conditions. If due to poor hammer-pile alignment control, a pile gate, template or fixed lead system may improve the ability to maintain location tolerance. Soil conditions such as near surface obstructions (see subsequent section) or steeply sloping bedrock having minimal overburden material (pile point detail is important) may prevent tolerances from being met even with good alignment control. In these cases, survey the as-built condition and contact the Geotechnical engineer for recommended action.
Piles encountering shallow obstructions.	If obstructions are within 3 feet of working grade, obstruction excavation and removal is probably feasible. If obstructions are at deeper depth, are below the water table, or the soil is contaminated, excavation may not be feasible. Spudding or predrilling of pile locations may provide a solution with method selection based on the type of obstructions and soil conditions.
Pile encountering obstructions at depth.	If deep obstructions are encountered that prevent reaching the desired pile penetration depth, contact the structural engineer/designer for remedial design. Ultimate capacity of piles hitting obstructions should be reduced based upon pile damage potential and soil matrix support characteristics. Additional foundation piles may be necessary.
Concrete piles develop partial horizontal cracks in easy driving.	Check hammer-pile alignment since bending may be causing the problem. If the alignment appears to be normal, tension and bending combined may be too high. The possible solution is as above with complete cracks.
Concrete pile spalling or slabbing near pile head.	Have Geotechnical Section determine pile head stress for observed blow count and compare with allowable stresses. If high calculated stress, add pile cushioning. If low calculated stress, investigate pile quality, hammer performance, hammer-pile alignment.
Concrete piles develop complete horizontal cracks in easy driving.	Have Geotechnical Section determine tension stresses along pile for observed blow counts. If high calculated tension stresses, add cushioning or reduce stroke. If low calculated tension stresses, check hammer performance and/or perform measurements.
Concrete piles develop complete horizontal cracks in hard driving.	Have Geotechnical Section determine tension stresses along pile. If high calculated tension stresses, consider heavier ram. If low calculated tension stresses, take measurements and determine quakes which are probably higher than anticipated.
Concrete piles develop partial horizontal cracks in easy driving.	Check hammer-pile alignment since bending may be the problem. If alignment appears to be normal, tension and bending combined may be too high; solution will then be the same as for complete cracks above.
Steel pile head deforms, timber pile top mushrooms.	Check helmet size/shape; check steel strength; check evenness of pile head, banding of timber pile head. If okay, have Geotechnical Section determine pile head stress. If calculated stress is high, reduce hammer energy (stroke) for low blow counts; for high blow counts, different hammer or pile type may be required.
Unexpectedly low blow counts during pile driving.	Investigate soil borings; if soil borings do not indicate soft layers, pile may be damaged below grade. Have Geotechnical Section investigate both tensile stresses along pile and compressive stresses at toe. If calculated stresses are acceptable, investigate possibility of obstructions/uneven toe contact on hard layer or other reasons for pile toe damage.

COMMON PILE INSTALLATION PROBLEMS & POSSIBLE SOLUTIONS	
Problem	**Possible Solutions**
Higher blow count than expected.	Have the Geotechnical Section review the wave equation analysis and check that all parameters were reasonably considered. Check hammer and driving system. If no obvious defects are found in driving system, field measurements should be taken. Problem could be preignition, preadmission, low hammer efficiency, soft cushion, large quakes, high damping, greater soil strengths, or temporarily increased soil resistance with later relaxation.
Lower blow count than expected.	Probably soil resistance is lower than anticipated. Have the Geotechnical Section assess soil resistance. Perform restrike testing (soil resistance may have been lot during driving), establish setup factor and drive to lower capacity. Hammer performance may also be better than anticipated, check, by measurement.
Diesel hammer stroke (bounce chamber pressure) higher than calculated.	The field observed stroke exceeds the calculated stroke by more than 10%. Compare calculated and observed blow counts. If observed are higher, soil resistance is probably higher than anticipated. If blow counts are comparable, have the Geotechnical Section reanalyze with higher combustion pressure to match observed stroke and assure that preignition is not a problem, e.g., by measurements.
Diesel hammer stroke (bounce chamber pressure) lower than calculated.	The field observed stroke is less than 90% of the calculated stroke. Check that ram friction is not a problem (ram surface should have well lubricated appearance). Compare calculated and observed blow count. If observed one is lower, soil resistance is probably lower than anticipated. If blow counts are comparable, reanalyze with lower combustion pressure to match observed hammer stroke.
Cannot find hammer in data file.	See if there is a hammer of same type, similar ram weight and energy rating and modify its data.
Cannot find an acceptable hammer to drive pile within driving stress and driving resistance limits.	Both calculated stresses and blow counts are too high. Increase pile impedance or material strength or redesign for lower capacities. Alternatively, check whether soil has potential for setup. If soil is fine grained or known to exhibit setup gains after driving, then end of driving capacity may be chosen lower than required. Capacity should be confirmed by restrike testing or static load testing.

SINGLE ACTING HAMMER INSPECTION CHECKLIST
(For PM Use Only)

Project/Pile: ____________________

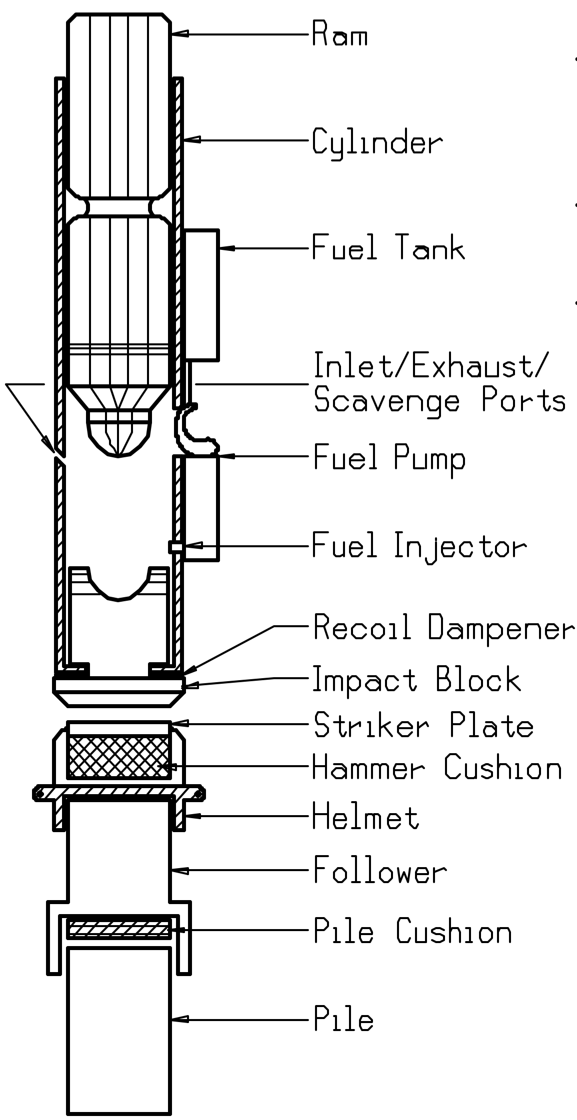
Date: ____________________

Conditions: ____________________

Hammer Name: ____________________

Serial No: ____________________

OBJECT | **REQUIREMENTS** | **OBSERVATIONS**



REQUIREMENTS	OBSERVATIONS
Ram Lubricated?	Yes / No
Exhaust Ports Open?	Yes / No
Fuel Pump	Hammer Setting ________
Recoil Dampener Undamaged?	Yes / No
Impact Block Lubricated?	Yes / No
Striker Plate	t= ________ D= ________
Hammer Cushion	t= ________ D= ________ Material ________
	How long in use? ________
Helmet Pile Cushion	Type or Weight? ________ Material ________ t= ________ Size ________ How long in use? ________

704.00 BRIDGES (STEEL STRUCTURES) (*SSHC Section 708*)

704.01 DESCRIPTION

A. This work includes the furnishing, preparing and erecting of all riveted, bolted or welded structures in which the main members spanning the supports are composed of steel.

704.02 MATERIAL REQUIREMENTS

A. Members of steel structures that are fabricated in the shop are inspected by NDR personnel before they are shipped to the job site. In some cases, when the fabrication is done outside of the state, the inspection will take place after delivery to the site of work. The Project Manager should have a copy of the shop inspection report and the mill test report before allowing the erection of any portion of the structure. Miscellaneous parts of the superstructure such as high tensile steel bolts will require field inspection and sampling according to the "*Materials Sampling Guide*".

B. Field welding may require the use of special welding electrodes as designated in the plans, specifications, or special provisions. Some of these welding electrodes may require special care and handling before their use will be permitted. (See *SSHC Section 708*.) Enter date steel is verified in SiteManager. Occasionally wrong size is delivered.

C. Concrete Industries rebar shipments will be documented to show bending details, heat numbers, quantity and project location by stationing.

704.03 CONSTRUCTION METHODS

A. Falsework (*SSHC Subsection 704.03*)

   1. Girders should be blocked so that the weight of any deck overhang does not bend the girder, which will ripple the deck.

B. Temporary Fastenings

   1. Contractors often request permission to use anchor supports for face forms, concrete curbs, Jersey barriers, raised medians on bridges. Any contractor desiring to use a temporary floor fastening may be allowed to use only some form of weakened section bolt or tie, cast in the floor. The weakened section must be so positioned that when broken off the break will be recessed below the surface. The resulting void must be patched with mortar.

   2. NOTE:

      a. No bolt without a weakened section may be used.

      b. No holddown device shot into the floor will be allowed.

         (1) Concrete arch bridges.

         (2) Support of girders or other large structural elements when required.

(3) Unusual or complicated work indicated in the plans.

(4) Support of girders over or under active railroad tracks.

(5) Support of girders carrying traffic or extending over highways or streets carrying traffic.

C. Submitting Plans

NOTE: Submission of falsework plans does not imply that OSHA regulations are satisfied, that the NDR, or the Project Manager assumes any liability for the falsework. Inspectors should not give the contractors advice on how to construct the falsework.

D. Bridges-Steel Beam

1. On bridges using weathering steel (A 588) for steel structures, the contractor shall:

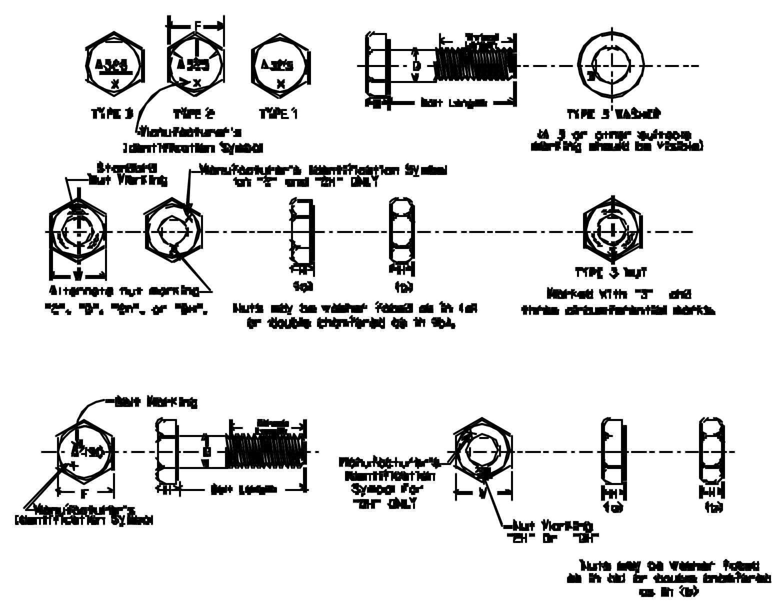
a. Use "high strength," A325M Type III bolts, A563 Grade DH3 nuts, and F463 Type III washers.

b. Limit shop painting to only areas under expansion joints and all bearings. Shop painting will be with a Zinc-rich primer and a colored topcoat. Field touch-up will be required for paint that is damaged and to fasteners in these areas and it will be done with same color and type of paint as the original painting.

c. Require special care to assure concrete slobbers are eliminated (or at least removed) from steel surfaces before the concrete hardens. Washing with water is the preferred method of removing concrete slobbers.

E. Structural Joints Using High Tensile Steel

	HEAVY HEX STRUCTURAL BOLTS BOLT DIMENSIONS (INCHES)			HEAVY HEX NUTS NUT DIMENSIONS (INCHES)	
BOLT DIAMETER (INCHES) D	WIDTH ACROSS FLATS F	HEIGHT H	THREAD LENGTH	WIDTH ACROSS FLATS W	HEIGHT H
1/2	7/8	5/16	1	7/8	31/64
5/8	1 1/16	25/64	1 1/4	1 1/16	39/64
3/4	1 1/4	15/32	1 3/8	1 1/4	47/64
7/8	1 7/16	35/64	1 1/2	1 7/16	55/64
1	1 5/8	39/64	1 3/4	1 5/8	63/64
1 1/8	1 13/16	11/16	2	1 13/16	1 7/64
1 1/4	2	25/32	2	2	1 7/32
1 3/8	2 3/16	27/32	2 1/4	2 3/16	1 11/32
1 1/2	2 3/8	15/16	2 1/4	2 3/8	1 15/32



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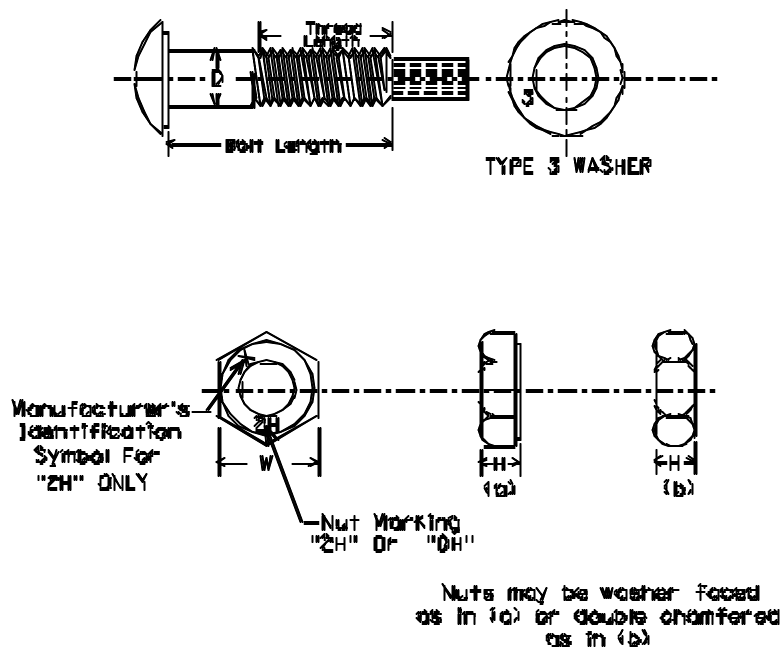
Bolts

DIRECT TENSION BOLTS



1. Must obtain Construction Division permission to use these bolts.
2. Special impact wrench that will hold bolt & tighten the nut must be used.
3. End of bolt will seperate at proper torque.

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1. *SSHC Section 1058* requires high tensile steel bolt, nut and washer material for structural steel joints to meet the requirements of ASTM Designation A 325/A 325M.

2. When heavy hexhead structural bolts and heavy hexagon nuts are used, a hardened washer is required only under the bolt head, or nut, whichever is the element being turned. Bolts and nuts may be washer faced, but these faces do not take the place of a hardened washer.

3. Heavy hexhead structural bolts manufactured to ASTM A 325/A 325M, Types 1, 2 and 3, the dimensions for which are shown in the ASTM tables, are identified on the top of the head by the legend "A 325", and the manufacturer's symbol.

4. Type 1 bolts, at the option of the manufacturer, may be marked with three radial lines 120 degrees apart.

5. Type 2 bolts shall be marked with three radial lines 60 degrees apart. Type3 bolts shall have the "A 325" underlined and the manufacturer may add other distinguishing marks indicating that the bolt is of a weathering type.

6. Heavy hex nuts for A 325 bolts are identified or at least one face by the manufacturer's mark and the number "2" or "2H", by three equally spaced circumferential lines, or by the legend "D" or "DH". Heavy hex nuts for A 325 Type 3 bolts shall be marked on one face with three circumferential marks and the numeral "3", in addition to any other distinguishing marks the manufacturer may elect to use.

7. Washers for A 325 Type 3 bolts shall be marked on one face near the outer edge with the numeral "3", or other distinguishing marks indicating that the washer is of a weathering type.

8. The marking on bearing surfaces of nuts and washers shall be depressed.

9. According to the specifications, high strength steel bolts may be installed by the turn of the nut method. It should be noted that the equivalent torque values given in SSHC Table 708.03 are experimental approximations and that the footnote to this table required that the torque-tension ratio be determined under actual conditions of the application. Wrenches will be calibrated and the torque-tension ratio will be determined at the site by Materials and Research Division personnel. The Construction Engineer should be notified as early as possible as to the time when the wrench and representative bolts will be present at the site in order that arrangements may be made to have appropriate personnel travel to the site and calibrate the wrench and establish the torque-tension ratio.

10. When Materials and Research Division personnel have calibrated the wrench and determined the torque-tension ratio, the bolt tension calibrator will be left with the project personnel so that the wrench calibration may be checked as the work goes on. Impact wrenches should be checked on a daily basis and manual torque wrenches at any time that, in the opinion of the Project Manager, conditions have varied form those present during the initial calibration.

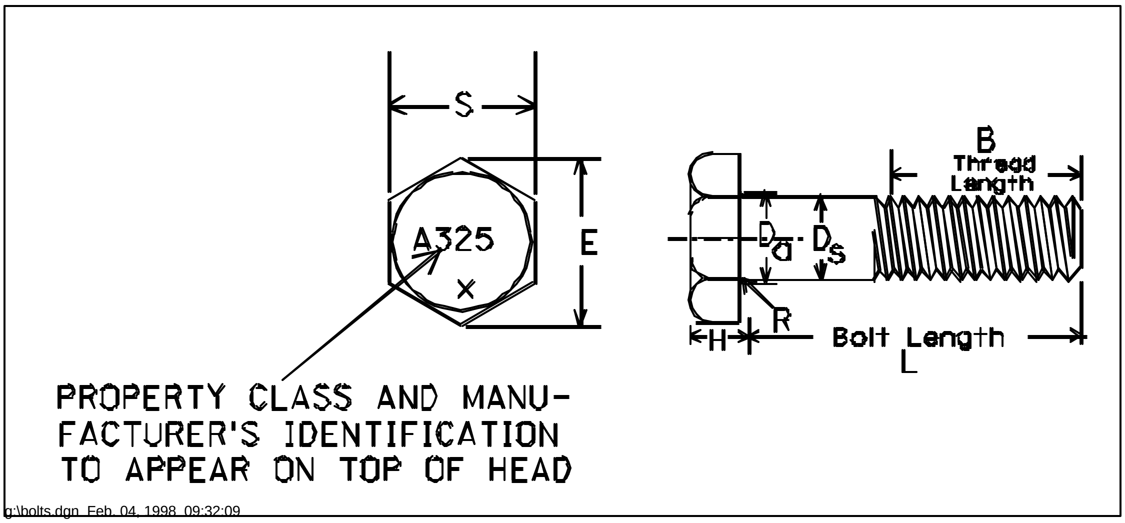
11. Impact wrenches should be calibrated under the same conditions, such as length of hose and power supply, that were present during actual installation of the bolts.

12. *SSHC Subsection 708.03* requires that the structure shall be adjusted to the requirements of blocking diagram before placing permanent bolts in field connections. This should be checked by the contractor and verified by the inspector prior to completing final phase of bolt tightening.

13. All splice plates and contact surfaces shall be clean.

F. High Strength Fasteners (*SSHC Section 1058*)

METRIC HEAVY HEX BOLTS



D	D_s		S		E		H		D_a	R	B (Ref.)		
											Thread Length (Basic)		
Nominal Bolt Size & Thread Pitch	Body Diameter		Width Across Flats		Width Across Corners		Head Height		Fillet Transition Dia.	Radius of Fillet	Bolt Lengths <125	Bolt Lengths >125 and <200	Bolt Lengths >200
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.			
M12x1.75	12.70	11.30	21.00	20.16	24.25	22.78	7.95	7.24	13.7	0.67	30	36	49
M14x2	14.70	13.30	24.00	23.16	27.71	26.17	9.25	8.51	15.7	0.6	34	40	53
M16x2	16.70	15.30	27.00	26.16	31.18	29.56	10.75	9.68	17.7	0.6	38	44	57
M20x2.5	20.84	19.16	34.00	33.00	39.26	37.29	13.40	12.12	22.4	0.8	46	52	65
M24x3	24.84	23.16	41.00	40.00	47.34	45.20	15.90	14.56	26.4	0.8	54	60	73
M30x3.5	30.84	29.16	50.00	49.00	57.74	55.37	19.75	17.92	33.4	1.0	66	72	85
M36x4	37.00	35.00	60.00	58.80	69.28	66.44	23.55	21.72	39.4	1.0	78	84	97

1. *SSHC Subsection 708.03, Paragraph 10.h*. Turn-of-Nut method shall be followed for tightening all high strength fasteners.

2. High Strength bolts and nuts, which have been torqued as outlined below, shall not be reused. This includes both black and galvanized bolts and nuts.

   a. Bolting

      (1) Receiving Shipments

         (a) Prior to installation, check shipping certifications and compare these to bolting kegs on site. Check for size, length, heat numbers, and general fastener condition i.e., rusted black bolts or non-lubricated galvanized nuts. Rotational-Capacity (RC) lots will need to checked.

   b. Installation Checklist

      (1) A pre-bolting meeting is strongly recommended/encouraged. Bolting procedures, Turn-of-Nut process described below, and the inspection process need to be discussed.

      (2) Site storage of fasteners is important. Storage should be in a sealed container within a sheltered storage shed.

      (3) Black bolts and nuts shall be oily to the touch when delivered and installed.

      (4) Galvanized nuts shall be checked to verify lubrication. A uniform dye color indicates lubricant has not been damaged. If there is no color, or color is not uniform, bolts and nuts shall be field lubricated with bees wax, stick wax, or other approved dry wax prior to installation.

      (5) Rusted or dirty bolts or nuts shall be cleaned and relubricated prior to installation.

      (6) Faying surfaces shall be free of burrs and foreign material; and bolted faying surfaces are to be painted with zinc rich paint.

      (7) All fasteners shall be free of dirt, moisture, rust, and be "well" lubricated.

      (8) Washers (when required) are to be placed under the **"turned element."**

      (9) Often contract documents will specify which way a bolt is to be installed. If there is no specific guidance, threaded ends of bolts will be turned inside and away from normal exposure to pedestrian and/or vehicular traffic for aesthetic reasons.

(10) During installation, particular care should be exercised so a snug-tight condition is achieved.

c. Rotational-Capacity

(1) The plans and specifications may eventually require a Rotational-Capacity (RC) test for all "high strength" fasteners. This test confirms component compatibility and the presence of adequate lubrication. Currently, it is only required when the Project Manager determines it is necessary.

(2) There are two separate Rotational-Capacity requirements:

(a). Fasteners (bolts, nuts, and washers) received at the project shall have been RC tested by the supplier or manufacturer prior to shipment. Therefore, each combination of production lots must have an unique RC lot number. This number must be readily identifiable on each container of fasteners.

(b). Prior to installation, the contractor shall field test all RC lots as supplied. Field tests are not intended to match the values provided by the supplier, but as a separate and added acceptance test.

(c) Field testing procedures are given in *SSHC Subsection 708.03, paragraph 10.h*.

d. Turn-of-Nut Method

(1) "Turn-of-Nut" method involves the following simple steps. Adherence to this procedure will assure a properly fitted and clamped connection. (*Refer to SSHC Subsection 708.03*.)

(a) Adequate number of bolts and pins shall be installed to bring a joint in tight contact and alignment. These bolts shall be brought to a snug-tight condition to insure that the joint is maintained in good contact during installation of remaining bolts. A washer shall be placed under the element to be turned.

(b) Remaining bolts in a connection shall be installed and brought to a snug-tight condition.

(c) Check initially installed bolts to assure they remained in a snug-tight condition.

(d) Tighten all bolts by the applicable Turn-of-Nut amount specified in *SSHC Subsection 708.03*. Additional rotation depends on the bolt length to diameter ratio and shape of connected pieces. For MOST installations (both faces normal to bolt Axis) the following table can be used to determine additional rotation for Turn-of-Nut.

NOTE: The following table is currently printed in English units only. When Standard diameter, lengths, and additional rotation values are developed for metric fasteners, another table will be prepared.

Turn of the Nut

	3/4" Dia. Bolts		7/8" Dia. Bolts	
	Bolt Length	**Additional Rotation**	**Bolt Length**	**Additional Rotation**
	0-3"	1/3 turn	0-3.5"	1/3 turn
	>3"-6"	1/2 turn	>3.5-7"	1/2 turn
	>6" -9"	2/3 turn	>7" - 10.5"	2/3 turn
NOTE:	All additional rotations have a ± tolerance. Refer to *SSHC Section 708*.			

	1" Dia. Bolts		1 1/8" Dia. Bolts	
	Bolt Length	**Additional Rotation**	**Bolt Length**	**Additional Rotation**
	0-4"	1/3 turn	0-4.5"	1/3 turn
	>4"-8"	1/2 turn	>4.5"-9"	1/2 turn
	>8" -12"	2/3 turn	>9" - 13.5"	2/3 turn
NOTE:	All additional rotations have a ± tolerance. Refer to *SSHC Subsection 708.03*.			

e. Snug Tight

(1) Snug tight is defined as the tightness that exists when all plies of a joint are in "firm" contact with each other. There shall not be air gaps between metal to metal or metal to bolt surfaces. For properly fitting surfaces, snug tight can usually be accomplished by:

(a) The full effort of a person using an ordinary spud wrench.

(b) A "few impacts" of an impact wrench. To quantify "few impacts," tighten a few bolts using the full effort method on a spud wrench. Then apply the job impact wrench, and roughly check how many impacts it takes to develop at least the same effort.

(2) After **ALL** bolts in the connection are snug tight:

(a) **ALL** nuts shall be match-marked with bolt point nut and base steel using paint crayon, or other means to provide a straight reference line for determining final relative rotation of parts during tightening.

(b) All bolts in a connection shall then be tightened additionally by an applicable amount of nut rotation specified above. Tightening should progress from the most rigid part of the joint to its free edges. On our normal web and flange splices, this would mean beginning at the centerline of a splice and progressing away (in each direction) from the centerline of splice.

(3) Inspectors should observe this operation at intervals to make certain the match-marking is done correctly, and that the opposite bolt head or nut does not turn during the tightening process. Inspectors also should check to see if proper rotation has been made considering tolerances given at the bottom of the nut rotation chart.

f. Inspection Wrench Calibration

(1) Tension Measuring Calibrated Devices

(a) Tension measuring calibrated devices (typically Skidmore-Wilhelm Calibrator) are calibrated to a high degree of accuracy, but can lose some of this accuracy after an extended period of time. Contractors can have the devices calibrated by the Materials & Research Laboratory.

(b) When each device is calibrated, a calibration sheet will be issued indicating the date the test was performed. Contractors must keep the calibration sheet with the tension-measuring device.

(c) Attentiveness needs to be exercised when using this Calibration Sheet. The inspector needs to check the sheet and compare the "Indicated Load on Gauge" column to those values listed in the "AVG" column under "Actual Load on Testing Machine." These are usually **NOT** the same.

NOTE: Be sure to take any difference (INDICATED versus ACTUAL) into account when calibrating the Job Torque Wrench!

(2) Torque Wrench Calibration

(a) At least once a day, three bolts of the same grade, size, and condition as those used in the structure shall be placed individually in a calibration device capable of indicating bolt tension. A washer shall be used under the part to be turned.

NOTE: There must be 3-5 threads exposed behind the nut. Check and add washers if required. For longer bolts, steel shim plates should be used.

(i) Tension bolt to 100 percent of "Minimum Bolt Tension" listed for a particular bolt diameter. Tension is read directly from the tension measuring calibrated device as corrected by accounting for differences between INDICATED versus ACTUAL. (Refer to *SSHC Subsection 708.03* for "Minimum Bolt Tension.")

(ii) Apply inspection torque wrench, rotate nut or bolt and increase tension by an additional 5%. Remember, a dial type wrench must be set to zero before checking torque. Record the inspection wrench's "TORQUE" when 105% of the tension is achieved.

NOTE: The turned element must be moving to indicate the correct torque.

(iii) **EXAMPLE:** (English units)
Assume:
1. 7/8" Diameter bolt
2. Skidmore Calibration

Minimum Bolt Tension
39,250 lbs-force

Skidmore Calibration
Gauge Reading 40,000 lbs-force
Actual Ave. at 40,000 = **38,800 lbs-force**

Calculations

- For 100% tension, corrected Skidmore gauge should read:

39,250 + (40,000-38,800) = **40,450 lbs-force**

- For 105% tension, corrected Skidmore gauge should read:

40,450 x 1.05 = **42,473 lbs-force**

(vi) torque reading on Inspection Wrench at 42,47O± lbs-force is recorded.

(a) Repeat this process for a total of three fasteners.

(b) The inspector notes the torque for three fasteners, averages this torque, and that becomes the Job Inspection Torque Value until the wrench is recalibrated the next day, or another size or length of bolt is to be inspected.

The Inspector shall record:

- The job inspection torque.

- The Tension Measuring device's calibration "date reported," serial and model number, and calibration lab number.

g. Turn-of-Nut Inspection (*SSHC Subsection 708.03*)

(1) After all fasteners in a joint are properly tightened by the Turn-of-Nut method, they shall be inspected as indicated:

(a) Installed fasteners shall be inspected the same day as installed by the contractor with the inspector present.

(b) The contractor shall use a calibrated torque wrench for the inspection operation.

(c) Ten percent of the bolts which have been tightened in the structure shall be tested with the inspection wrench the same day as installed. At least two bolts, selected at random, in each connection shall be tested. If no rotation (nut or bolt head) is noted by job inspecting torque wrench and the faying surfaces are in tight contact the connection shall be accepted as properly tightened. If any nut or bolt head is turned, all bolts in the connection shall be checked, and all bolts whose nut or head is turned shall be tightened and reinspected.

(d) Bolts tightened by the Turn-of-Nut method may reach tensions substantially above minimum torque values specified, but this shall not be cause for rejection.

(e) Care should be taken, however, to not overstress the bolts. If most of the bolts exceed 20% of minimum bolt tension, the contractor's procedures should be reviewed to determine:

(i) Is the snug-tight procedure correct?

(ii) Are there nicks or burrs on the threads?

(iii) Are the nuts or bolts rusty or dirty?

(iv) Check for residual lubrication. All threaded fasteners (black and galvanized) are required to be lubricated. Black bolts and nuts need to have a water soluble oil, and galvanized nuts are to be lubricated as per ASTM A 563. Prelubricated galvanized nuts will be dyed typically to a blue color. If there is no indication of color OR if the color is faded, the bolts shall be field lubricated with bees wax, stick wax, or some other dry lubricant.

(v) Is calibrating device correct?

(4) Bolts and nuts must always be inspected prior to installation. Items of major concern are:

(a) Nicks or burrs in the threads

(b) Rust

(c) Presence of dirt or other foreign material

(d) Fastener lubrication

(e) All dirt, foreign material, and rust must be removed prior to use. Black bolts may require reoiling to remove rust etc. If reoiling is required, excess oil must be removed prior to installation. When rust cannot be removed by oiling, the bolt or nut must be rejected. Bolts or nuts with nicks or burrs on threads must be rejected. Relubrication will necessitate rechecking fasteners in the lot for Rotational-Capacity.

(5) Plan ahead before girder splices have been fully tightened. Make necessary adjustments prior to tightening the bolts in a connection. The best way to assure that beam lines are straight and true is to:

(a) Scribe a line at the center of each bearing on all masonry plates or concrete.

(b) Set beams and make snug tight connections proceeding to the forward pier. Then go back and straighten the beam line, checking to be sure bearings remain centered on their seats. Once the previous span is aligned and tightened, proceed to the next forward span.

(c) Check to be sure beam ends are aligned prior to tightening the splice.

(d) This will require coordination between survey and inspection crews and the contractor.

h. Galvanized Bolts

(1) *When using galvanized hardware, a lubricant approved by ASTM A 563 shall be applied to the nuts.* Galvanized nuts "typically" are delivered to the project pre-lubricated. Usually, pre-lubricated nuts are stained and have a distinguishing color. If a lubricant has been applied at the fabrication shop, a field reapplication is not necessary provided original lubrication has not been removed in some manner. For situations where fabrication shop lubricant is in question, field application of bees wax, stick wax, or some other dry lubrication shall be required. Rotational-Capacity requires the test to be conducted with fasteners in the same condition as they will be during installation.

(2) A WORD OF CAUTION:

(a) Lubrication is required to minimize galling during installation. Since nuts are lubricated (both threads and faces), it is important that nuts be rotated during tightening.

(b) Fasteners (bolts and nuts of any type) shall not be tightened, then removed, reinstalled, and retightened.

G. Welding (*SSHC Subsection 708.03*)

1. Contractors may be allowed to tack weld form hardware to the shear connectors on steel girders. (The intent is to eliminate the request procedure.)

2. This policy does not apply to the rebar stirrups which extend out of the top of prestressed girders.

H. Shear Connectors

1. OSHA has made a determination that shear connectors on steel girders are a tripping hazard. However, OSHA, after receiving petitions from FHWA, AASHTO, and other organizations, issued relief from the field welding requirements. The Department and other transportation agencies were concerned that field welded shear connectors created a bridge that would not be as safe as a bridge with shop welded shear connectors.

2. Girders may arrive on-site with all the shear connectors shop welded and this will not be a citable violation of the OSHA shear connector requirements. It will be considered a "de minimis" violation, or in other words, a minor concern that has a very low probability of occurrence and where expenditure of resources is not warranted to ensure compliance.

3. 100 percent conventional fall protection is required for all workers working overhead (6 feet or higher).

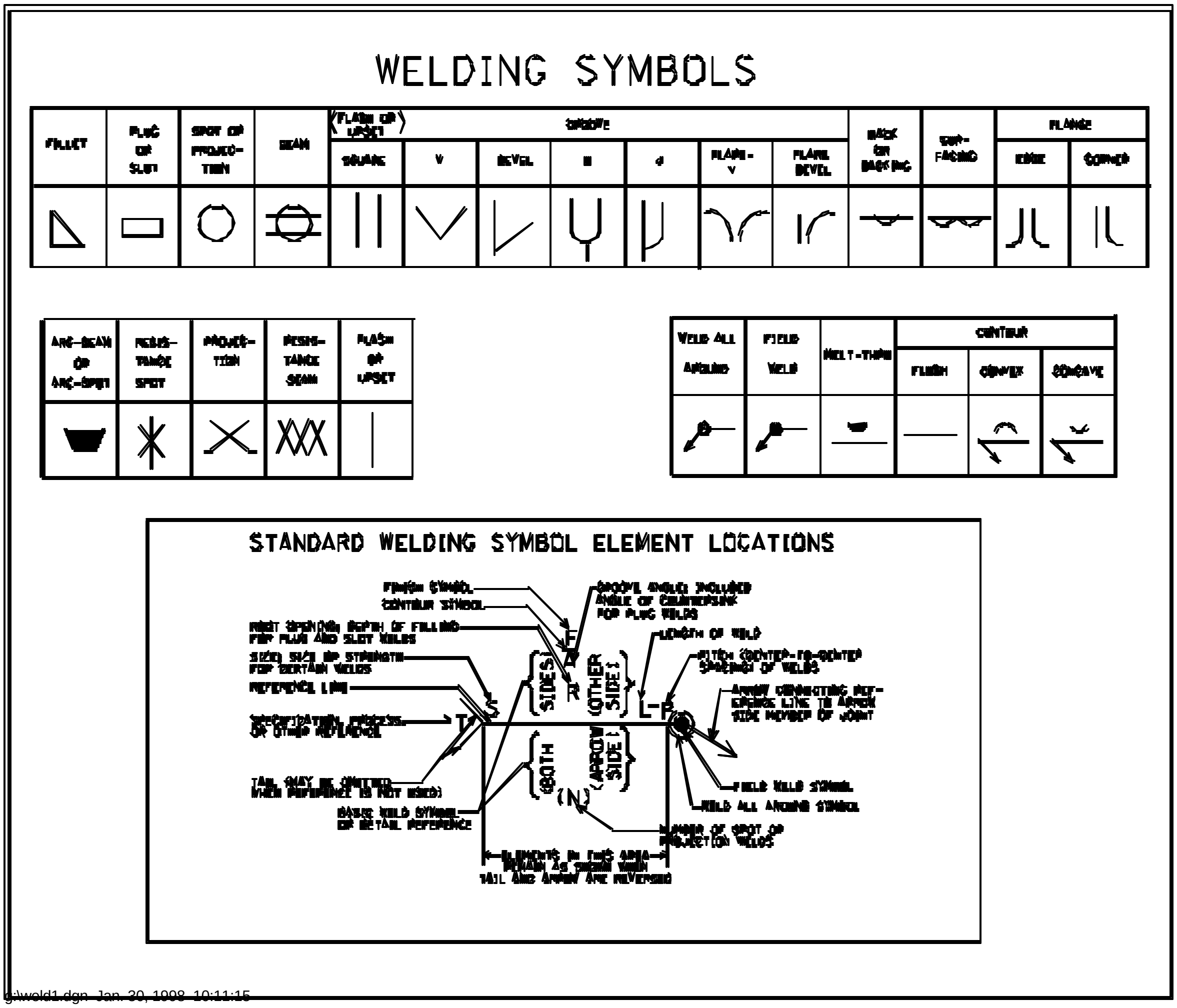
4. Shear connectors may either be shop welded or field welded.

- If they are field welded then the inspector needs to realize that welding shear connectors is a critical operation. The bridge may fail if the shear connectors are not welded properly.

- **Use a "big" hammer to check field welded shear connectors.**

Table 708.01 Shear Connector Checklist		
1.	An arc shield (ferrule) of heat-resistant ceramic or other suitable shall be furnished with each stud. The material shall not be detrimental to the welds or cause excessive slag and shall have sufficient strength so as not to crumble or break due to thermal or structural shock before the weld is completed.	
2.	Only approved studs shall be used. The arc shield used in production shall be the same as used in qualification tests.	
3.	Before installation of the studs, the contractor shall submit to the inspector for approval information on the studs to be furnished as follows:	
	a.	The name of the manufacturer.
	b.	A detailed description of the stud and arc shield.
	c.	A certification from the manufacturer that the stud is qualified as specified in the contract.
	d.	A copy of the qualification test report as certified by the testing laboratory.
4.	The studs, after welding, shall be free from any defect or substance which would interfere with their function.	
5.	Studs shall be end welded to steel with automatically timed stud welding equipment connected to a suitable power source.	
6.	If two or more stud welding guns are to be operated from the same power source, they shall be interlocked so that only one gun can operate at a time and so the power source has fully recovered from making one weld before another weld is started.	
7.	At the time of welding studs shall be free from any rust, rust pits, scale, oil or other deleterious matter which would effect the welding operation.	
8.	Welding shall not be done when the base metal temperature is below 0 degrees or when the surface is wet or exposed to rain or snow.	
9.	When necessary to obtain satisfactory welds, the areas on the beam or girder to which the studs are to be welded shall be brushed or ground free of mill scale or rust.	
10.	The arc shields or ferrules shall be kept dry. Any arc shield which shows signs of surface moisture from dew or rain shall be oven-dried at 250 degrees for two hours before use.	
11.	The first two studs welded on each beam or girder, after being allowed to cool to a temperature of 150 degrees or less, shall be bent 30 degrees by either striking the studs on the head with a hammer or placing a pipe or other suitable hollow device over the stud and manually or mechanically bending the stud.	
12.	When the temperature of the base metal is below 32 degrees, tow studs in each 100 studs welded, shall be bent in addition to the first two bent as specified in paragraph 11 above.	
13.	Studs on which a full 360 degree weld is not obtained shall be repaired by adding a 3/16 inch fillet weld in place of the lack of weld as ling as the repair weld extends 3/8 of an inch beyond the area on each end of where the lack of weld was. The shielded metal-arc process with 7018 or 8018 low hydrogen electrodes shall be used.	
14.	Longitudinal and lateral spacing of studs with respect to each other and to edges of the beam or girder flanges may vary a maximum of one inch from the location shown on the drawings. The clear distance between the studs shall not be less than one inch unless approved by the engineer. The minimum distance from the edge of the stud base to the edge of the flange shall be the diameter of the stud plus 1/8 inch, but preferably not less than 1-1/2 inch.	
15.	Prequalification. Studs which are field applied in the flat (down hand) position to a planar and horizontal surface are deemed prequalified by virtue of the manufacturer's stud-base qualification tests and no further application testing is required. The limit of flat position is defined as 0-15 degree slope on the surface to which the stud is applied.	

Table 708.02 Shear Connector Welder Qualifications	
1.	Before any production studs are welded by an operator, they must first shoot tow studs on a piece of material similar to the production member in thickness and properties. If the actual thickness is not available, the thickness may vary plus or minus 25%. All test studs shall be welded in the same general position as required on the production member.
2.	The test studs shall be visually examined. They shall exhibit a full 360-degree flash.
3.	In addition to the visual examination, the test shall consist of bending the studs after they are allowed to cool, to an angle of approximately 30 degrees from their original axes by either striking the studs on the head with a hammer or placing a pipe or other suitable hollow device over the stud and manually or mechanically bending the stud.
4.	If on visual examination the test studs do not exhibit 360 degree flash, or if on testing, failure occurs in the weld zone of either stud, the procedure shall be corrected, and two more studs shall be welded to separate material and tested again.
5.	If either of the second two studs fails, additional welding shall be continued on separate plates until two consecutive studs are tested and found to be satisfactory before any production welding begins.


WELDING SYMBOLS
STANDARD WELDING SYMBOL ELEMENT LOCATIONS
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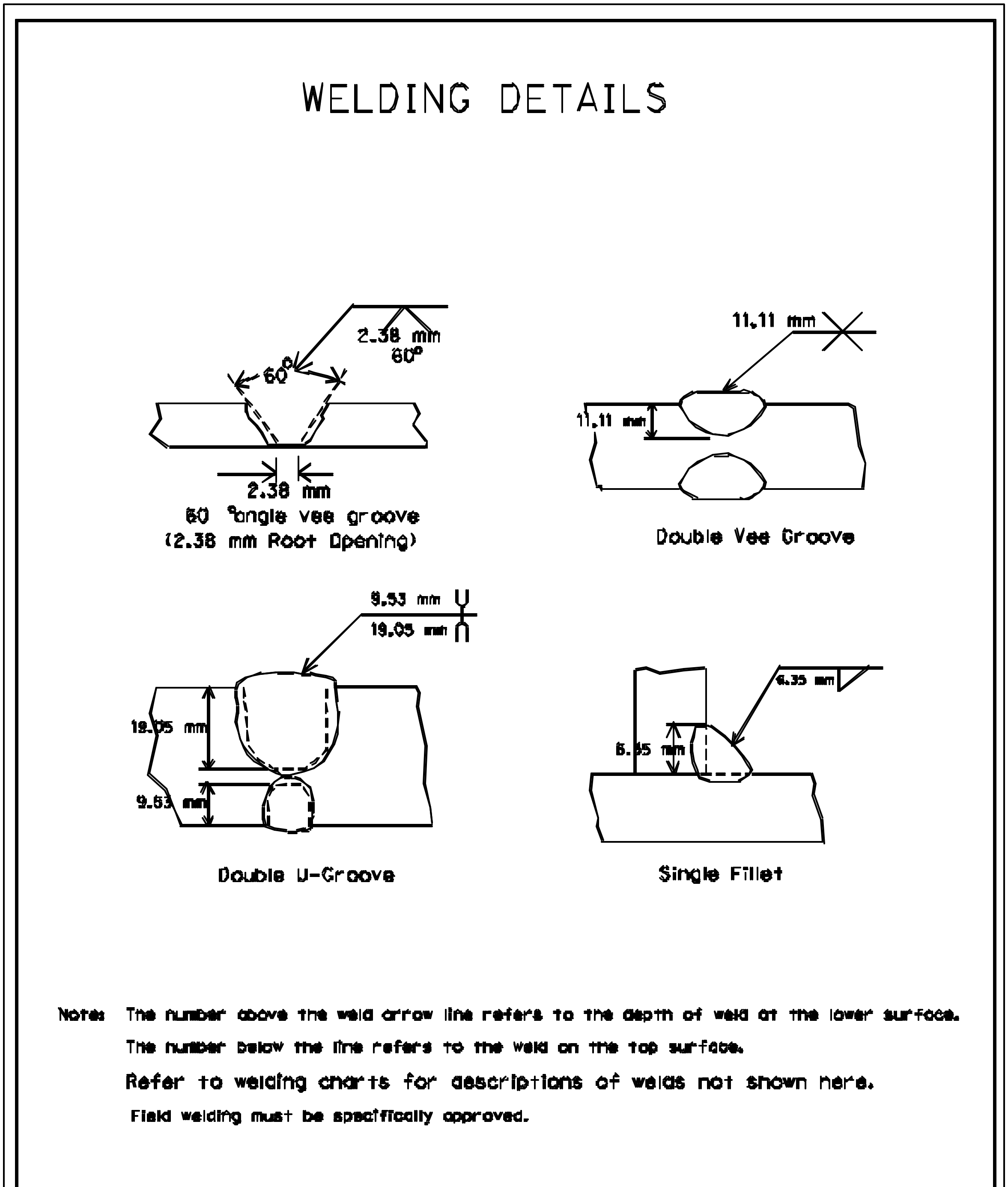

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I. Trouble Shooting

1. Many operating variables can affect the quality and appearance of the weld. Methods for correcting undesirable characteristics are discussed in the following paragraphs.

J. Weld Spatter

1. Spatter does not affect weld strength but does produce a poor appearance and increases cleaning costs.

   (a) Be sure to control excessive splatter. Try lowering the current. Be sure the current is within the recommended range for the and size electrode (see attached Table).

   (b) Be sure the polarity is correct for the electrode type.

   (c) Try a shorter arc length.

   (d) If the molten metal is running in front of the arc, change the electrode angle.

   (e) Watch for arc blow.

   (f) The electrode is not too wet.

K. Undercut

1. Generally, the only harm from undercutting is impaired appearance. However, undercutting may also impair weld strength, particularly when the weld is loaded in tension or subjected to fatigue. To minimize undercut:

   (a) Reduce current, travel speed, or electrode size until the puddle is manageable.

   (b) Change electrode angle so the arc force holds the metal in the corners. Use a uniform travel speed and avoid excessive weaving.

L. Rough Welding

1. If polarity and current are within the electrode manufacturer's recommendations but the arc action is rough and erratic, the electrodes may be wet. Try electrodes from a fresh container. If the problem occurs frequently, store open containers of electrodes in a heated cabinet.

M. Porosity and Surface Holes

1. Most porosity is not visible. But severe porosity can weaken the weld. The following practices minimize porosity:

   (a) Remove scale, rust, paint, moisture, or dirt from the joint. Generally use an E6010 or E6011 electrode for dirty steel.

   (b) Keep the puddle molten for a long time, so that gases may boil out before the metal freezes.

(c) Steels very low in carbon or manganese or those high in sulfur or phosphorus should be welded with a low-hydrogen electrode. Minimize admixture of base metal with weld metal by using low currents and fast travel speeds for less penetration.

(d) Try using a short arc length; short arcs are required for low-hydrogen electrodes.

2. Surface holes can be avoided by many of the practices used to minimize porosity.

N. Poor Fusion

1. Proper fusion exists when the weld bonds to both walls of the joint and forms a solid bead across the joint. Lack of fusion is often visible and must be avoided for a sound weld. To correct poor fusion:

(a) Try a higher current and a stringer-bead technique.

(b) Be sure the edges of the joint are clean, or use an E6010 or E6011 electrode.

(c) If gap is excessive, provide better fitup or use a weave technique to fill the gap.

O. Shallow Penetration

1. Penetration refers to the depth the weld enters into the base metal. For full-strength welds, penetration to the bottom of the joint is required. To overcome shallow penetration:

(a) Try higher currents or slower travel.

(b) Use small electrodes to reach into deep, narrow grooves.

(c) Allow some gap (free space) at the bottom of the joint.

P. Cracking

1. Many different types of cracks may occur throughout a weld. Some are visible and some are not. However, all cracks are potentially serious, because they can lead to complete failure of the weld. The following suggestions may help control potential cracking.

2. Most cracking is attributed to high-carbon or alloy content or high-sulfur content in the base metal. To control this type of cracking:

(a) Use low-hydrogen electrodes.

(b) Preheat. Use high preheat for heavier plate and rigid joints.

(c) Reduce penetration by using low currents and small electrodes. This reduces the amount of alloy added to the weld from melted base metal.

(d) To control crater cracking, fill each crater before breaking the arc. Use a back-stepping technique so as to end each weld on the crater of the previous weld.

3. On multiple-pass or fillet welds, be sure the first bead is of sufficient size and of flat or convex shape to resist cracking until the later beads can be added for support. To increase bead size, use slower travel speed, a short arc, or weld 5° uphill. Always continue welding while the plate is hot.

4. Rigid parts are more prone to cracking. If possible, weld toward the unrestrained ends. Leave a 1/32 inch (0.8 mm) gap between plates for free shrinkage movement as the weld cools. Peen each bead while is still hot to relieve stresses.

Q. How to Reduce Arc Blow

1. All arc blow is not detrimental. In fact, a small amount of arc blow can sometimes be used beneficially to help form the bead shape, control molten slag, and control penetration.

2. When arc blow is causing or contributing to such defects as undercut, inconsistent penetration, crooked beads, beads of irregular width, porosity, wavy beads, and excessive spatter, it must be controlled. Possible corrective measures have already been suggested in the preceding text. In general, here are some methods that might be considered:

   a. If DC current is being used with the shielded metal-arc process - especially at rates above 250 amperes - a change to AC current may eliminate problems.

   b. Hold as short an arc as possible to help the arc force counteract the arc blow.

   c. Reduce the welding current - which may require a reduction in arc speed.

   d. Angle the electrode with the work opposite the direction of arc blow.

   e. Make a heavy tack weld on both ends of the seam; apply frequent tack welds along the seam, especially if the fitup is not tight.

   f. Weld toward a heavy tack or toward a weld already made.

   g. Use a back-step welding technique.

   h. Weld away from the ground to reduce back blow; weld toward the ground to reduce forward blow.

   i. With processes where a heavy slag is involved, a small amount of back blow may be desirable; to get this, weld toward the ground.

   j. Wrap ground cable around the work piece and pass ground current through it in such a direction that the magnetic field set up will tend to neutralize the magnetic field causing the arc blow.

3. The direction of the arc blow can be observed with an open-arc process, but with the submerged arc process must be determined by the type of weld defect.

4. Back blow is indicated by the following:

   a. Spatter.

   b. Undercut, either continuous or intermittent.

   c. Narrow, high bead, usually with undercut.

   d. An increase in penetration.

   e. Surface porosity at the finish end of weld on sheet metal.

5. Forward blow is indicated by:

   a. A wide bead, irregular in width.

   b. Wavy bead.

   c. Undercut, usually intermittent.

   d. A decrease in penetration.

R. The Effects of Fixturing on Arc Blow

1. Steel fixtures for holding the work pieces may have an effect on the magnetic field around the arc and, thus, on arc blow. Usually, the fixturing causes no problem with stick-electrode welding when the current does not exceed 250 amperes. Fixtures for use with higher currents and with mechanized welding should be designed with precautions taken so that an arc-blow-promoting situation is not built into the fixture.

2. Each fixturing device may require special study to ascertain the best way to prevent the fixture from interfering deleteriously with the magnetic fields. The following are some points to note:

   a. Fabricate the fixture from low-carbon steel. This is to prevent the buildup of permanent magnetism in the fixture.

   b. Welding toward the closed end of "horn type" fixtures reduces back blow.

   c. Design the fixture long enough so that end tabs can be used if necessary.

   d. Do not use a copper strip inserted in a steel bar for a backing. The steel part of the backup bar will increase arc blow.

   e. Provide for continuous or close clamping of parts to be seam-welded. Wide, intermittent clamping may cause seams to gap between clamping points, resulting in arc blow over the gaps.

f. Do not build into the fixture large masses of steel on one side of the seam only. Counterbalance with a similar mass on the other side.

704.04 METHOD OF MEASUREMENT

A. Structural steel is usually measured by the pound (kg). Structural steel for handrail is also measured by the pound. Ornamental handrails are measured by the lineal feet of rail between end posts. These values are listed on the plans and may be used in the final computation for payment.

704.05 BASIS OF PAYMENT

A. PMs are authorized to pay for steel plates and shapes as soon as the material arrives at the fabricator.

B. The Nebraska Department of Roads had determined that it may be possible to improve inspection procedures and to lower construction costs on bridges and other structures where significant quantities of steel are required if stockpiled materials are paid for upon receipt by the fabricator. Therefore, the Department will allow partial payments for stockpiled steel plates and shapes prior to fabrication. The procedure that must be followed before partial payment will be made is as follows:

1. The prime contractor must request partial payment from the Department's Project Manager for the specific project where payment is requested.

2. The Bridge Divisions, Fabrication Inspector [(402)-479-4763] will be responsible for verifying fabricators' invoices and forwarding them to the project managers; for verifying manufacturer's Certified Mill Test Report and forwarding copies to the PM and M&R Division; and for inspection of the steel.

3. The fabricator must provide the Department's Fabrication Inspector the steel manufacturer's paid invoice for the material. The Project Manager will make the payment for the amount shown on the invoice, which directly is attributed to the project for which payment is being considered. The invoice should be annotated to show:

   (a) the project number

   (b) steel quantity in pounds applicable to the project

   (c) material grade

   (d) material heat number

4. There must be identifying marks placed on each piece for which payment will be made.

5. Steel must be stored in orderly fashion to readily facilitate identification of specific materials to specific projects. Project materials cannot be commingled with other projects – each project's materials must have a separate location.

6. The Manufacturer's Certified Mill Test Reports must be provided to and approved by the Bridge Division before payment will be authorized. The Bridge Division will notify the Project Manager when payment is authorized.

7. The Department will verify that the material is properly stored before payment will be made.

8. The Prime Contractor will make payment to the fabricator within 20 days after the Department has paid for the material.

9. Payment is only authorized for materials that are stored within Nebraska as specified in Subsection 109.07 of the Nebraska *Standard Specifications for Highway Construction*.

705.00 REINFORCEMENT (*SSHC Section 707*)

705.01 DESCRIPTION

A. The reinforcement of concrete for structures consists of furnishing and placing deformed metal reinforcing bars or welded-wire fabric in the concrete as required by the plans and specifications.

705.02 MATERIAL REQUIREMENTS (*SSHC Subsection 707.02*)

A. Samples of reinforcing steel and welded-wire fabric are required by the Central Laboratory unless these materials are shipped from tested stock. Generally reinforcing steel has been sampled and tested before shipment to the project, and will arrive with acceptance tags attached. At the time this steel is placed in the work, the structure inspector should collect, record in field book, and submit the tags to the Project Manager. Steel arriving untagged should not be incorporated in the work until approved by the Materials Engineer. See the "*Materials Sampling Guide*".

B. The Materials and Research Division requires that two 6 ft (2.0 m) sample lengths of epoxy-coated reinforcing steel be submitted for testing purposes, and a special provision to that effect will be included in future contracts.

C. Similarly, the *Materials Sampling Guide* requires two 6 ft (2.0 m) sample lengths for uncoated reinforcement bars be provided (unless shipped from tested and approved stock). Enter the date resteel is verified on-site in SiteManager.

705.03 CONSTRUCTION METHODS (*SSHC Subsection 707.03*)

A. Placement and Checking (Bridge Deck)

1. Bridge plans specify nominal slab thickness and nominal clearance of reinforcing bars from face of the concrete. This section will establish acceptable deviations from nominal plan dimensions.

2. Four dimensions must be given special attention when checking placement of bridge slab reinforcing:

   (a) Slab thickness.

   (b) Clearance of bottom reinforcement from bottom of slab.

   (c) Distance from bottom of slab to top of top mat of reinforcement.

   (d) Cover over top mat of reinforcement

B. Slab Thickness

1. This shall be the nominal slab thickness shown on the plans with a tolerance of minus zero and plus ½ inch (13 mm).

C. Clearance of Slab Reinforcement

1. The reinforcing steel shall be placed to monitor the nominal clearances shown in the plans ± ¼ inch (5 mm). Contractors must provide an adequate number of bolsters and/or bar chairs of suitable height and strength to maintain clearance within this range.

2. Contractors must provide an adequate (sag shall be minimal, see *SSHC Figure 707.01*) number of bar chairs of suitable height and strength to maintain the distance within this range of tolerance.

D. Protection of Material (*SSHC Subsection 707.03*)

1. The Specifications provide that steel reinforcement shall be protected at all times from damage. When placed in the work, it shall be free of dirt, loose scale, detrimental rust, paint, oil or any foreign material. Detrimental rust is defined as heavy reddish coating formed on iron or steel when chemically attached by moist air. This must be removed by wire brushing. However, a light layer of rust or mill scale that is not readily removed with a wire brush is acceptable.

E. Placing and Fastening (*SSHC Subsection 707.03*)

1. Positioning - It is essential that inspectors give special attention to the placement of reinforcing steel in all structures. Reinforcement shall be placed in the exact position shown in the plans and held securely in that position to preclude movement or shifting during placement of the concrete. On a 7 inch (175 mm) thick bridge floor, designed with the top steel 1 ¾ inch (45 mm) below the surface, a sag or displacement in the top steel of only ½ inch (13 mm) will reduce the strength of the floor 19 percent. The reduction in strength of thinner sections such as culvert slabs and walls is even more critical.

2. Present policy is to tie all bar intersections except when the bar spacing is less than 12 inches (300 mm) in both directions in which case alternate intersections may be tied. This requirement is enforceable through *SSHC Subsection 707.03* in that it specifically defines the frequency of tieing. The Project Manager should thoroughly study the project documents in order to be aware of this requirement as well as any change which might occur in this revision.

3. Horizontal reinforcement in slabs shall be spaced vertically by means of approved metal chairs. The type and adequacy of bar support systems which includes the spacing of bar supports shall be in accordance with the Concrete Reinforcing Steel Institute's "Manual of Standard Practice", unless other stipulations are provided in the contract provisions. A copy of this manual may be obtained from the District Construction Engineer. Bar supports which are located at exposed concrete surfaces shall be galvanized, plastic coated or stainless steel to a depth of ½ inch (13 mm) minimum from the concrete surface. Chairs may also be used to keep vertical columns and wall steel from contacting the form.

4. Field welding will be permitted only when shown on the plans or with written permission of the Construction Engineer. Reinforcement can best be checked as the work progresses rather than waiting until the contractor has enclosed the reinforcement with forms. In the case of walls and columns it is virtually impossible to do the checking after the forms are in place. When bent bars are used, a check should be made that there are no cracks or splits at the bends. Stirrup hooks should be rotated to different positions in order that the hooks do not fall in the same location when a series of stirrups are used in beams or columns.

5. No welding will be allowed on the main vertical steel of high mast lighting tower foundations except at the very top and bottom where the end loops may be tack welded. If a more rigid cage is desired, additional vertical steel will be required to act as the frame and lifting points for the cage. The required loops may be tack welded to this additional vertical steel. The required vertical steel will then need to be wire tied to the tack welded loops.

6. Welding of all loops, other than the top and bottom loop, to the required vertical steel will not be allowed. Additional bracing may be tack welded to the added vertical bars, if required. The added vertical bars should be sized to support the required load.

7. *SSHC Subsection 704.03* requires the contractor to give the Project Manager sufficient advance notice before starting concrete operations in any unit of a structure, to permit the inspection of forms and reinforcing bars. The Project Manager shall require all reinforcing steel to be accurately placed and firmly held in position.

F. Special Attention Areas

1. Tie-Downs and Supports

   a. *SSHC Subsection 707.03* require that the top mat of reinforcing steel is to be tied down at not greater than 4 feet (1.2 m) spacing measured in each direction. This requirement can partially be met by wiring the top mat down to shear lugs at 4 feet (1.2 m) spacing along the beam. Regardless of beam spacing, the top mat must be tied to the forms or the bottom reinforcing mat at 4 feet (1.2 m) spacing. Likewise, the top reinforcing mat is to be tied to the bottom reinforcing mat on a 4 feet (1.2 m) grid in floors of concrete slab bridges. Tying should include bars near the ends of the bridge and bars near the curbs. **At least 50 percent of the bar contacts must be tied unless the spacing is more than 1 ft (300 mm) and then every bar contact must be tied.**

2. Epoxy Coated Bar

   a. Epoxy coated reinforcing steel requires the use of epoxy or plastic coated bar supports and tie wires (*SSHC Subsection 707.03*). Epoxy coated tie wires may tend to slide or break. If this occurs, they should be double tied or stronger ties used.

3. Clearance Check

   b. The specified clear distance from surface to reinforcing steel must be maintained. To check this, a clearance guide ¼ inch (5 mm) less in thickness than the specified clearance to top steel should be temporarily fastened to the bottom of the finishing machine screed. The finishing machine should then be operated along the bridge to insure that proper clearance is obtained. It will be necessary to bend all tie wire loops down to permit the clearance gauge to pass. Any steel not properly placed must be corrected.

4. Checks During Placement

   a. Checks of slab thickness and cover over top reinforcement must be made in the finished concrete directly behind the finish machine. A thickness and cover check should be made at the same location of an approximate grid of 10 ft (3 m) transverse and 20 ft (6 m) longitudinal. These checks must be documented in the field book. When the slab is of deficient thickness or cover checks indicate incorrect rebar placement corrections must be made immediately.

5. Cleaning Forms and Steel

   a. Mud and other foreign material must be removed from the steel and forms prior to placement. Remove any trapped/ponded water before placing the concrete.

G. Epoxy-Coated Reinforcement (*SSHC Section 1021*)

1. Epoxy coatings are applied to reinforcing bars by a fusion-bonded process. This means the coating achieves adhesion to the bar as a result of a heat-catalyzed reaction. Besides chemical adhesion, there is also physical adhesion of the coating to the bar.

H. Care and Handling

1. Epoxy coated bars are subjected to many quality control tests and inspections prior to leaving the supplier's facility. However, from that point forward, careless handling and construction practices can cause excessive coating damage. Contractors should be strongly encouraged to exercise care in handling, storage, and placing of epoxy coated bars. If problems are noted after delivery, the inspector is to contact the Materials and Research Division.

2. Handling

   a. During unloading epoxy coated bars from the truck, care must be exercised to minimize scraping of the bundles or bar-to-bar abrasion from sags in the bundles. Skidding bundles from the truck onto the ground should not be allowed. Use of power hoisting equipment for unloading and handling is strongly encouraged. Further, equipment for handling the bars should have protective contact areas. Specifically, nylon slings or padded wire rope slings should be used and bundles should be lifted at multiple pick-points.

3. Storage

   a. Epoxy coated bars should be stored on timbers or other suitable protective cribbing. All types of reinforcing bars should be stored off the ground as close as possible to the area where they will be used. The following storage practices are suggested to prevent damage:

   b. Store bars above the ground on timbers, cribbing, or dunnage placed close enough together to prevent sags in the bundles.

   c. If a large quantity of bars has to be stored in a small area, bundles can be stacked if adequate blocking is placed between the layers.

   d. While fading of the coating's color is not specifically detrimental, it should be avoided to the fullest extent possible. One recommended method is to cover exposed bundles with burlap or dark plastic.

NOTE: If plastic or other nonporous material is used for covering, the ends must be left open to allow air movement. Without this, condensation under the cover could cause damage.

   e. Long-term site storage (from one year to the next) of epoxy coated bars is not recommended.

4. Placing

   a. Placing of epoxy coated bars is done similar to uncoated bars. The KEY exception is that coated bars require more careful handling and placing. Once bundles have been opened, dragging one bar over another or over any abrasive surface MUST be avoided.

   b. After epoxy coated bars are placed, walking on the bars by construction personnel should be held to a minimum. Bars in high traffic areas or runways for concrete placement should be protected with plywood or other suitable material. Concrete placement equipment shall not be placed on, or supported by, any reinforcing steel.

   c. Bar supports and tie wires for epoxy coated reinforcement shall be coated with epoxy, nylon, or plastic.

I. Field Inspection

1. Epoxy coated bars should be inspected for damaged coating:

   a. when received at the job site, and

   b. after they are placed in the structure.

2. Damage Evaluation and Repair

   a. Damaged coating shall be evaluated as outlined below. The "holiday detector" should be used to determine coating flaws.

   b. Bent Bars

      (1) Examination of physical coating condition on the outside radii of hooks and other bends might reveal cracks in the coating. When cracking of the coating is evident, the contractor must remove loose coating, clean the area, and repair.

   c. Fading of Color

      (1) When epoxy coated bars are exposed to sunlight over a period of time, fading of the color may occur. Since discoloration does not harm the coating nor affect its corrosion protection properties, such fading will not be cause for rejection.

   d. Damaged Ends

      (1) Damage to ends because of field shearing, dragging or whatever must be repaired in the field.

J. Repair of Damaged Coating

1. When a damaged coating must be repaired, the patching or touch-up material should be applied in strict accordance with the instructions furnished by the manufacturer. Generally, surface preparation consists of a **THOROUGH** manual cleaning of damaged areas, including complete removal of: (1) unbonded epoxy and (2) all rust. Cleaning is usually accomplished with a power driven wire brush, hand steel brush, and/or emery paper. Care should be exercised during preparation so that excessive sound epoxy is not damaged. Acceptance criteria for epoxy repair and touchup materials is in accordance with the original epoxy resin manufacturer's recommendations.

2. Epoxy coated reinforcing steel is used in concrete bridge decks to prevent spalling of the concrete which is, in turn, caused by the corrosion of the reinforcing steel. The epoxy coating prevents the corrosion of the reinforcing steel. Two factors influence the capability of the coating to prevent corrosion. One of these factors is the thickness of the coating. The other factor is the integrity of the coating, i.e., the absence or presence of defects in the coating which would allow moisture and de-icing chemicals to reach the metal itself.

3. The epoxy coating on the rebars may have three types of defects when the bars arrive at the site. One of these is defined in the Specifications as a "holiday." A holiday is a small hole in the coating which is not visible to the naked eye. This type of defect is the result of some inadequacy in the application process. Holidays can be detected only with an electronic detector and the Specifications permit two holidays per 1 foot (300 mm).

4. The second type of defect, which may be present in the epoxy coating when the bar arrives at the site, is defined as handling damage. Handling damage may take the form of scuffs, scars, scratches or any other wound to the coating caused by rough handling. The Specifications permit a "reasonable" amount of handling damage. Handling damage is generally visible to the naked eye since rust will form over the damaged spot after a sufficient amount of time passes. A fresh cut or scar in the coating would probably be difficult to locate visually, but would be readily picked up with an electronic detector.

5. The third type of defect, which may be present in the epoxy coating when the bar arrives at the site, is due to what may be considered as an "uncoatable" bar. During the rolling process, some bars are formed with very sharp edges on the deformations and ribs.

6. These edges are very difficult to coat adequately, and coating applicators usually avoid coating bars so formed. The defect in coating on these edges may or may not be visible to the naked eye. This particular defect can be detected with an electronic detector. When this defect is present, the detector will indicate this flaw by a constant 'beeping' when run along a rib. In most instances, the thickness of the epoxy coating will be very low in these areas or there may be no coating at all where the sharp edges are present.

7. Materials and Research Division personnel will inspect epoxy coated rebars at the coating applicator's plant in some, but not, all cases. In cases where inspection is made at the applicator's plant, the bars will have a maximum of two holidays per meter, plus handling damage, is allowed, when they arrive at the site. In addition, the coating thickness, on bars inspected at the applicator's plant, must meet the specification requirements for thickness of coating. Bars not so inspected at the applicator's plant will have an unknown number of holidays and possibly uncoated sharp edges plus handling damage when they arrive at the site and, in addition, the coating thickness will not have been checked. Bars that contain rolling defects or have uncoated sharp edges that are found during the inspection shall be rejected.

8. The basis for acceptance will be the total of defects per 1 foot (300 mm) of bar, i.e., holidays plus handling defects as located with the electronic detector.

9. A total of six defects in any 1 foot (300 mm) of the bar will be permitted. As an example, in a bar of given length, if any 1 foot (300 mm) section of that bar has no more than the two allowable holidays and four handling defects, the bar is acceptable, providing none of the four handling defects has an area greater than 0.0025 $ft.^2$ (225 mm^2). [A square measuring 0.05 ft x 0.05 ft (15 mm x 15 mm) has an area of 0.0025 $ft.^2$ (225 mm^2)]. All handling defects having an area greater than 225 mm^2 must be repaired.

10. The following points may be helpful in the inspection and repair of epoxy coated rebars in the field.

    a. Inspect bars for coating defects, using the electronic detector, as they come out of the bundle.

b. It may not be necessary to check all bars in each bundle, but enough bars out of each bundle should be checked in order to determine the quality of coating on all bars in the bundle.

c. When the number of defects per 1 foot (300 mm) section exceeds six, only the number of defects necessary to bring the bar into compliance need be repaired. Only exception is that all defects greater than .00005 in^2 (.035 mm^2) must be repaired.

d. Repair of defects is accomplished with an approved two component epoxy compound supplied by the coating manufacturer.

e. Epoxy compounds used for repair have a minimum temperature at which they may be used and a limited pot life, as recommended by the manufacturer.

f. Any rust showing through the defect must be removed before applying the epoxy compound. A file or grinding wheel may be used provided no substantial reduction in the area of the bar occurs.

g. Coating thickness of the painted repair area must be as specified for the factory applied coating.

h. Coating on bars may be damaged during placement at the site. Such damage to the bars must be repaired when the bars are in place, if the six defects per 1 foot (300 mm) section limitation is exceeded.

i. Check coating thickness if bars were not inspected at the coating applicator's plant. This should be done as they come out of the bundle. Coating thickness is checked with a magnetic thickness gage.

j. To obtain a holiday detector, contact the nearest branch laboratory or the Construction Division. "Electometer" magnetic thickness gages may be obtained by requisition from the Engineering Equipment Section, "Inspector" or "Microtest" thickness gages which are used for checking paint film thickness cannot be used for checking epoxy coating thickness on reinforcing steel.

11. For situations where there is no information available as to what type of touch-up material should be used, 3M Corporation has two products available:

a. SCOTCHKOTE 213 is often used to repair minor nicks and gouges.

b. SCOTCHKOTE 312 is a two component epoxy that has been used to repair both small and large areas of damage.

NOTE: Repaired areas do not have as much corrosion or abrasion resistance as factory-applied coatings.

K. Bar Designation System

1. You must be very careful when you review a bar list. Currently, steel bar in the USA is usually measured in English units. Do not assume anything; measure to be sure you are getting the correct size. In general, the mark number for reinforcing bars as shown in the plans generally uses the following designation system. The first letter or letters identify the general location of the bar such as abutment, pier, or slab bar.

Location	Code
Abutment	A
Pier	P
Slab	S

2. The first number or numbers indicate the size of the bar and the last two numbers indicate whether the bar is bent or straight. (Even numbers are straight bars and odd numbers are bent bars.)

3. For example, P1002 would be a straight No. 10 bar located in the pier; A415 would be a bent No. 4 bar located in the abutment. The last two numbers also indicate the approximate length of the bar. The lower the number the longer the bar; for example, a S602 bar would indicate the longest, straight, No. 6 bar used in the slab, whereas a S612 bar would indicate that there are five groups of straight, No. 6 bars that are longer than the S612 in the slab. The reinforcing steel table in *Appendix 4* lists pertinent information concerning the standard bar designation system.

L. Splicing

1. All reinforcement shall be furnished in the full lengths indicated in the plans. Splices, not shown in the plan, shall not be allowed without approval of the Project Manager. Welding shall be allowed only if shown in the plans or authorized by the Construction Engineer in writing.

2. When splices are required, they should be staggered as far as possible in order that a plane of weakness is not caused in the member. The laps should be at least as long as is shown in the plans and if no lap is shown, the bars should be lapped as required in *SSHC Subsection 707.03*. Splices should preferably be made in areas of low stress concentration. The bars in the top of a slab or beam should be spliced in a positive moment section (bottom of slab or beam in tension) and the bars in the bottom of a slab or beam should be spliced in a negative moment section (top of slab or beam in tension). For example, the longitudinal bars in the top of a slab should be spliced near the center of the span rather than over a pier and the longitudinal bars in the bottom of the slab should be spliced near the pier rather than in the middle of a span. Following is a tabulation of 24 and 36 diameter lap requirements for the various sizes of rebars.

ASTM Standard Reinforcing Bars				
		Nominal Dimensions - Round Sections		
Bar Size Designation	Weight Pounds per Foot	Diameter Inches	Cross-Sectional Area - Sq. Inches	Perimeter Inches
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.650	1.693	2.25	5.320
#18	13.600	2.257	4.00	7.090

LAP REQUIREMENTS			
Metric Bar Size	English Bar Size	24 Diameter Lap Grade 40 Steel	36 Diameter Lap Grade 60 Steel
10	2	6 in (150 mm)	9 in (225 mm)
10	3	9 in (225 mm)	14 in (350 mm)
10	4	12 in (300 mm)	18 in (450 mm)
15	5	15 in (375 mm)	23 in (575 mm)
15	6	18 in (450 mm)	27 in (675 mm)
25	7	21 in (525 mm)	32 in (800 mm)
25	8	24 in (600 mm)	36 in (900 mm)
30	9	27 in (675 mm)	41 in (1025 mm)
30	10	30 in (750 mm)	44 in (1100 mm)
35	11	33 in (825 mm)	49 in (1225 mm)

3. There are times when splicing of rebar in a manner other than lapping is necessary. Examples include:

   a. Complicated placement where the cage could be tied off site, in sections, and set in place.

   b. Reinforcement cages for drilled shafts.

   c. Situations where an existing rebar is not long enough to develop strengths by lapping.

4. Example: During removal of an existing curb on a bridge deck widening project existing rebar is either cut with the saw or broken during concrete demolition. In this case additional demolition is needed to provide a lap development length.

5. Mechanical splices are only authorized where shown in the plans and materials must be in the NDR Approved Products List. Currently, several couplers are manufactured which can be used to mechanically splice rebar. Mechanical splices, for field approval, shall develop 125% of the rebar's yield strength. Consideration for splice usage must be initiated by the contractor. The Project Manager is to forward that request to the Construction Division for review.

705.04 METHOD OF MEASUREMENT (*SSHC Subsection 707.04*)

A. Reinforcing steel for concrete structures is measured by the pound. Quantities to be paid for are computed from the theoretical mass of bars and wire mesh. The mass of steel reinforcement required for structures of varying sizes is usually given in tables on standard and special plans. The quantities contained therein may be used for computing final payment for structures except bridges. Plan quantity may be used for final quantity reinforcing steel for bridges.

706.00 CONCRETE CONSTRUCTION (*SSHC Section 704)*

706.01 DESCRIPTION

A. This section of the Specifications deals with the construction of structures composed of portland cement concrete. This work includes constructing, setting and supporting the forms, and handling, placing, finishing and curing the concrete for bridges, box culverts, arch culverts, headwalls, retaining walls and steps, and the miscellaneous structures listed in the incidental construction portion of the Specifications.

706.02 MATERIAL REQUIREMENTS

A. Composition of Concrete

1. The class of concrete to be used in the work is specified in the plans or special provisions and shall be one of those described in *SSHC Subsection 1002.02*. In the event that the contractor has a choice of several classes, he/she is required to advise the Project Manager by letter of the one to be used. This information should be obtained prior to any concrete construction to allow engineering personnel to make provisions for necessary inspection and testing. The contractor may not change classes of concrete during construction without the written permission of the Project Manager.

2. *SSHC Subsection 1002.03* prescribes requirements for concrete materials. The Contractor’s responsibility for material requirements may be summarized as follows:

   a. Check with Materials & Research as to the approval of cement, coarse aggregate, fine aggregate, air-entraining agent and curing compound.

   b. Submit samples of non-approved materials to the Central Testing Laboratory in sufficient time before use to allow time to receive results. The size and frequency of samples are provided in the "*Materials Sampling Guide*".

   c. Materials for which approval has not been received must not be used in the work.

3. The inspector is concerned not only with the approval of materials but also with the storage of materials. Bag cement shall be stored in a dry location. If stacked more than 8 bags high for a period of time the lower layers take on a "warehouse set" and should not be used. Cement stored over 90 days must be retested before use.

B. Admixtures

1. Admixtures are those ingredients in concrete other than portland cement, water, and aggregates, that are added to the mixture immediately before or during mixing. Admixtures typically encountered on our jobs can be classified by function as follows:

   a. Air entraining admixtures (optional)

   b. Water reducing admixtures (optional)

c. Set retarding admixtures (required)

d. Set accelerating admixtures (optional)

e. Finely divided and permeability mineral admixtures (Fly Ash & Silica Fume) (optional)

f. Coloring agents (normally not used for NDR work) (optional)

2. The amount of any admixture used in a mix should be as recommended by the manufacturer. Effectiveness of an admixture depends upon such factors as type, brand, and amount of cement; water content; aggregate shape; gradation and proportions; mixing time; slump; and temperatures of concrete and air.

3. Concrete with a low air content shall not be incorporated into work. One addition of air entraining admixture is allowed at the site according to specification.

4. Concrete with a high air content should not be incorporated into work except under extreme circumstances. If low compressive strengths result, the concrete may be required to be removed and replaced. (*SSHC Subsection 106.05*)

C. Air Entraining Admixtures

1. Air entraining admixtures are used to purposely entrain microscopic air bubbles in concrete. Air entrainment will dramatically improve the durability of concrete exposed to moisture during cycles of freezing and thawing. Entrained air greatly improves concrete's resistance to surface scaling caused by chemical deicers.

2. Rules-of-Thumb

a. As cement content increases, air agent must increase to maintain equal entrained air.

b. As cement fineness increases, the amount of air agent must increase to maintain equal entrained air.

c. As coarse aggregate size decreases, the air content increases for a given amount of air agent.

d. As fine aggregate volume increases, the air content increases for a given amount of air agent.

e. As mixing water increases, the air content increases for a given amount of air agent.

f. Air entraining admixtures should be introduced into mix at the plant, but additional may be added at the site to adjust mix for correct air content.

g. Air entraining admixtures should (usually) be added to the front of the truck at the plant. If corrosion inhibiting admixture is used, air entraining agents should be added to the back of the truck.

D. Water Reducing Admixtures (Type A) (optional)

1. Water reducing admixtures are used to reduce the quantity of mixing water required to produce concrete of a certain slump or reduce the water/cement ratio. Regular water reducers reduce water content by about 5% to 10%.

2. Adding a water reducing admixture to a mix without reducing water content can produce a mixture with a much higher slump.

   a. Rules-of-Thumb

      (1) Typically, water reducing admixtures do not reduce the rate of slump loss; in most cases, it is increased. Rapid slump loss results in reduced workability and less time to place concrete at the higher slump.

      (2) Typically, water reducing admixtures decrease on bleed water because less water is available.

      (3) Certain types of sulfate starved portland cements may cause false set with certain brands of water reducers. Typically, water reducers contain lignosulfonates and these sulfates are easily attracted by sulfate starved cements. This action may cause early false set.

      (4) Despite reduction in water content, water reducing admixtures can cause a significant increase in drying shrinkage.

E. High Range Water Reducing Admixtures (Type F) (optional)

1. They are added to concrete with low-to-normal slump and water content to make high slump "flowable" concrete. Flowable concrete is a highly fluid, but workable concrete that can be placed with little or no vibration and can still be free of excessive bleeding or segregation. Flowable concrete has applications:

   a. In areas of closely spaced and congested reinforcing steel.

   b. In tremied concrete where "self consolidation" is desirable.

   c. In pumped concrete to reduce pump pressure.

   d. To produce low water/cement ratio - high strength concrete. High-range "super plasticizers" can reduce water content by about 12% to 30%.

2. Rules-of-Thumb

   a. The effect of most super plasticizers in increasing workability or flowable concrete is short lived. Typically, maximum is 30 to 60 minutes followed by a very rapid loss in workability.

b. Typically, super plasticizers are added as split treatments (part at the plant part at the site). Sometimes the addition is totally at the site.

c. Setting time may be affected depending on the brand used, dosage rate, and interaction with other admixtures.

d. Excessively high slumps of 10 inches (250 mm) or more may cause segregation.

e. High-slump, low water/cement super plasticized concrete has less dry-shrinkage than does high-slump high water/cement conventional concrete.

f. Effectiveness of super plasticizer is increased with an increased amount of cement and/or increased fineness of cement.

g. Effectiveness of water reducers on concrete is a function of their chemical composition, cement composition and fineness, cement content concrete temperature, and other admixtures being used.

h. Some water reducing admixtures, such as lignosulfonates, may also entrain some air in the mix.

F. Retarding Admixtures (required)

1. Retarding admixtures (retarders) are used to delay the initial set of concrete. High temperatures of fresh concrete 85°F (30°C) and up often cause an increased rate of hardening. Since retarders do not decrease the initial temperature of concrete, other methods of counteracting the effect of temperature must be used.

2. Rules-of-Thumb

a. Retarders are sometimes used to delay initial set of concrete when difficult, long placement times, or unusual placement conditions exist.

b. Retarders offset the set acceleration effect of hot weather.

c. Retarders can be added at the site.

d. In general, some reduction in strength at early ages (one to two days) accompanies the use of retarders.

e. Use of retarders must be closely monitored, because there is probably no single admixture which has caused more field problems.

f. If too much retarder has been used in a mix:

(1) Time will usually counter the effects.

(2) Be sure to maintain the cure during the added time.

G. Accelerating Admixtures (optional)

1. Accelerating admixtures (accelerators) are used to accelerate the setting time and strength development of concrete at an early age. Strength development can also be accelerated by using:

   a. Type III "high-early" cement

   b. Lowering water/cement ratio

   c. Curing at controlled higher temperatures

2. Calcium Chloride ($CaCl_2$) is the material most commonly used in accelerating admixtures. Besides accelerating strength gain, calcium chloride also causes an increase in drying shrinkage, potential reinforcement corrosion, discoloration, and potential scaling.

   a. Rules-of-Thumb

      (1) Always add calcium chloride in solution form as part of the mixing water.

      (2) Calcium chloride is not an antifreeze agent. When used in allowable amounts, it will only reduce the freezing point of concrete by a few degrees (may cause deck cracks).

H. Finely Divided Mineral Admixtures

1. These admixtures are powdered or pulverized materials added to concrete to improve or change the properties (plastic or hardened) of concrete. Based on the mineral's chemical or physical properties, they are classified as: (1) Cementitious, (2) Pozzolans, (3) Pozzolanic and Cementitious, and (4) Nominally inert. Typical PCC mix designs use pozzolanic and cementitious minerals.

2. Pozzolanic Materials

   a. A pozzolan is a siliceous or aluminosiliceous material that in itself possesses little or no cementitious value but will, in finely divided form and in the presence of water, chemically react with the calcium hydroxide released by the hydration of portland cement to form compounds possessing cementitious properties. Pozzolans include fly ash and silica fume.

3. Fly Ash (Class C & F)

   a. Fly ash is a finely divided residue that results from the combustion of pulverized coal in electric power plants.

4. Silica Fume

   a. Silica fume, also referred to as micro-silica or condensed silica fume, is another material that is used as a pozzolanic admixture. This light to dark gray powdery product is a result of the reduction of high-purity quartz with coal in an electric arc furnace.

b. Fly ash and silica fume have a spherical shape. Silica fume has an extremely small particle size (about 100 times smaller than the average cement particle). Although silica fume is normally in powder form, because of its small size and increased ease of handling the product is commonly available in liquid form.

c. Rules-of-Thumb

(1) Mixes containing fly ash will generally require less water (about 1% to 10%) for a given slump. Silica fume concrete requires more water for a given slump.

(2) The amount of air-entraining admixture required to obtain a specified air content is normally greater when fly ash or silica fume is used. The amount of air-entraining admixture for a certain air content is a function of the fineness, carbon content and alkali content.

(3) Fly ash will generally improve the workability of concretes of equal slump. However, fly ash in low slump concrete will tend to tear and have reduced workability. Silica fume tends to reduce workability, thus high-range water reducers are usually added to maintain workability.

(4) Concrete using fly ash or silica fume generally shows less segregation and bleeding than plain concrete.

(5) Use of fly ash will reduce the amount of heat buildup in concrete. Silica fume most likely will not reduce the heat of hydration, because typically high-range water reducers are used and they increase mass temperatures.

(6) Use of fly ash will tend to generally retard the setting time of concrete. Silica fume alone will accelerate the setting time, however, high-range water reducers tend to offset this.

(7) Use of fly ash generally aids the pumpability of concrete. With adequate and correct curing, fly ash generally reduces the permeability. Silica fume is especially effective in this regard.

(8) With adequate and correct curing, fly ash generally reduces for permeability. Silica fume is especially effective in this regard.

I. Concrete Temperatures

1. Recommended Concrete Temperatures

   a. Concrete should be between 45°F and 80°F (7°C and 27°C) when placed. To ensure a concrete temperature of at least 50°F (10°C) for 72 hours after placement the concrete for thin sections such as culvert walls, end posts, piling encasements, etc. should be 65°F (18°C) or higher, since the only additional heat source is the heat of hydration. Concrete for massive sections such as abutments, heavy piers, and footings should be in the 55° to 65°F (13° to 18°C) range.

   b. Since only dry insulation is effective, any insulation that has a propensity to absorb water or become saturated must be protected with a waterproof membrane. The insulation system must provide complete coverage and be secured to provide maximum protection during the full curing period.

   c. For typical protection applications, insulated forms must be left undisturbed for 96 hours before being removed.

2. Checking Temperature of Concrete

   a. For checking compliance with minimum temperature requirements during the 48-hour period after placement thermometer wells should be cast in the concrete during the pour. The following procedure for checking temperature is suggested:

      (1) Drill a 5/16 inch (8 mm) hole through the form at one or more locations where temperature checks will be made.

      (2) Grease the thermometer probe and insert it through the hole about 4 inches (100 mm) into the plastic concrete.

      (3) Remove probe after the concrete is set and cover hole with insulating material.

      (4) Further checks can be made by inserting the thermometer through the insulation into the well developed in step 2. Leave thermometer in place if desired, but protect from damage or theft.

NOTE: The thermometer stem should be inserted about 3 inches (75 mm) into the concrete because the sensitive portion of the stem is about 1¾ inch (44 mm) below the groove.

   b. Record the temperature daily for 5 days following the pour. Temperature readings below 50ºF (10°C) during the first 48 hours should be entered in the Field Book and reported to the District Construction Engineer for evaluation of possible damage or price adjustment.

   c. A thermocouple - - with recorder can also be used to document temperatures during curing.

3. Deck Concrete Temperature and Curing

   a. Subsection 706.03 identifies requirements for placing and curing concrete bridge floors. Of importance for this section are:

      (1) Plastic concrete, when placed, shall not exceed 86°F (30°C).

      (2) The curing method requires "wet" burlap cure for four (4) days.

      (3) If the forecast high outside air temperature for the day is predicted to be above 80°F (26°C) the contractor should cast the deck starting at 5:00pm.

   b. The placing of concrete will require close monitoring to comply with the specifications. Obtain a weather report to determine predicted air temperature, wind velocity, and relative humidity for the pour day.

   c. The above information should be discussed by the inspector, contractor, and ready mix plant operator before a deck pour. The pour should not be attempted if concrete temperature is predicted at 86°F (30°C) or higher and predicted air temperature is above 86°F (30°C).

4. Temperature Field Documentation

   a. The temperature of concrete should be taken as soon as concrete is placed. It should be taken when the first load is placed. Additional checking is warranted if the temperature is running at or near maximum. Air temperature should also be taken about the same time as the concrete temperature.

5. Maximum Air Temperature--No continuous placement is to be attempted when temperature forecast is above 86°F (30°C).

   a. Working time of concrete varies with the temperature of concrete, and concrete temperature varies with the temperature of different materials used in the mix. In order to determine the dosage rate of retarder, an estimate of the mix temperature must be made. The following are suggested estimating methods:

      (1) The temperature of concrete from previous placements could be taken.

      (2) If a ready mix producer is placing concrete the day before a deck placement, this concrete could be checked for concrete temperature.

   b. Regardless of the method used, make the best estimate of what the concrete temperature will be during the warmest part of the day. Remember, concrete shall not be placed in new decks if the concrete temperature is above 85°F (30°C).

706.03 CONSTRUCTION METHODS

A. Prepour Meeting

1. It is very important to use the prepour meeting to discuss the specifics of placement, establish communication, and resolve potential "sticky" issues prior to placement. Generally it is recommended to discuss:

   a. Chain-of-command. Who is in charge for the contractor? Who needs to be notified if material tests do not comply with specifications? Establish prior to placement how test results are reported (i.e., does the Contractor want to be notified verbally, or in writing each time?).

   b. More cement paste will cause more cracks and less paste means fewer cracks.

   c. Material requirements and admixtures needed for the placement (Examples: Single cement source, concrete temperature and methods used to cool the mix, source and amount of any admixtures, specific mixes required for bridge decks, etc.)

   d. Vibration can make a stiff mix workable with better results than adding water.

   e. Procedures for introducing admixtures during mixing operations need to be discussed and formalized. For example: How and where will the air entraining agent be introduced? There is a growing concern that placement location of admixtures is causing significant variability in mixes. The plant monitor must watch and document how admixtures are introduced during mixing.

   f. Method and frequency of acceptance testing during any placement. Inform the Contractor what is expected if non-acceptable material is found during placement.

   g. Scheduling, truck availability, placement method, and required placement rates.

   h. Establish an acceptable source of preplacement weather forecasting. Agree on weather parameters which will be used for "go" or "no-go" decisions both "prior to" and during the placement activity.

   i. Larger limestone aggregate will reduce deck cracks. The gradation tables all have tolerances. Make sure we get as large of limestone aggregate as is available.

2. Adequate Labor Force

   a. At preplacement meetings talk about and, before starting a placement be sure the contractor has:

      (1) Proper and adequate materials to protect the placement.

(2) Adequate numbers of sufficiently skilled laborers available.

(3) Proper tools on the job.

(4) Arranged for the rate of delivery of concrete to make the placement operation efficient.

b. 25 cy (20 cubic meters) per hour should be a minimum placement rate. Any method of delivery to the deck should be checked to see that rate of placement can be such that finishing operations can proceed at a steady pace, with final finishing completed before the concrete starts its initial set.

B. Concrete Plant Inspector's Checklist

1. Specifications regarding plant inspection, equipment approval, and batching operations should be reviewed for familiarity. **In addition to proper plant calibration, the inspector should verify that each truck mixer used on the job has a current certification as required by *SSHC Section 1002*.** It is good practice to inspect a random sample of ready mix trucks that will be used on the job, verifying that the certification accurately reflects the truck's condition. Truck certification numbers should be recorded in the inspector's diary and will need to be reverified at least every 30 days.

2. Batching and mixing should be limited to the lead truck until slump and air content have been tested for conformance with specifications. **Contractors may make preliminary tests at the plant but project acceptance is based on job site tests.** It is intended that the ready mix plant supply concrete to the construction site that conforms to all applicable specifications at the point where the acceptance sample is taken.

a. *SSHC Table 1002.02*, Concrete Proportions, lists slump and air content requirements.

b. If concrete is being delivered which deviates much from these target values, the contractor is responsible for taking corrective action to bring the mix to within target values. Even if the current mix is within specified limits. The intent of the tolerance is to provide latitude during placement for unforeseen changes in materials, mixes, and placement methods. Placing concrete "consistently" near a tolerance limit is not desirable and warrants additional sampling.

c. What is important, is the contractor's response to test results approaching tolerance limits. Continually having to add water and/or air agent to each load at the site will not be permitted. If such practice is occurring, the inspector shall notify the contractor (or whomever was designated as "the" responsible individual in charge of the concrete at the site.) Ultimately, it is the contractor's responsibility to initiate immediate corrective action.

3. Non-responsiveness on the contractor's part is reason to initiate sampling and testing of each truck or halt placement. The purpose for additional testing is to ensure that no noncomplying materials are incorporated into the project.

4. In some cases admixtures, such as water reducers, are required to be added in split doses or sometimes totally at the site.

5. All Structural Concrete

   a. At the start of each day's placement, no concrete is to be placed in the forms or on the deck until the first truck has been sampled, tested, and approved. Incorporation of materials from this truck will not be permitted unless desired slump and air content are within specified limits. Continuous placement shall not begin until after test results indicate the material meets specified requirements.

   b. If the first load is close to a limit value, it is recommended to sample and test the second load unless site experience indicates it is not necessary.

   c. Initial start up test results (if taken from the truck chute) must account for method of placement. For example: If placement will be through a pump, air values should be on the high side of target to account for loss during pumping. Again, site/project experience should be factored in this decision.

   d. Routine acceptance testing will be at a minimum frequency of one sample per 100 yd^3 (100 m^3). This frequency may be changed for large, continuous placement where placement rates warrant a lesser frequency. Minimum quantity placed between routine acceptance tests is 100 yd^3 (100 m^3). This rate of testing may be increased (made more frequent) if the inspector has a concern that target values are not being met.

NOTE: Only the Materials and Research Division has authority to approve decreasing (less frequent) testing frequencies from those listed in *Materials Sampling Guide*. PLAN AHEAD and obtain approval for those cases where a variance would be reasonable.

(1) For routine acceptance testing, obtain a representative sample at the last practical point before incorporation, but prior to consolidation.

NOTE: When concrete is placed by means other than directly from the back of the truck the sample shall be taken after the concrete has passed through the conveyance method being used. (This includes placement by bucket, belt, pumps, power buggies, etc.)

(2) Routine acceptance sampling and testing does not require holding a truck until results are available. However, if there are obvious deficiencies, the inspector has the authority to hold that truck until test results are available.

(3) Inspectors should be alert to obvious visual changes in consistency, with routine acceptance air and slump tests being made as noted above. Any load having questionable consistency should be checked for slump, and air content.

(4) If noncomplying test results are found during routine acceptance sampling, no more material (from that truck or others) shall be incorporated until complying test results are obtained. When test results indicate noncomplying material:

(a) The rest of that load shall be rejected and not incorporated, unless adjustments can be made to bring it back into compliance.

(i) In an attempt to bring noncomplying concrete into compliance, the supplier may make field adjustments (i.e.. add air entraining agent, or rotate the drum). Such "field" adjustments shall be an EXCEPTION and not the general rule and the 90 minute time restriction shall not be waived for any situation.

(b) For all noncomplying test results the inspector shall immediately notify the contractor or their representative in charge of the concrete. This notification shall also inform the Contractor if noncomplying materials have been incorporated into the structure.

(c) If test results indicated noncomplying materials have been incorporated, the inspector shall make a note in the diary indicating the test results, approximate volume incorporated, location the material was placed, and to whom the notification was given. The inspector should also note a noncomplying event on that particular truck's delivery ticket.

(d) When noncomplying materials are found, the inspector will: a) hold each truck, and b) initiate sampling and testing of each truck until two consecutive loads meet specifications. At this point sampling and testing may return to normal project acceptance frequency.

6. Specifications spell out requirements that materials must meet to be acceptable. Further, the *Materials Sampling Guide* identifies a frequency for sampling/testing and whether the test is an acceptance or assurance test.

   a. Authority for initially rejecting noncomplying materials and poor quality work performance is given to the inspector in *SSHC Subsection 106.05*. This rejection authority is only superseded by the Project Manager. There is an old saying to the effect "*We shall not knowingly incorporate noncomplying material into a project*." This means exactly what it says and there is ample support in the specifications for this position.

7. During placements, the inspector should alternate sampling among the various trucks involved in the operation.

8. If there is a specific truck which is identified as causing a problem with consistency, that truck shall be rejected from further use.

9. Transit mixers shall be completely emptied of wash water before reloading. If the truck's top fill hopper is washed after loading, no wash water shall be allowed to enter the mixer.

10. The inspectors will need to satisfy themselves regarding compliance with the specifications for the number of drum revolutions at mixing speed.

11. If water, air entrainment or other admixtures are added at the project site, acceptance testing will not be performed until all additions have been made AND required mixing has been completed following the change.

C. Falsework

1. General: *SSHC Subsection 704.03*, paragraph 7.f. requires the contractor to submit 6 copies of falsework plans when required or when certain conditions apply. These plans shall be prepared by an Engineer registered in the State of Nebraska. The contractor shall prepare falsework plans, as called for in plans or in the special provisions, and for:

- Support of plastic concrete for concrete slab bridges with spans greater than 50 ft (15.25 m) in length.

- Cast-in-place concrete girders

- Slab bridge false work should allow for ? inch (3 mm) of deflection for each 10 feet (3 m) of span. This means that on an 80 foot simple span bridge the falsework should be I inch high at midpoint.

2. Falsework Inspection

a. Contract requirements governing falsework construction are contained in *SSHC Subsection 704.03, paragraph 7*.

b. The Project Manager should observe the falsework as it is erected to ensure that:

(1) Only sound materials are used.

(2) Quality work is used.

(3) During concrete pour, the falsework will carry the load. (More than ½" movement is bad.)

NOTE: Any inspection and/or acceptance by the Project Manager is not intended to relieve a contractor of responsibility under the contract for falsework design and construction.

c. By specification, a contractor is responsible for proper evaluation of the quality of their falsework materials. However, the Project Manager should not permit use of any material, when there is doubt as to the materials ability to safely carry the load. If there is any question, the contractor should be required to perform a load test or furnish other evidence of structural adequacy.

d. Timely inspection is essential. Falsework deficiencies should be brought to the contractor's attention at once. Deficiencies include:

(1) Poor quality work.

(2) Use of unsound or poor quality materials.

(3) Construction which does not conform to the contractor's falsework drawings.

e. If the contractor fails to take corrective action, a noncompliance letter shall be issued. Corrective action will be required prior to placement of any additional dead or live load to the support structure.

3. Falsework Foundations

a. Falsework piling should be driven to adequate bearing unless mudsills or spread footings can be founded on rock, shale, compact gravel, coarse sand, firm clays in natural beds, or well compacted fill.

(1) Falsework Piles

(a) If requested, pile bearing values will be determined by the wave equation. Otherwise, the contractor is responsible for adequate foundation support.

(b) The pile bearing value required to support the design load must be shown on falsework drawings, and the pile driving operation must be inspected sufficiently to ensure that falsework piles attain required bearing.

b. Mudsills and Spread Footings

(1) Foundation material should be inspected before the footings are placed.

(2) To ensure uniform soil bearing, falsework pads must be set on material that provides a firm even surface, free of bumps or depressions within the pad bearing area. If necessary to obtain uniform bearing, a thin layer of sand may be used to fill in surface irregularities.

(3) Continuous pads must be analyzed differently than individual pads, and the two should not be considered equivalent. A change from one to the other requires resubmittal in the Construction Division for review by the Bridge Division.

(4) Falsework pads should be level. Benches in fill slopes should be cut into firm material, with the pad set well back from the edge of the bench.

(5) Many soils lose their supporting capacity when saturated. Adequate falsework construction must provide for drainage and protect pads from being undermined or ponded in water.

c. Soil Load Test

(1) Project Managers should require the contractor to perform a soil bearing test if there is any doubt as to the ability of foundation material to support the falsework load without appreciable settlement. One method to evaluate in-situ bearing capacity is to perform a plate bearing test as per ASTM D-1 194. (The above referenced method is not the only such test procedure, but is included to provide one method of determining in-situ capacity.)

4. Falsework Materials

a. One aspect of a falsework design and review is based on the use of undamaged, high-quality materials. Material strength values must be reduced if lower quality materials are to be used. Obviously, evaluation of the quality of materials actually furnished is an important, and essential, part of the falsework inspection procedure.

(1) Timber

(a) Inspecting falsework materials is necessary to prevent the use of materials which obviously do not meet the "undamaged high-quality" design criteria.

(b) Falsework materials delivered to the job site, should be equal to or greater than the grade, or type of material, assumed in the design review. Timber having large shakes, checks or knots, or which are warped or split should not be used at critical locations. Abused timber, although stress graded, may no longer be capable of withstanding the original allowable stress.

(c) Rough sawn timbers should be measured to determine their actual dimensions. Unlike surfaced/finished material, the dimensions of roughcut timber are not uniform from piece to piece. The variation may be appreciable, particularly in the larger sizes commonly used for falsework posts and stringers. If actual dimensions are smaller than the dimension assumed in design, the member may not be capable of carrying the imposed load without overstress. Therefore, undersized material should not be incorporated into the falsework, unless the design is reevaluated using smaller dimensions.

(2) Structural Steel

(a) Used beams, particularly beams salvaged from a previous commercial use, should be examined carefully for loss of section due to welding, rivet or bolt holes, or web openings which may adversely affect the ability of the beam to safely carry the load imposed by the falsework design.

(b) Welded splices should be inspected visually for obvious defects. Radiographic inspection or other methods of nondestructive testing will not be required as a means of determining the quality of the splices unless the Project Manager has reason to believe the welds are defective.

(3) Manufactured Products

(a) Manufacturer's ratings are based on the use of new material or used material in good condition. The determination as to whether a manufactured product is in good condition is highly subjective and requires experience and judgment.

(b) When manufactured assemblies are used in falsework, they shall be shown on the falsework plans along with their identification number. The actual assembly shall be clearly and permanently marked with the identification number.

b. Identification numbers will allow field inspectors to verify the capacity and proper application of various devices.

c. Identification by the contractor applies not only to jacks, beam hangers, overhang brackets, and similar devices, but to all vertical steel shoring systems as well.

d. Manufactured products such as tubular steel shoring and steel overhang brackets are particularly vulnerable to damage by continual reuse. Fabricated units in which individual members are bent, twisted, or broken will have a substantial reduction in load carrying capacity. Steel shoring materials should be examined carefully prior to use. Shoring components should not be used if they are heavily rusted, bent, dented, or have broken/damaged welds or other defects. Connections, in particular, should be examined for evidence of cracked or broken welds. Miscellaneous components such as screw jack extensions, clamps, and adjusting pins should be inspected as well.

e. Proprietary scaffolding must be used as intended and not subjected to additional stresses or conditions for which it was not originally designed and tested.

(1) Cable Bracing

(a) Cable bracing systems must be carefully inspected to ensure that field installation conforms to details shown on the falsework drawings. This is particularly important with respect to the location and method of cable attachment to any falsework.

(b) Prior to installation, each cable should be inspected to verify that the type, size, and condition (new or used) are consistent with design assumptions. Used cable should be inspected for strength-reducing flaws. Use of obviously worn, frayed, kinked, or corroded cable should not be permitted.

(c) Particular attention should be paid to cable clamp fasteners. Improperly installed clamps will reduce the safe working load by as much as 90 percent. Also, the omission of the thimble in a loop connection will reduce the safe working load by approximately 50 percent. After installation, clamps should be inspected periodically and tightened as necessary to ensure their effectiveness.

(d) A cable clamp has two parts - the "U-Bolt" and the "Saddle." Also a cable has two parts, the wrapped non-continuous end (dead end) and the continuous portion which supports the load (live side). Always put the cable clamp's "saddle" on the live side and the "U-bolt" over the "dead end."

5. Falsework Quality

a. High quality work, particularly in such details as wedges, fasteners, bracing, friction collars, jack extensions, etc., is critical to the proper performance of falsework. Accordingly, construction details should receive close attention from the project inspector.

(1) Timber Construction

(a) The following checklist is included as a guide to points which require special consideration:

(i) Diagonal bracing, including connections, must conform to details shown on the falsework drawings.

(ii) Diagonal bracing should be inspected after any falsework has been adjusted to grade. Connections must be securely fastened to ensure their effectiveness in resisting horizontal forces. Bolted connections may need retightening.

(iii) Timber posts may be wedged at either the top or bottom for grade adjustments, but not at both locations. Large posts may require two or more sets of wedges (side by side) to reduce compression stresses perpendicular to the grain.

(iv) Blocking and wedging should be kept to a minimum. It is poor workmanship to extend a short post by piling up blocks and wedges. This practice should not be permitted.

(v) Particular attention should be given to falsework bents where grade adjustment is provided at the bottom of the posts. Differential grade adjustment of posts within a particular bent may induce undesirable stresses in the diagonal bracing.

(vi) Splicing of wood posts will not be allowed unless shown on approved falsework plans.

(vii) The ends of spliced posts must be cut square. The need for a post splice should have been anticipated by the contractor and the splice detail shown on falsework drawings. If this is not the case, the contractor must submit a detail for approval.

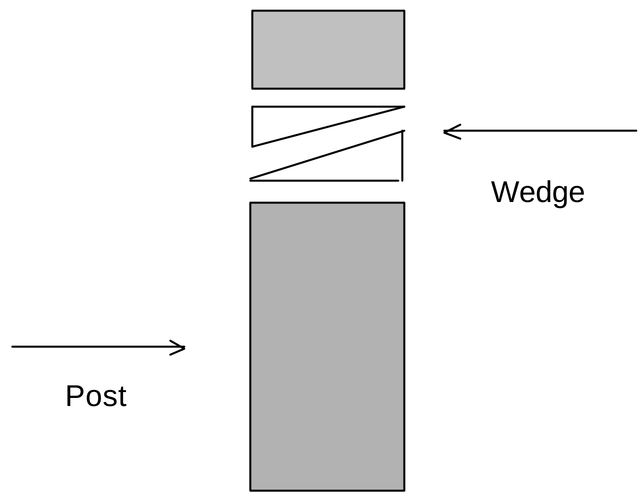
(viii) Posts must be plumb and centered over the falsework pad or corbel.

(ix) Abutting edges of soffit plywood should be set parallel to the joists and continuously supported on a common joist.

(x) A sufficient number of telltales must be installed to accurately determine the amount of joint take-up and settlement. Telltales should be attached to the joists as close as possible to the supporting post or bent.

(xi) Full bearing must be obtained between all members in contact. Deficiencies in this respect may be improved by feather wedging. If the joint requires more than a single shim or wedge, extra care should be taken to ensure that full bearing is obtained.

FULL BEARING WEDGE



When using wedges, it is a good practice to use wedges inserted from both sides rather than deeply setting a single wedge. Using only one wedge increases the twisting effect on the member.

- o When using wedges, it is good practice to install them parallel to and with the flat (nontapered) side against the main member. This improves contact with the main member and decreases the chance of a wedge "backing out" from vibration.
- o Nail or clamp the wedge in place after installation.

(2) Steel Shoring (Scaffolding)

a. This checklist may be used as a guide by inspectors when inspecting falsework constructed of steel shoring.

(1) Shoring components should be inspected prior to erection. Any component that is heavily rusted, bent dented or rewelded, or which is otherwise defective, should be rejected. Fabricated units having individual members that are bent twisted, broken, or where welded connections are cracked or show evidence of rewelding should be rejected.

(2) A base plate, shore head, or screw jack extension device should be used at the top and bottom of all vertical components.

(3) All base plates, shore heads, and extension devices must be in firm contact with the footing at the bottom and the cap or stringer at the top.

(4) Shoring components should fit together evenly, without any gap between the upper end of one unit and the lower end of the other unit. Any component which cannot be brought into proper contact with the component it is intended to fit, should not be used.

(5) Shore heads, extension devices, and similar components must be axially loaded. Eccentric loads are not permitted on any shoring component.

(6) All locking devices on frames and braces must be in good working order, coupling pins must align the frame or panel legs, and pivoted cross-braces must have the center pivot in place.

(7) Shoring should be plumb in both directions. Maximum deviation from true vertical should not exceed 3 inches per 1000 inches (3 mm per meter).

6. Miscellaneous Falsework Items

a. This checklist covers items that may be used in either type of support system.

(1) New high strength bolts shall be used on any item that requires bolts to be torqued.

(2) Friction collar bolts and concrete anchors should be torqued initially and checked again just prior to concrete placement.

(3) Permanently deflected stringers should be placed with the crown turned upward.

(4) Jacks should be plumb and not overextended.

7. Falsework Adjacent to Traffic

a. This will be an unusual situation in Nebraska. If it occurs, the Construction Division should be notified.

8. Falsework Field Changes

a. If supplemental calculations are necessary to verify compliance with contract requirements, he change will be considered substantial. In this case, the proposed change must be submitted for review and approval in the same manner as the original drawings.

b. The following are examples of changes considered substantial and must be shown on revised falsework drawings, regardless of other considerations:

(1) A change in size or spacing of any primary load-carrying member.

(2) A change in method of providing lateral or longitudinal stability.

(3) Any change, however minor, which affects the falsework to be constructed over or adjacent to a traffic opening.

(4) A revised concrete placing sequence, if it significantly affects the stresses in load-carrying members.

(5) When revised drawings are required, they must be submitted for review in the same manner as the original falsework drawings. The Department does not approve falsework! Time shall be allowed for review of revised falsework drawings. Typically this is the same as required for the original submittal.

(6) The PM should be alert to and document any field changes to falsework plans.

9. Falsework Inspection During Concrete Placement

a. As concrete is being placed, the falsework should be inspected at frequent intervals. In particular, look for the following indications of potential failure:

(1) Excessive compression at the tops and bottoms of posts and under the ends of stringers.

(2) Pulling of nails in lateral bracing.

(3) Movement or deflection of braces.

(4) Excessive deflection of stringers.

(5) Tilting or rotating of joists or stringers.

(6) Excessive settlement of tell-tales.

(7) Posts or towers that are moving out of plumb.

(8) Sounds of falling concrete or breaking timbers.

(9) If any member deflects unduly or shows evidence of distress, such as splintering on the bottom of stringers, crushing of joints or wedges, etc., placement work in the affected area should be stopped immediately and the falsework strengthened by addition of members, installation of supplementary supports, or some other means.

(10) Settlement of the falsework should be limited to a maximum of ? inch (10 mm) deviation from the anticipated settlement. Should actual settlement exceed the anticipated settlement by more than the ? inch (10 mm) allowable, and if it appears that a serious problem is developing, concrete placing should be temporarily discontinued in affected areas until the contractor provides satisfactory corrective measures. Concrete placing should not be resumed until the Project Manager is satisfied that further settlement will not occur.

(11) If it is apparent that satisfactory corrective measures cannot be provided prior to initial setting of the concrete, the Project Manager shall stop placing of concrete and contact the Construction Division.

(12) One important and often overlooked point is the danger of curing water softening the falsework foundation. Some means should be provided to prevent curing water from reaching and soaking the foundation material beneath the falsework bearing pads.

(13) The contractor should provide the drainage for any water that accumulates in box-girder cells. Such accumulated water could easily overstress the falsework.

b. Falsework and Centering

(1) It is the contractor's responsibility to provide form work adequate to support the dead load of the fresh concrete. However, the inspector shall consult with the contractor and the Project Manager concerning any form work which he/she has reason to believe is inadequate to support the load capacity. In calculating the strength of centering, a mass of 150 lb/ft^3 (2400 kg/m^3) shall be assumed for fresh concrete.

(2) All falsework shall be rigidly braced and cross braced. Timber piling shall be free from defects with at least a 7 inch (175 mm) butt and a 5 inch (125 mm) tip, measured under the bark. The contractor shall provide jacks or suitable wedges to take up any settlement in the form work during the placing of the concrete. When setting grades for falsework or structure forms, allow 1/16 inch (1.5 mm) settlement or "take-up" for each lap in the falsework timbers.

(3) Build falsework for slab bridges with ? inch camber for each 10' of span. Deflection after forms are removed should bring deck back to the proper elevation.

(4) Settlement caused by the concrete loads may be checked as placing of the concrete progresses by means of vertical "telltales" fastened to the bottom of the floor form. When this settlement has reached the amount allowed for "take-up" in the falsework timbers, any further settlement should be prevented by means of the wedges or jacks previously noted. Any adjustments that have to be made must be completed before the concrete has taken its initial set. If adjustments are made after the concrete has set, the concrete may be damaged

irreparably. (In general, if falsework settles more than ½ inch, the PM must investigate and determine the damage.)

10. Removal of Falsework (SSHC Table 704.02)

a. Specifications and applicable special provisions, contain specific criteria which must be met before falsework may be removed. Project Managers and inspectors should review these sections prior to falsework removal operations.

b. The Project Manager should discuss falsework removal methods and procedures at the preconstruction and/or prepour meeting. The need to provide for employee and public safety is of particular concern.

c. In general, all elements of the falsework bracing system must remain in place for the specified time period or until concrete attains the specific strength. In the case of cast-in-place, post tensioned construction, falsework elements must not be removed until stressing is completed.

D. Forms

a. The inspector shall check the lines, grades and dimensions on all structural form work before allowing the contractor to place concrete. On walls and columns this is best done as the form work progresses.

b. Forms shall be made of wood, metal or other approved materials. The forms shall be substantial, unyielding and mortar tight. All forms for exterior exposed surfaces, except those locations requiring a specific texture finish as listed in *SSHC Subsection 704.03* shall be lined with pressed wood, plywood or other approved materials used in the largest practicable panels. Forms shall be coated with a colorless oil to prevent sticking to the concrete. The forms should be oiled before placing the reinforcing steel to avoid splattering of oil on the steel. Forms for walls and columns, or wherever else required, may be constructed with the bottom board removable for cleaning out wood chips, dirt, etc., before placing the concrete. Metal tie rods or anchors within the forms shall be constructed so as to permit their removal to a depth of one inch below the surface of the finished concrete. All tie rod and tie-wire holes shall be filled with cement mortar as soon as possible to insure proper bond with the structure concrete.

c. Pier columns may be constructed using a laminated fiber form which is moisture resistant and seamless. These forms must be capable of withstanding the hydraulic pressure of fresh concrete. Any questions concerning the acceptability of a proposed fiber form should be referred to the Construction Engineer through the District Construction Engineer.

d. Removal of Forms and Falsework

(1) Specific requirements concerning the time limitations for form removal are listed in *SSHC Subsection 704.03*. Proper inspection includes both the monitoring of this time and the method of removing forms. Stresses in concrete due to its own weight must be introduced slowly and carefully during form removal operations to prevent concrete failures. For instance, the removing of falsework from under a cantilevered element, must begin at the point furthest from the support and proceed toward the support. In removing the falsework from under a structure that is continuous over its supports, removal should begin near the areas of maximum dead load positive moment and proceed in both directions towards the supports. In general, all

falsework should be removed before placing any surcharge, such as sidewalks and railings, on the superstructures.

(2) The requirements listed in the Specifications are based on sound engineering principals and the structures inspector should be thoroughly familiar with and rigidly enforce these requirements.

12. Use of Insulated Forms for Protection

a. Commercial insulation may be used for protecting concrete during cold weather, or when the contract documents require controlling the heat of hydration. This technique is the contractor's option and could be used in lieu of housing and heating. The contractor must furnish housing and heating and/or insulation of sufficient quality and thickness to maintain concrete at a temperature of not less than 50°F (10°C) for the first 72 hours after placing, and above 41°F (5ºC) for the next 48 hours.

E. Placing Concrete

1. Concrete shall be proportioned, mixed and handled in accordance with the requirements of *SSHC Section 1002*. The inspector should also refer to the Materials and Research Manual which outlines the method of proportioning, sampling and field testing the materials necessary for the production of concrete. The contractor shall organize his/her work so that the maximum interval between batches shall not exceed 30 minutes.

2. Concrete should not be placed in footings, columns, etc, until all pile driving within a radius of 50 feet has been completed. If concrete pours must be made within this area prior to the completion of pile driving, such concrete shall set at least three days before further driving is permitted within this radius. Concrete shall not be placed without special permission in steel pile shells for cast-in-place concrete piles for each bent, pier, or abutment until all the shells for that bent pier or abutment have been driven (*SSHC Section 703*).

3. When depositing concrete in the forms, segregation must be avoided. The mass of concrete should be generally free of surface cavities resulting from the trapping of air and water along the forms. Careful spading of concrete along vertical forms and tapping of the forms will usually release the air and water bubbles. Forms which are not mortar tight will leak cement paste and result in "sand streaking." Forms should be mortar tight to the maximum extent possible. Chutes shall be of metal or metal lined and of sufficient number to preclude the necessity of shifting the chutes. If necessary, the contractor shall leave holes in the forms for the entry of the chutes or pipes. Concrete must be deposited within 8 ft (2.5 m) horizontally of the place of its final location. Concrete shall not be dropped vertically more than 5 feet (1.5 m). Concrete in walls, footings, columns, etc, shall be placed in continuous horizontal layers not more than 18 inches (450 mm) thick and vibrated to a monolithic mass. Do not allow dried concrete to collect on forms or reinforcing bars where it will fall into the work.

4. See Section 1003.06 Concrete Cylinder Policy for cylinder requirement.

F. Placement Considerations

1. If there is any doubt about the concrete temperature exceeding 86°F (30°C), the contractor needs to identify measures which will be implemented to keep mix temperatures within specifications. If the contractor is not prepared to maintain a mix temperature below specifications, the pour should be postponed.

2. There are several ways concrete temperatures may be kept within specifications. They are:

   a. Scheduling placements during cooler times of the day.

   b. Wetting the aggregate stockpiles.

   c. Covering/shading the aggregate stockpiles.

   d. Maintaining a supply of portland cement on hand to preclude getting hot material from the supplier.

   e. Chilling the mixing water is one of the most effective ways to lower mix temperatures.

   f. Shaved ice can be used, however, the ready mix operator must submit a proposal for this to the Project Manager for review by the Construction Division.

NOTE:

- No payment will be made for methods taken to keep concrete temperatures within specifications.
- If pour has to be delayed because of temperature, and pouring is the controlling operation, no working days will be charged.
- Location of permissible headers should be discussed with the contractor during the pour, it appears the temperature may exceed 86°F (30°C).
- When casting deck on Phased Construction under traffic make sure potholes in the driving lanes are filled.

3. General - The wind velocity temperature relationships stated in the specifications should be enforced to avoid loss of water from the concrete surface faster than it can be replaced by normal bleeding and to avoid the resultant formation of plastic shrinkage cracks. Anemometers and thermometers must be available on site to measure wind velocity and temperature.

4. Concrete in bridge floors shall be placed uniformly on both sides of the centerline and shall be placed continuously between specified joints. The sequence of placing shall be in accordance with the pouring diagram shown in the plans. If no pouring diagram is shown in the plans, concrete shall be placed as directed by the Project Manager.

5. Wet the deck forms and approach slab grade before placing the concrete. Concrete shall be adequately vibrated to encase the lower bars of the reinforcing mat where these are near the deck form.

6. Special attention shall be given to finishing the riding surface on the bride floors. *SSHC* Subsections 706.03, 710.03, and 711.03 explain concrete bridge floor finish.

7. It has been the policy to permit the contractor to use mechanical finishing machines of an approved type whether or not they are required by the plans or special provisions.

8. Method of Finish - When the hand method is employed, the concrete surface shall be struck off with a strike board which conforms to the cross section shown in the plans. If this is pulled by hand, care shall be taken not to displace the reinforcing steel by the workmen doing the pulling. A small air winch anchored to a girder outside of the day's pour will pull the strike off at a slow, uniform rate, giving a truer surface with no displacement of the reinforcing steel. The strike board shall be operated with a combined longitudinal and transverse motion, always carrying a small roll of concrete in front of the cutting edge. The strike off shall be pulled a sufficient number of times to properly distribute the concrete. A longitudinal float generally is required and is described in *SSHC Section 704*. The longitudinal float shall be lapped 1/2 its length when moved to a new position and shall be operated across the surface a sufficient number of times to produce a uniform, smooth riding surface. Occasionally during the finishing operation, conditions may require the use of the long-handled transverse float, which require extreme care in its use to preserve the desired cross-section and a smooth riding surface.

9. Regardless of whether hand or machine finishing methods are used, the floor surface shall be tested for trueness with a straightedge 10 foot (3 m). The bridge contractor is required to furnish a 3 m master straightedge for use in trueing and checking the working straightedges.

10. A burlap drag is required and this operation should be performed as soon as the surface will support the drag. A tined surface is also required by the specifications.

11. Templates used to support the strike off should be in short sections [(10 to 14 ft) (3 m to 4 m)] so they may be removed as the finishing operation advances, allowing the final floating and surface testing to take place, and the wet burlap to be applied immediately. Decks should be cast after the afternoon high temperature is reached. (In summer, this can be as late as 7:00 p.m.) Protection of the aggregates from the sun is also helpful.

12. When mechanical self-propelled finishing machines are used, they shall be capable of obtaining a finish equal to or better than that obtained by the hand method. The screeds of the finishing machine should be set to the exact cross section shown in the plans. Elevation shots will be required for the setting of the riding rails. The usual procedure is to give a fill to grade at the locations where girder shots were taken. The contractor will then set the rail to the correct height to accommodate the machine. An "eyeball" check of the rail for smoothness should always be made. On girder bridges the rail will follow a line that should be smooth after the girders have deflected from the dead load. Correct elevations of the rail can be checked by measuring the distance from the screed to the formwork which should give the correct thickness of slab.

13. Careful attention should be given to the depth of cover over the top steel. With the extensive use of salt, the service life of the steel is reduced if the concrete cover is less than that shown in the plan. (The finishing machine must be dry run to check the minimum clearance of the reinforcing steel and to check the grade of the expansion devices.)

14. If the finishing machine is used when there is a transition between regular crown and full superelevation, a system should be worked out well in advance of pouring to insure that the screed can be changed rapidly and correctly at intermediate points of the transition. This is important in order that there are no long delays caused by screed adjustments while pouring the transition.

15. Retarders – Retarders shall be used to delay the setting time of the bridge floor concrete. If the temperature is 60°F (15°C) and rising, retarders must be used. A good goal is to be finishing at the next pier before the concrete is setting-up at the previous pier. Acceptable retarders are Pozzolith 300R and Doratard-17. Water reducing admixtures like WRDA-82, Procrete-N, and Masterpave-N are not acceptable retarders.

16. When a retarder is required the rate of placing concrete for any positive moment section will be within two-thirds of the initial setting up time of the retarded concrete after the previous negative moment section has been poured. For example, if the initial set takes place in 6 hours, the pouring of a positive moment section must be completed within 4 hours after the completion of the previous negative moment section. This same procedure should be required regardless of whether or not retarders are used.

17. Calibration of Concrete Proportioning Equipment - Calibration of this equipment should be as described in the National Ready Mixed Concrete Associations' Quality Control Manual.

G. Placement Methods (Pumping, Belting, And Crane Bucket) (*SSHC Subsection 704.03*)

1. Much concern has been expressed about the method of concrete placement because of lost entrained air. Rough handling of plastic concrete during placement has, at times, reduced entrained air to less than 2% not to mention potential segregation problems. While testing at the point of placement "should" identify such problems, varying placement conditions during the pour can affect concrete conditions significantly.

2. General conditions which must be avoided (Points to watch for), or at least severely minimized, are explained for each delivery system that follows: If one of the following cannot be avoided, at least be aware of the condition, and be sure to conduct additional testing should any of the conditions present themselves.

3. Crane and Bucket

    a. In the past it was felt the crane and bucket placement method did not adversely affect concrete. This is now in question when viewed from loss of air and potential segregation. Therefore, this method will now also require testing at the placement location, if practical.

b. Points-to-Watch For

(1) Free fall of unrestrained concrete shall not exceed 5 ft (1.5 m.) Avoid exceeding a 5-ft. free fall by removing a section of form work for intermediate placement or by use of a tremie.

(2) Discharge from the bucket must be controllable.

(3) Cross section of the drop chute should allow it to be inserted into the form work without interfering with reinforcing steel.

4. Belt Placement

a. Belt equipment is typically used to convey concrete to a: (1) lower, (2) horizontal, or (3) somewhat higher level.

b. Points-to-Watch For

(1) Keep the number and distance of drops between belts to an absolute minimum. Drops tend to encourage segregation and reduce entrained air.

(2) As belt conveyors are removed from the line (i.e., as on deck pours), recheck the "as placed" air content.

(3) Be sure all mortar is being removed at the discharge. (No mortar should be on the return belt.)

(4) Check discharge for potential segregation problems.

(5) In adverse weather (hot and/or windy conditions), long belt runs need to be covered.

H. Pump Placement

1. The modern mobile pump with hydraulic placing boom is economical to use in placing both large and small quantities of concrete. These units are used to convey concrete directly from a truck unloading point to the concrete placement area.

2. Points-to-Watch For

a. Typically, pumps are initially flushed with a thin water/cement paste mixture to coat the lines. This slurry must be wasted and the lines charged with the project mix before beginning. Observe, and be sure initial pump charge is thoroughly removed from the pipelines.

b. Always pump at a constant rate and keep pipelines full of concrete. High air loss can occur when concrete is allowed to free-fall inside pump lines.

c. Avoid, if at all possible, having steep angles in the pump pipelines. Steep angles and slow placement rates are probably the worst conditions for minimizing air loss and segregation. If this condition occurs:

(1) Attempt to relocate the pumper, thereby minimizing lift angle.

(2) If discharge is not maintaining a constant flow with the partial concrete head in the pipe, request the pump operator to place a reducer and short section of hose at the discharge end. The purpose is to avoid free falling concrete from impacting the deck or forms at high velocity.

(3) If the above condition is unavoidable, watch and test the discharge frequently for loss in air and potential segregation.

3. Rule-of-Thumb for Pumping

a. Pump concrete with pipelines as flat as possible (or at least with minimal down angle).

b. Minimize (or eliminate) free falling concrete in the pipelines. To do this, maintain some amount of concrete head in the pipelines.

c. Pump concrete through as few elbows and restrictions as possible.

d. Pump concrete at "some" constant rate.

e. Watch and test the air content frequently, when drop may exceed 5 feet.

I. Consolidation of Concrete

1. The contractor must establish a pattern for vibrating the concrete and ensure the pattern is followed across the entire deck.

2. Consolidation of concrete should be accomplished by the use of a sufficient number of vibrators of a type approved by the Project Manager. The vibrators must be of such an intensity as to visibly affect one-inch slump concrete over a radius of 18 inches (450 mm). The contractor is required to furnish a tachometer for the purpose of checking the speed of the vibrator elements.

3. Lateral movement of the concrete by means of a vibrators shall be avoided. Over vibration is harmful and is evidenced by grout appearing in the concrete around the vibrator head. Insert and withdraw the vibrator slowly. It should not come in contact with reinforcing steel which extends into previously placed concrete nor should the vibrator head be placed in concrete which is taking its initial set.

J. Reinforcement Bar Cover

1. Reinforcement bar cover has contributed to shadow effect. This occurs when reinforcing cage is not rigid or has only a minimum of cover and too much vibration was used. The remedy:

a. Increase bar cover to 2 ½ inches (65 mm) from minimum of 2 inches (50 mm).

b. Maintain uniformity of bar cover.

c. Build in rigidity to the reinforcing bar cage by placing diagonal braces as described above.

d. Reduce slump and do not over vibrate the concrete.

e. Require a dry run to check alignment and uniform spacing between the edge of the mule and rebar cage.

2. Shadowing occurs when slip forming a radius because of nonuniform form pressures inside the mule. The problem manifests as repetitious surface bumps, not depressions as one might think. This problem is inherent with slipforming a radius and is especially noticeable as the radius becomes smaller. In order to minimize shadowing effects, the contractor needs to have finishers work out the bumps by hand.

K. Use of Finishing Machine (*SSHC Subsections 710.03 and 711.03*)

1. The finishing machine shall be approved before use. Care must be taken to adjust the screeds to proper crown. Support rails must extend beyond the bridge at both ends at proper grade and sufficient distance to accommodate the machine. This permits finishing to begin promptly at the start of the run and also permits the required straightening to proceed on schedule at the end of the run.

L. Straightedging

1. Following the finishing machine, straightedging should be completed to check for longitudinal smoothness. Straightedges, 10 ft (3 m) in length, need to be operated parallel to centerline of roadway. Each pass should overlap the previous one by a half length. If bull-floating (mopping) is needed to close up the surface, it should always be followed by straightedging.

M. Tining (Transverse Grooving)

1. Tine bridge decks with a rake. No longer use a bull-float.

2. After straightedging, and as soon as practical following finishing, the entire traffic surface, except areas within approximately 2 ft (600 mm) from the curbs, shall be given a suitable tining with corrugated tining rake.

3. Tine all bridge decks where posted speed limit will be 40 mph or greater, except for county road bridges 100 feet (30 m) or less in length that have gravel approaches and no plans exist for future hard surfacing.

4. On bridge decks, stop the tining 2 ft (600 mm) from the face of the bridge curb.

5. **Do not overlap the grooving.**

N. Curing

1. The Bridge Deck Curing Special Provision defines how to cure the deck.

2. The surface must be covered with wet burlap as soon as possible. (Slight surface marring and removal of tining is acceptable.) Burlap must be wet before placing. In hot dry weather, it is better to be a little early than late with burlap cover.

3. Since shrinkage cracks are due to rapid loss of mix water before the concrete has attained adequate strength, it is imperative that curing protection be initiated before much evaporation can occur.

O. Ways to Avoid Deck Cracks

1. Verify falsework is stable.

   (a) Temporary piles need to have significant bearing – practical refusal is best.

   (b) Wood crush needs to be minimized. Avoid gaps between layers of timbers – be careful to shim the entire length of support timbers.

2. Avoid unnecessary vibrations.

   (a) Use shooflys where possible to keep traffic away from the bridge.

   (b) Do not rest falsework on active bridge during phased construction unless there is no other alternative.

   (c) However, when it comes to intentional consolidation – the contractor should be very careful to establish a fix pattern for vibration and make sure it is achieved along the entire length of the deck and approaches.

3. Check the temperature of the concrete as it arrives on site. It should not be greater than 86°F.

4. Check the slump and if the slump is less than 3.5 inches, confirm that the mix is not too dry – especially if retarders or water reducers are used. Low slump measurements are a good indicator that mix is too dry especially on hot days. Also, with a low slump, it will be hard to get the mix around and in between rebars and tining with the tining rake is much more difficult.

5. Verify camber on girders is correct.

6. Avoid skewed construction of approach sections. If there must be a skew, limit it to 20 degrees. If skew is above 20 degrees, then reinforce the area near the obtuse angles because the stress is significantly increased in this region.

7. Cover the concrete with saturated wet burlap 1 ½ hours after the concrete leaves the truck or pump chute.

8. If the outside air temperature is predicted to be above 80°F (26°C) then start casting the deck at 5:00 pm and finish before dawn.

9. Check the outside air temperature during casting. It should be less than 86°F.

10. If the evaporation rate during casting exceeds .15 lbs/sf/hr, then fogging as prescribed in the Nebraska Fogging Special Provision will replace the evaporating water, keep the deck cool, and slow the setting time.

P. Seal Bridge Deck Cracks

1. Bridge deck cracks should be sealed before de-icing salt is ever applied on or near the deck.

2. High molecular weight methacrylate is the best sealant and is squeegeed into cracks.

Q. Cold Weather Placement

1. On account of the high incidence of shrinkage cracks due to artificial heat during the protection period, no bridge floors will be constructed during cold weather except with the special written permission of the Construction Division.

R. Floor Drains

1. Check floor drain locations against floor grades to be sure deck surface will drain. Adjustments of drain height may be advantageous on every flat grade surface. Also, at this time, study the discharge area from the floor drain for potential damage to features under the structure such as shoulders, railroads, or berm slopes. Major problems foreseen should be brought to the attention of the Construction Division.

S. Flowable Fill (*SSHC Section 1003*)

1. The inspector shall make daily entries in the field book on all concrete placed for each project. Record concrete placement location, all results of sieve analysis tests, all data on test beams made and tested and all quantities placed.

2. Flowable fill can be used for the following purposes:

   a. Backfilling culverts.

   b. Backfilling culverts constructed under bridges.

   c. Filling void between culvert and culvert liner.

   d. Plugging culverts.

   e. Slope stabilization.

3. Free water in the sand pile must be considered as mix water because a mix design uses oven dried sand.

4. The plans may call for a sewer pipe to receive a gasket, otherwise, see *SSHC Section 722*.

5. If the contractor uses crushed limestone for granular backfill, it shall meet the requirements for Granular Backfill. (Refer to *SSHC Section 1033*.)

6. Remember flowable fill is a liquid until the water has dissipated. Bulkheads should be strong enough to withstand the hydraulic pressures.

7. Under normal conditions, flowable mortar should be set-up sufficiently within 24 to 48 hours for placement of the final lift of either earthfill or special backfill. If "set-up" does not occur or if it seems slow, typically the problem relates directly to drainage of the granular backfill. Often contamination or "dirty" granular backfill is the culprit. Check to be sure it is draining. If not, additional time will help.

8. Placement of 2 ft (0.6 m) of flowable mortar.

T. Installation of Joints (*SSHC Subsection 704.03*)

1. Reinforcement

   a. Reinforcement must be accurately placed and rigidly fastened. If cages are not rigid and braced diagonally in both transverse and longitudinal directions, problems can occur. The remedy:

      (1) Recommended Procedure:

         (a) Epoxy coated smooth bar, about ¼ inch (6 mm) in diameter can be placed diagonally from the top of a leading cage to the bottom of the second trailing cage. (Description is referenced to direction of paver's travel.)

      (2) Alternate Procedure:

         (a) Welding of diagonal braces to provide longitudinal rigidity is possible, but material would need to be epoxy coated and repair of weld location is necessary.

2. Preformed Neoprene Joints

   a. Preformed neoprene expansion joints are used on a large number of bridges.

      (1) Inspection Checklist

(a) Neoprene cellular joints, if properly installed, provide a leak-proof joint capable of functioning within expansion limits of the bridge. To insure that a joint will function properly, there are a number of precautions that should be noted regarding the installation of this type of joint. Precautions:

(i) A neoprene seal can be placed in two positions, one correct and one incorrect. Make sure that the seal is not installed upside down or sideways.

(ii) Position of the ½ x ¼ inch (13 x 6 mm) keeper bars on vertical face of the expansion plate angles has to be consistent with the recommendations of the manufacturer of the neoprene seal. The depth that a seal is set varies greatly with the different manufacturers.

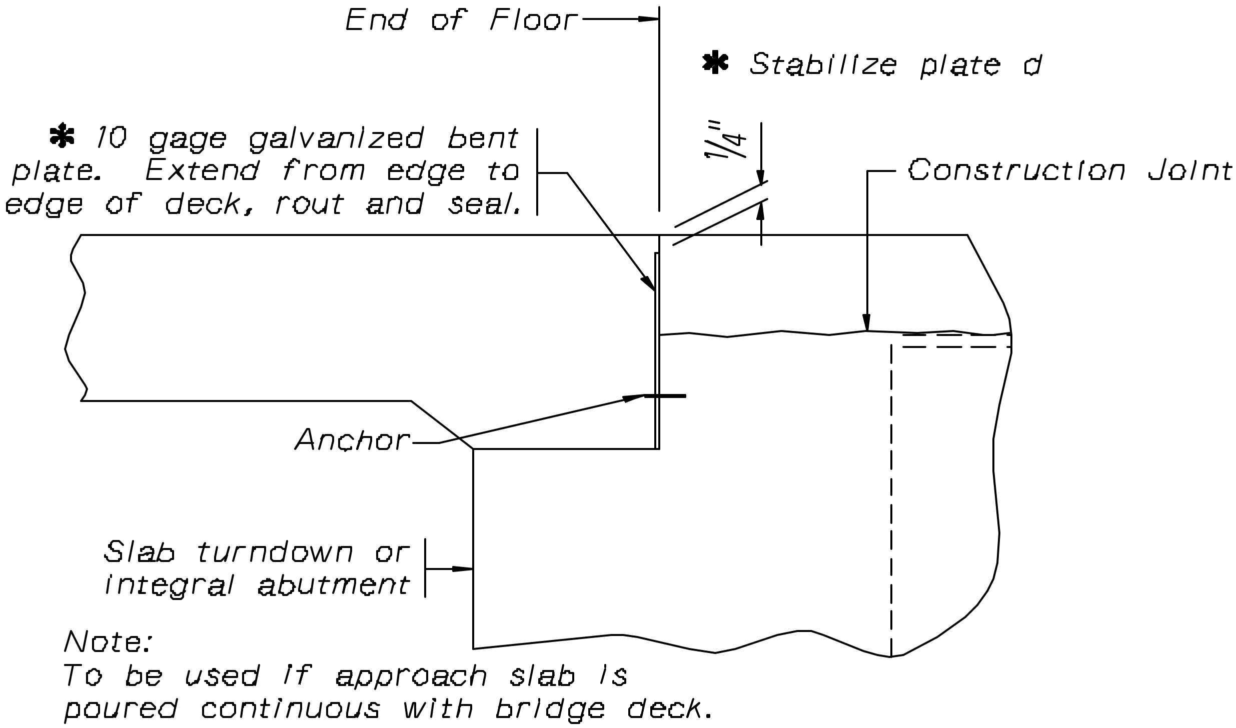
(iii) The neoprene seal has to be installed so bottom of the seal touches top of the ½ x ¼ inch (13 x 6 mm) keeper bars, but should not be forced past the keeper bars.

(iv) Make sure expansion opening between angles of the expansion device are consistent with the expansion setting shown on design plans and that the same expansion opening is maintained from gutter to gutter.

(v) The neoprene seal must project beyond the outside edge of slab as shown on the plans.

b. Summary

(1) When uncertain as to which side of the seal is top, or when the position of keeper bars is in question, the contractor must be required to submit drawings prepared by the manufacturer which indicate correct position of installation.



OPTIONAL JOINT DETAIL

U. Curing Concrete

1. The structure inspector should give careful attention to the curing, since proper curing is essential to good quality concrete.

2. When the evaporation rate exceeds 0.15 lb/sf/hr, the contractor must either fog the entire deck while placing the concrete; cover the concrete with wet burlap 1 ½ hours after the concrete leaves the truck; or take some action which will lower the evaporation rate on the entire deck below the 0.15 lb/sf/hr limit.

3. Applying wet burlap as soon as possible is essential – limited removal of tining is acceptable. The wet burlap should always be on the deck by 1½ hours after that portion is finished.

V. Concreting in Cold Weather (*SSHC Subsections 704.03 and 1002.02*)

1. As colder weather approaches each fall, the Department experiences a series of problems connected with concrete construction in cold weather. The first indication of the problem usually shows up as a low test result on a 7 day cylinder. At that stage, it is not known if the problem is an improperly fabricated cylinder.

2. A cylinder which has been exposed to colder conditions than the structure, or if the low strength actually represents the concrete in the structure. Sometimes the later cylinder tests show satisfactory results, but in other cases, low strengths are found in these tests also.

3. In some cases, definite information regarding the true condition of the concrete in the structure can only be obtained by coring the material and carrying out a series of special tests.

4. The best fogging system may be the simplest. Hand held fogging nozzles that mix compressed air and water to form a fog are some of the best fogging systems observed. (One nozzle that works very effectively is called a Hydro-Air Washer made by Power Systems Inc. of Lancaster, TX.)

W. Simultaneous Casting of Deck and Approach Slabs

1. Casting the approach slabs and the deck simultaneously creates a smoother transition and ride. However, to avoid maintenance and to preserve the integrity of the deck and the approach slabs, a metal bond breaker should be placed over the abutment across the entire width and depth of the deck. This will ensure that a random crack does not occur before the joint can be cut. At the grade beam, the joint is usually blocked out with styrofoam.

2. The rail that the finishing machine rides on must be uniformly rigid. Unfortunately, where the rail passes over the grade beam and abutment, the rail is frequently more rigid than either side of these substructures. This can cause a dip either side of the abutment and the grade beam, which can result in a “bump” over the abutment, and grade beam.

3. Another problem can result when the deck overhangs the outside girder. Typically, the deck forms are supported by outrigger jacks braced against the outside girder. The weight of the concrete and the finishing machine can momentarily bend the outside girder as the placing operation progresses. Temporary construction braces (usually wood blocks) between all girders can prevent girder movement.

X. Surface Checking (Not in Spec)

1. A 10 ft (3 m) straightedge surface check shall be conducted on all bridges and deck overlays not covered by the Smoothness Specification. Surface areas inaccessible to profilometer shall also be checked.

2. On some projects only one wheel path may be included in the placement width. For price adjustment or incentive pay, only the portion within the traveled lane shall apply. Variable width sections for on and off ramps, which are outside the through traveled lane, will be checked with the surface checker.

Y. Test Procedure for Smoothness

1. A Special Provision entitled "Bridge Deck and Approach Slab Smoothness" will usually be included in the contract proposal. This Provision deals with the method of testing for smoothness and the method for correcting surfaces outside of the smoothness limits. The contractor is responsible for scheduling the testing, which will be performed by Materials and Research Division personnel. The contractor must give the Project Manager seven days notice prior to the date he requests that testing be done. The Project Manager shall contact the Materials and Research Division and arrange for testing on the requested date. Evaluation

2. Materials and Research Division will furnish a profile index to the contractor within 72 hours of the completion of the tests.

Z. Smoothness of Bridge Decks

1. Checklist - The following items should be checked and procedures followed prior to, during, and after the overlay is placed to insure a smooth riding deck surface:

   a. Guide rails are used to support and guide the finishing machine. Check for rail deflection during passage of finish machine. Any vertical or horizontal movement could compromise smoothness and rideability. Request that the contractor readjust anchor legs and/or tie-downs.

   b. Check that all propulsion and control equipment are fully operational prior to placing concrete. The contractor shall traverse the finishing machine over the entire length of section to be placed. This not only serves to verify that equipment and control systems are functioning properly, but also provides a check to assure that screeds are adjusted for proper crown and height above existing surface.

   c. Sufficient materials (water, cement aggregate, and admixtures) are available on site to complete the intended placement in a continuous operation.

   d. The contractor may have to limit size of placement or provide additional mixers (HD-LS only).

      (1) If a mobile mixer is not large enough to provide adequate volume for the placement, or

      (2) If there is no provision for recharging.

   e. Ensure that adequate number of vehicles are available at the work site to transport mix from mixer to the placement area at a volume necessary to provide a uniform rate of forward progress. Any equipment working on the deck should be checked for oil and hydraulic fluid leaks.

   f. Contractor must provide sufficient, trained personnel to carry out the various phases of deck placement. Timeliness is of utmost importance during placement operations. Be sure specialized crafts, such as finishers, are adequately represented and preferably have only one task during the placement.

g. Check concrete for smoothness with the 10 ft (3 m) straightedge. The straightedge should be placed on the surface from a vertical position, not pushed over the surface. Irregularities can be detected by comparing deck surface with a straightedge. Irregularities noted at this time should be corrected.

2. Surface Correction

a. Corrective work shall be done in the presence of the Engineer with a diamond bladed grinder at least one meter wide. Grinding residue must be controlled. After the deck is ground, a second test will be made to determine if the deck now meets the smoothness requirements. This second test will also be performed by Materials and Research personnel and it is anticipated they will be on-site at the time of grinding, in order that they may perform the retest while the grinding equipment is on-site.

3. Acceptance

a. Materials and Research personnel will notify the Project Manager whether or not the corrective work has resulted in an acceptable deck surface. If grinding cannot correct the surface profile, the Specification requires removal and an overlay with high-density low slump concrete.

b. Troubles and expense of this sort could virtually be eliminated by careful and detailed inspection by project personnel during construction and proper handling of test cylinders.

4. Missed Texturing

a. There will be times, due to various reasons, when texturing will have to be omitted from a pour. One such event could be when inclement weather catches a pour and covering prevents texturing. Obviously this condition is **NOT** desirable.

b. After full cure time has expired, grind in the required texture.

AA. Approach Sections--Bridge Approach Tapers

1. On deck overlay construction, normally some treatment of the approach is necessary and will be indicated on the plans. Watch the contract documents for bid items for ACC material. For projects where asphalt tapers are proposed and no quantity for ACC is given, an extra work order will be required.

a. Shoulder Maintenance - When temporary concrete barrier rails are used on deck repair and overlay jobs, traffic is constricted into a narrower lane. This in turn could cause a rapid deterioration of shoulders at bridge approaches and require the following corrective measures:

(1) Ruts developing in earth and granular shoulders should be repaired as necessary with a granular surfacing material. This is extra work order and a change order will be issued for this work.

(2) Ruts and loss of asphaltic cement concrete surfacing on Interstate shoulders should be repaired using an asphalt cement concrete pre-mix, hot mix, or some similar treatment to minimize the development of holes or ruts. A change order may be needed for this work unless there is an ACC contract item for shoulder maintenance and even then it may have to be extended.

(3) When shoulder strengthening was not included as a bid item, but is needed for the project, the change order must consider:

(a) Present shoulder construction and experience with shoulder stability in the immediate area.

(b) Traffic volumes, percent of trucks, and duration of potential problem.

BB. Setting Beams

1. The following should be used as a guide in conjunction with *SSHC Section 704*:

a. On diaphragm piers, beams may be set as soon as doing so will not mar or chip the concrete. It is recommended that 24 hours be considered a minimum cure time. (In cooler weather, ambient temperatures below 40°F (5°C), the minimum time indicated should be increased to 48 hours.)

b. No beams may be set on piers until the cap concrete is at least 7 days old and has its design compressive strength.

c. On stub abutments, steel beams and girders may be set as under A above. Concrete beams on stub abutments, same as A above. On full abutments (solid and continuous from spread footing), same as A above.

706.04 METHOD OF MEASUREMENT

A. The cubic yards of concrete for structures of varying sizes are computed from dimensions shown in the plans and placed in tables in the plans. All structures using the same type of concrete are lumped together.

707.00 BRIDGE DECKS AND OVERLAYS (*SSHC Sections 710 and 711*)

707.01 DESCRIPTION

A. The concrete bridge floor is the wearing surface of the bridge superstructure and is commonly referred to as the bridge "deck". This work consists of forming, reinforcing, and placing concrete to the lines, grades, and typical cross sections shown in the plans.

707.02 MATERIAL REQUIREMENTS

A. See Subsection 706.02

B. Density Testing

1. Durable, low maintenance bridge decks require impermeable (very dense) concrete. Therefore, checking density during placement is an essential part of deck surfacing and overlay inspection. Test frequencies for determining the density of bridge deck surfacing and overlays are listed in *SSHC Subsection 711.04*. A test should be taken at 5 ft (1.5 m), 10 ft (3 m), 15 ft (4.5 m), and every 50 ft (15 m) thereafter per placement width per bridge. Density tests will not be required for overlaying approach paving areas.

2. It is always desirable to take more than the minimum nuclear density tests per length of overlay placed. If densities are at or near the lower specification limits, additional testing will need to be performed.

3. Vibrating Mix at Test Well Location

   a. On some projects, contractors have been vibrating the concrete mix in the test well with a hand-held vibrator prior to passage of the finishing machine. This practice will not be permitted.

   b If the oscillating screed vibrators are functioning properly, complying density of the concrete mix in the test well will be obtained without any difficulty. Obtaining required density at test well locations, without supplemental vibration, assures us that the contractors' equipment and placement procedures are capable of producing the desired results throughout the overlay being placed.

4. Density Test Wells on Bridge Deck Repair Projects

   a. Follow guidelines in *SSHC Subsection 710.04, para. 7.b.*

707.03 CONSTRUCTION METHODS

A. General – The wind velocity-temperature relationships stated in the specifications should be enforced to avoid loss of water from the concrete surface faster than it can be replaced by normal bleeding and to avoid the resultant formation of plastic shrinkage cracks. Anemometers and thermometers must be available on site to measure wind velocity and temperature.

1. Concrete in bridge floors shall be placed uniformly on both sides of the centerline and shall be placed continuously between specified joints. The sequence of placing shall be in accordance with the pouring diagram shown in the plans. If no pouring diagram is shown in the plans, concrete shall be placed as directed by the Project Manager.

2. The deck forms shall be dry when using HD-LS but must be wet when using silica fume concrete before placing the concrete. Concrete shall be adequately vibrated to encase the lower bars of the reinforcing mat where these are near the deck form.

3. Special attention shall be given to finishing the riding surface on the bridge floors. *SSHC* Subsections 706.03, 710.03, and 711.03 explain concrete bridge floor finish.

4. It has been the policy to permit the contractor to use mechanical finishing machines of an approved type whether or not they are required by the plans or special provisions.

5. Method of Finish - When the hand method described in Section 704 is employed, the concrete surface shall be struck off with a strike board which conforms to the cross section shown in the plans. If this is pulled by hand, care shall be taken not to displace the reinforcing steel by the workmen doing the pulling. A small air winch anchored to a girder outside of the day's pour will pull the strike off at a slow, uniform rate, giving a truer surface with no displacement of the reinforcing steel. The strike board shall be operated with a combined longitudinal and transverse motion, always carrying a small roll of concrete in front of the cutting edge. The strike off shall be pulled a sufficient number of times to properly distribute the concrete. A longitudinal float generally is required and is described in

6. *SSHC Section 704.* The longitudinal float shall be lapped 1/2 its length when moved to a new position and shall be operated across the surface a sufficient number of times to produce a uniform, smooth riding surface. Occasionally during the finishing operation, conditions may require the use of the long-handled transverse float, which require extreme care in its use to preserve the desired cross-section and a smooth riding surface.

7. Regardless of whether hand or machine finishing methods are used, the floor surface shall be tested for trueness with a 10 ft (3 m) straightedge. The bridge contractor is required to furnish a 10 ft (3 m) master straightedge for use in trueing and checking the working straightedges.

8. Phased construction of a bridge deck usually requires a form longitudinally down the bridge deck near the center of the bridge. The location of the form is shown in the plans. Sometimes it is more efficient to move the location of the longitudinal phasing joint. On bridges with concrete girders it is nice if the joint can be lined up to use the notched lip in the girder flange. However, the resulting lane widths must be checked to confirm there is adequate clearance for vehicles.

B. Bridge Deck Curing

1. When the high temperature for the day that the deck will be cast is expected to exceed 80°F the deck should be cast at night. The Contractor should contact the concrete plant and schedule the concrete deliveries to the bridge deck to begin at 5:00 pm. The Contractor must also confirm that the concrete will have a 1-hour set delay when it arrives on the deck.

C. Bridge Deck Joints

1. If a joint compound is not specified the Contractor may use hot tar to seal bridge deck joints.

E. Deck Overlay Preparation

1. Securing an adequate bond at the interface of the existing prepared deck surface and proposed overlay course is essential in obtaining a durable and maintenance free bridge deck system. General surface preparation requires milling, shotblasting, and/or sandblasting depending on the surface condition or amount of existing surface material to be removed. Any reinforcing bar which is exposed must be sandblasted to remove all rust contaminants, and unsound concrete. Also, prior to placing the grout the surface must receive an air blast to remove dust and other foreign particles from the prepared surface.

2. The surface, once cleaned, must remain clean until the grout and concrete is placed. There have been cases where the prepared deck surface has become contaminated during the decking operations by concentrated traffic of vehicles transporting the concrete. This is especially true when the skid-steer type loaders are used to transport mix. The deck surface is contaminated by the abrasive action between the concrete surface and the rubber tires, and also from oil and other foreign material tracked in from off the bridge. Contamination can be recognized by discoloration or oil on the deck surface. Contamination is especially noticeable in the wheel paths used by the vehicles.

3. Core specimens taken and tested for bond strength from areas as mentioned above showed a marked decrease in bond strength between the interfaces.

4. To prevent the cleaned deck surface from being contaminated by traffic, the contractor shall cover any prepared surface with sheets of plywood, multiple layers of plastic, or other suitable material. To ensure a clean surface prior to placement of the overlay system, areas which become contaminated shall be resandblasted followed by an air blast.

F. Class I Floor Repair (*SSHC Sections 710 and 711*)

1. Follow guidance in SSHC Subsections 710.04, para. 1 and 711.04, para. 1.

G. Work on Adjacent Lanes

1. *SSHC Section 423* prescribes traffic provisions when traffic is present.

708.00 Bridge Diaphragms

A. Steel diaphragms, if allowed, are shown in the plans for prestressed beam structures. Shop drawings are required for steel diaphragms showing details of beam layouts, location of the diaphragms, and location of mounting holes.

1. High strength bolts for steel diaphragms shall be tightened by Turn-of-Nut method. (Refer to *SSHC Subsection 708.03* for information on proper bolt inspection and installation.) Inspection and field installation acceptance will be based on observing proper Turn-of-Nut procedures. (A tensioning device and inspection torque wrench is recommended, but will not be required.)

2. Concrete diaphragms at piers of prestressed concrete girder bridges should be cast to 2/3 of their intended depth. The final 1/3 and the deck are then placed at the same time. However, there are instances where allowance has been given for specific diaphragms to be placed prior to slab placement. If there is a construction option shown in the plans, the diaphragm can be poured separate from the deck. Note the construction joint detail will show how to strike-off the surface. Consult with the Construction Division in situations where the contractor requests to place concrete diaphragms other than as shown in the plans.

3. Phased bridge decks which have inverted “T” girders should not have the portion of the diaphragms cast between the two girders on each side of the longitudinal phasing construction joint until the second phase deck is cast. If the girder diaphragms for the gap between the two girders which are on each side of the phasing joint are cast before the second phase deck is cast, the diaphragms will lock the girders under the second phase deck at a position higher than the phase 1 girders. Cast the diaphragms between the two girders that are on each side of the phasing construction joint at the time the second phase deck is cast. The remaining girder diaphragms in the second phase should be cast before the deck is cast.

    a. Casting the intermediate (midspan) diaphragms before the deck is cast removes some of the girder camber and will make the structure more stable for the deck casting.

709.00 Girder Shims

A. Definition

1. A girder shim is defined as the distance measured from top of girder to top of finished slab. There are three different types of bridges which we build that have girder shims. The first type is a steel girder bridge, either a rolled beam section or a plate girder section. The second type is a prestressed girder (NU Girder Section). The third type is a prestressed twin tee girder. When taking shim shots on a prestressed twin tee girder, they should be taken at the edges of the twin tee. Take shim shot on steel girders or NU girders along the girder centerline.

2. For each type, the definition of the girder shim is the same; girder shim is the distance measured from the top of girder to top of finished slab.

3. Stages of the Girder Shim Process The Bridge Division, upon completion of the design, will prepare the shim input forms. After the project has been let, we send these forms to the Project Manager. After the girders are erected and prior to forming the deck for the slab, shim shots are required to be taken. These shim shots should be taken at the bearings, field splices, and at 3 m intervals along the length of the girder. The shim shots can be recorded on the input forms.

4. The H.I. Elevation needs to be recorded by the inspector at the time the shim shots are taken.

5. The rod readings at each location are recorded on RDP Form 50a. This information is normally sent by computer to the Bridge Division. The Bridge Division will run a computer program which uses the grade of the roadway, crown of roadway, the dead load deflection of the girder, and your rod readings to determine the amount of shim at each location.

6. The Bridge Division will look at the shims to see if they are too large or too small. The final shim information will be sent to the Project Manager along with solutions to any problems which may have occurred.

7. The proper girder shims are critical to ensure that construction of the bridge is in accordance with the intended design.

8. Composite Girders

    a. There are two methods of designing girders. One method is a non-composite design and the other method is a composite design. The non-composite design is basically the slab sitting on top of the girders. By providing shear connectors on the top of the top flange, we can tie the slab to the girders into what we call a composite section. On prestressed girders, the stirrups extending out of the girder into the slab provide the composite action. The composite section produces a more economical design. The Bridge Division designs the girders as a composite section.

    b. AASHTO Specifications

(1) In order for this composite action to actually take place, it is critical that these shear connectors extend into the slab the proper amount. For steel girders, AASHTO specifications require that the shear connectors penetrate at least 2 inches (50 mm) above the bottom of the slab.

(2) The AASHTO specifications also state that the clear depth of concrete over the tops of the shear connectors for steel girders shall not be less than 2 inches (50 mm). So this gives the Bridge Division a range for the location for the top of the shear connectors.

(3) Proper vs. Improper Shims

(4) When you are inspecting a job, a visual inspection of the relationship of the shear connectors to the slab reinforcement will help you determine if something is wrong. Based on the slab thicknesses that we normally use [7.5 inches (190 mm) or 8 inches (205 mm)] thick, the length of stud that we normally use [5 inches (125 mm long)] and if the slab is reinforced, the end of the sheer connector should be located somewhere between the top and bottom transverse slab reinforcing steel.

(5) We specify 1 inch (25 mm) of clearance between the bottom of the slab and the bottom transverse reinforcing steel. A ¾ inch (20 mm) bar is the largest bar specified. Therefore, knowing that we need 2 inches (50 mm) of penetration for the shear connectors, the top of the shear connector should always be above the transverse bar in the bottom of the slab.

3. Problems and Solutions

a. When we have the problem of too large of a shim, there are a couple of things we can do to solve this problem. One solution is to provide some reinforcing bars at each shear connector location that properly extend into the slab. Another solution is to weld a plate onto the top of the shear connectors to gain the proper penetration length.

b. Where we have the problem of too small of a shim (top flange extending into the slab) there is only basically one thing you can do. That is to raise the grade of the roadway.

4. Critical Item - Proper Girder Seat Elevations

a. The most important thing that our inspectors can do to insure proper shims is to make sure that the girder seats are poured to the proper elevations. If the girder seat elevations are wrong, you can almost be sure that you will have problems with your shims. If your girder seats are correct, more than likely your shims will also be correct.

5. Critical Item - To Ensure Proper Shim

   a. Steel girders must be set on substructure by following the blocking diagram shown on the plans.

Example Computer Print

IDENT	PROB. NO.	GIRD. NO.	DIST. CL PROJ. TO CL ROADWAY	E FROM BASELINE	H.I. ELEV.
7018	1	1	O.C.	10.0000 LT.	1719.24

Girder No.	Station	Centerline Grade	Crown Correction	Girder Elevation	Dead Load Deflection	Rod Reading	X Distance	Shim
1	22+10.77	1715.662	-0.150	1714.920	0.0	4.32	0.0	0.592
1	22+20.77	1715.753	-0.150	1715.020	0.015	4.22	10.00	0.598
1	22+30.77	1715.840	-0.150	1715.100	0.023	4.14	20.00	0.613
1	22+40.77	1715.925	-0.150	1715.180	0.021	4.06	30.00	0.616
1	22+50.77	1716.006	-0.150	1715.260	0.011	3.98	40.00	0.607
1	22+60.77	1716.084	-0.150	1715.320	0.001	3.92	50.00	0.616
1	22+65.77	1716.122	-0.150	1715.350	0.0	3.89	55.00	0.622
1	22+70.77	1716.189	-0.150	1715.370	0.004	3.87	60.00	0.644
1	22+80.77	1716.281	-0.150	1715.470	0.019	3.77	70.00	0.630
1	22+90.77	1716.300	-0.150	1715.490	0.033	3.75	80.00	0.693
1	23+ 0.77	1716.365	-0.150	1715.550	0.040	8.69	90.00	0.705
1	23+10.77	1716.427	-0.150	1715.610	0.033	3.63	100.00	0.701
1	23+20.77	1716.486	-0.150	1715.700	0.019	3.54	110.00	0.655
1	23+30.77	1716.342	-0.150	1715.730	0.004	3.51	120.00	0.666
1	23+35.77	1716.588	-0.150	1715.770	0.0	3.47	125.00	0.648
1	23+40.77	1716.594	-0.150	1715.810	0.001	3.43	130.00	0.636
1	23+50.77	1716.644	-0.150	1715.860	0.011	3.38	140.00	0.645
1	23+60.77	1716.690	-0.150	1715.900	0.021	3.34	150.00	0.661
1	23+70.77	1716.733	-0.150	1715.950	0.023	3.29	160.00	0.656
1	23+80.77	1716.773	-0.150	1715.980	0.015	3.26	170.00	0.658
1	23+90.77	1716.809	-0.150	1716.010	0.0	3.23	180.00	0.649

710.00 Pot Bearings

A. The Materials and Research Division inspects pot bearings at the site. In order to facilitate the work, we request that the Materials and Research Division be notified immediately when the pot bearings arrive at the site. This will permit Materials and Research personnel to inspect the bearings in a timely manner.

B. The person to notify is Mr. Mark Burham at Materials and Research. His phone number is (402) 479-4746.

711.00 Barrier Rails

711.01 Description

A. Fixed Form Jersey & Retrofit Rail

1. Before cast-in-place barrier rail is constructed on the existing bridge curb section, *SSHC Subsection 704.03*. requires that old concrete which is to be in contact with the new concrete be cleaned of all laitance (loose particles of concrete, dirt, or other foreign materials).

2. Structurally, the existing curb surface need not be roughened, but must be clean. To assure a clean surface and to obtain maximum bond at the interface, sandblasting the old curb surface shall be required. Other methods of cleaning may be approved by the Project Manager.

3. Surface preparation, such as sandblasting, should be completed prior to setting the epoxy coated dowels.

4. When retrofit is part of a deck overlay, the contractor may request permission to place the finish machine on the retrofit rail. Construction's policy will be:

   (a) A minimum cure time of at least 48 hours prior to placing the mass of a finish machine on the rail, AND

   (b) Finish machine rail support feet must be spaced less than 1’-9” (550 mm) apart.

      (1) If these conditions are unacceptable to the contractor, a minimum cure time of 72 hours will be required. After 72 hours there are no special conditions for placing a finishing machine on the barrier rail.

B. Cast-In-Place (Retrofit) Barrier Rail

1. This work is routinely combined with a deck repair project and includes an overlay. Often contractors will place the new rail prior to placing overlay. In these situations, the contractor intends to place the finish machine's rail on top of the new barrier rail. Question: How long must the new rail cure before allowing the deck finishing machine to be placed on it?

   a. 48 hours must expire prior to placing the weight of a finishing machine on the rail.

   b. Rail supports (legs) must be placed at a spacing of no greater than 18 inches (500 mm).

   c. Rail supports and rail cannot be placed until the surface has sufficiently cured to prevent scuffing and/or marring.

   d. Care must be taken to prevent damage to the face or back of the barrier rail.

C. Slip Form Barrier Rail

1. Slip form rails have at times displayed transverse cracks, longitudinal cracks, reinforcing steel shadows, and nonuniformity of top elevations. Consideration of the following construction problems and solutions will help to eliminate problems:

2 Longitudinal Cracks

(a) Longitudinal cracks and vertical cracks near posts can be prevented with proper construction techniques. (Consolidate uniformly, obtain proper rebar clearance and wet cure.)

711.02 Material Requirements (See Section 706)

711.03 Construction Methods

A. Concrete Surface Finish (Rail and Beams)

1. Ordinary surface finish is required for rails. Beams need only have "popcorns" filed.

B. Surface Finish

1. The type of surface finish required for concrete structures is governed by the special provisions, the plans and *SSHC Subsection 704.03*. A pre-construction study of these sources will bring to light any possible differences of opinion concerning requirements and allow time for their solution.

2. For either ordinary surface finish, rubbed finish, grout cleaned finish, or floated surface finishes, the contractor should be required to perform the work as promptly as practical after the removal of the forms. If this work is started promptly, and the surface finishing work performed before the concrete becomes excessively hardened, a much better surface finish will be obtained. Also, this better finish will be obtained with less work and consequently at lower cost.

3. If the required finish is a rubbed finish, then *SSHC Subsection 704.03* does not authorize plastering an excess of mortar on the surface of the concrete. The mortar is to be applied, as stated in the Specifications.

4. Note that proper rubbing is a sequence of three steps:

a. The surface is thoroughly saturated and then rubbed with the medium coarse stone faced with mortar. The paste (rubbed up from the surface of the concrete, and not applied as a plaster) is left on.

b. The surface is wetted and rubbed with a fine carborundum stone. The paste is left to dry on the surface.

c. The dried paste is rubbed off completely with burlap. Some laborers will not distinguish between coarse and fine stones, or the contractor may originally furnish only one grade. Check with the Project Manager as to the proper degree of fineness of the stones being used, on the basis of the finished results. Request the Project Manager's inspection of the first finishing work done in order that he/she can set standards for methods and results in subsequent work. Ordinary surface finish, rubbed finish, grout cleaned finish, and floated surface finishes include leaving all chamfer lines and all plane surfaces intersection lines cut clean and straight.

5. Special provisions currently allow the use of a special surface coating as an alternate to a rubbed surface finish.

6. Special attention and inspection should be given to the close tolerance required in finishing of the concrete at the bearing plate areas on abutment and pier caps. Promptly after the concrete has hardened sufficiently, remove the anchor-bolt templates and finish the bearing area to a true surface. A small carpenter's level is very helpful to level the area. Prompt and efficient performance of this work will save much grinding of the hardened concrete at the time the bearing plates are set, and will yield better, more uniform bearing areas.

NOTE: To enhance the ability to hand finish slipped rail, CONFlLM is recommended. CONFlLM is a Master Builders product and should be used per manufacturer's recommendations.

712.00 HAND RAILS (*SSHC Section 716*)

712.01 DESCRIPTION

A. This work shall consist of furnishing and erecting all steel or ornamental handrail and all miscellaneous hardware such as anchor bolts, capacity plates, and splices.

712.02 MATERIAL REQUIREMENTS

A. Handrails shall conform to the horizontal and vertical curves specified in the plans. Posts shall be set normal to the top of the curb, except when otherwise noted in the plans or special provisions.

712.03 CONSTRUCTION METHODS

A. Ornamental Handrail

1. Care must be taken in storing, handling, and erecting ornamental handrail so as not to permanently mar or injure the finish on the post and rail elements. Aluminum ornamental handrail which is to be stored in the open should be removed from the cardboard cartons since cartons may stain the handrail when they become wet and considerable effort is required to remove these stains.

2. Ornamental handrail inspection is not generally waived at the fabrication plant even if small quantities are involved. If the Project Manager does not have a copy of a shop inspection report on file indicating inspected material, the material should be inspected by Materials and Research Division. If there is a question of whether the material has been inspected or not, the Materials and Research Division should be contacted for clarification.

3. The Project Manager should make a visual check of the handrail before placing it in the structure. In the case of aluminum tubing, "carbon streaks" that develop in the manufacturing process are not cause for rejection. However, the carbon streaks should be limited to one 90-degree segment of the surface of any rail. Particular attention is necessary at the time of erection. Tubing should be placed in the bridge railing in such a manner that the carbon streaks are not visible to traffic.

713.00 PAINTING (*SSHC Section 709*)

713.01 DESCRIPTION - The painting of metal structures has a dual purpose. The primary function of paint application is to preserve the life of the metal. A second function, especially important in highway grade separations, is to produce and maintain an improved appearance. Painting includes the preparation of the surface and the application of the paint coatings.

A. Painting (*SSHC Section 709*)

1. New Non-Weathering Structural Steel

   a. Shop applied paint system shall be used for non-weathering steel bridges.

   b. A field applied "top coat" is usually required. A top coat will also be required when it is deemed necessary due to aesthetics.

   c. The contractor will be required to touch-up any damaged areas after erection. Touch-up with top coat paint system shall be the same paint as the shop coat.

2. New Weathering (ASTM A 588) Structural Steel

   a. The plans require shop applied prime paint to selected areas on the structure. They also require:

   b. The approved paint system.

   c. Only paint where shown in the plans with approved paint system.

   d. The contractor to touch-up any damage to primed areas after erection prior to top coating. This includes bolts in those areas. Touch-up paint shall be the same paint as the shop coat.

3. Field Painting

   a. Field painting of structural steel shall be done as shown in the plans and special provisions.

713.02 MATERIAL REQUIREMENTS - Paint sampling should be done according to the "*Materials Sampling Guide*" unless the paint to be used is from tested stock in which case it will be tagged to show acceptance.

A. Mixing Paint

1. Follow the manufacturers recommended mixing and thinning procedures.

713.03 CONSTRUCTION METHODS

A. Painting Structural Steel

1. Paint which has been applied on rust, or dirty surfaces will peel and crack. If rust blisters form under the paint film, they can, in time, seriously reduce the effective cross section of structural shapes. The specifications require that all erection work be completed before the cleaning process is started. The cleaning should be done in a systematic manner, with the painters cleaning a given area or member before painting it.

2. Paint shall be applied as prescribed by contract specifications or the manufacturer's recommendations, whichever is most demanding. The Project Manager shall determine the correct procedure if the contract specifications differ from the manufacturer's recommendations.

3. The Project Manager or inspector should insist that the painting be done systematically, with painters working in groups on a given coat. The practice of having cleaners and painters spread out all over a bridge, with the inspector not knowing what men are working on each operation, nor which members have been cleaned and painted, should not be permitted. Painting should, in general, be started with the highest bridge members and progress downward, in order to cover areas where paint has dripped from the work above. Painting operations below deck level, should be permitted only after the deck slab concrete has been placed. Girders painted prior to the concrete placement are likely to be spattered by form leakage and may be badly scarred by form removal, necessitating considerable recleaning and repainting of all coats.

4. The plans and specifications require different paint film thickness depending on the type of paint specified. The Project Manager should check the plans and specifications to determine the types of paint required to verify that the correct system has been certified and should check for the required dry film thickness.

   a. County bridges usually only get one coat.

   b. New state structures usually get two coats.

   c. Repainting an existing structure usually means adding a third coat.

5. The Project Manager or inspector should check the dry film thickness of the shop and field coats of paint applied on structural steel in accordance with the following instructions:

6. Shop Coat - The shop coat of paint may or may not have been checked in the fabricator's shop; nevertheless the shop coat should always be checked in the field, and any deficiency in paint film thickness corrected, before the second coat is started. When the dry film thickness of the shop coat is found to be inadequate, the Materials and Research Engineer should be notified in order that the particular fabricator involved may be made aware of the situation.

7. Second and Third Coats - Checking the thickness of the second and third coat with the magnetic gauge is accomplished by measuring the cumulative thickness of the first (or shop coat) and the additional coats. The dry film thickness of the second coat should always be checked and any deficiency in paint film thickness corrected before the third coat is started. Any deficiency in paint film thickness must be corrected before the work can be considered complete and consideration of acceptance given.

8. The equipment used to check the dry film paint thickness is called a magnetic dry film thickness gauge. One or two of these gauges are being furnished to each District Office for use in the District in checking the painting of steel structures. These gauges are expensive, delicate instruments and must be carefully handled and always kept in the carrying case when not in use. The procedure for using the gauge is as follows:

   a. Turn dial to maximum reading.

   b. Place pole on the surface to be measured.

   c. Be sure the magnetic contact is touching the painted surface.

   d. Slowly and as continuously as possible, rotate the dial clockwise until magnetic contact breaks. A click will be heard when the pin breaks contact. At this point the coating thickness can be read on the dial indicator. The reading will remain on the dial when the gauge is removed from the surface being checked. The gauge can also be held in any position to take a reading. The magnetic gauge reads directly in mils. A reading of 2 on the dial indicates that the thickness of the paint film is 2 mils or .002 inch.

9. The frequency of testing for paint thickness should be as follows:

   a. Girders - Each line of girders should be checked at a maximum interval of 50 ft (15 m) and at each check point, 3 or 4 tests should be made. For example, on a 200 ft (60 m) bridge each line of girders should be checked at the abutments and at 3 intermediate points. At each one of these points three or four places should be checked such as a point on the web, a point on each flange, and a point on a stiffener.

   b. Separators, Cross-frames and Floor Beams - Alternate lines of separators, cross-frames and floor beams should be checked two times at one location. For example, the top and bottom angle should both be checked for every other line of cross-frames.

   c. Lateral Bracing - Lateral bracing should be checked at about 50 foot intervals.

   d. Miscellaneous Material - Material such as expansion devices, tie rods, bearing plates and drainage systems should be spot checked for required paint film thickness.

10. Additional tests should be made, as required, to determine the extent and location of any areas deficient in paint film thickness.

11. The bridge notebook or diary should verify that the paint film thickness on each structure meets the thickness requirement specified, and the entry should include the signature of the inspector and date of inspection.

714.00 CULVERTS (*SSHC Sections 717 to 726*)

714.01 GENERAL

A. The backfill near a pipe or box culvert is more expensive than excavation in the surrounding area. Therefore, in the *SSHC Subsection 702.03*, limits are placed on the quantities "Excavation for Box Culvert" and "Excavation for Pipe, Pipe-Arch Culverts, and Headwalls."

715.00 CONCRETE BOX CULVERTS (*SSHC Section 717*)

715.01 DESCRIPTION

A. A culvert may be defined as a structure to convey water under a roadway. Concrete box or arch culverts are used when drainage areas are too large for the conventional culvert pipe or when cattle passes under the roadway are desired. These structures are cast-in-place according to standard or special plans under *SSHC Sections 702, 704, 705 and 717.*

B. The contractor may request that culverts be built to the nearest whole English units. Any material savings will be deducted from the payments due the contractor.

715.02 MATERIAL REQUIREMENTS

A. See Section 706.02. Note in SiteManager the date the reinforcing steel is verified on-site.

715.03 CONSTRUCTION METHODS

A. General - The concrete placement for box and arch culverts is discussed in Section 706 of this manual. *SSHC Subsection 717.04* further provides that foundation excavations shall be "as dry as practicable before concrete is poured". This requirement recognizes the necessity of an adequate foundation for roadway structures. When the excavation for a footing is completed, the project manager or his/her representative should be contacted for his/her approval of the footing subgrade before any concrete is placed. In the event that unsuitable foundation subgrades are encountered, suitable ones composed of sand, gravel, concrete aggregates or a concrete seal course must be constructed (see *SSHC* Subsections 702 of this manual).

1. Construction of curtain walls on culvert footings usually is quite a problem because of the difficulty in maintaining the excavation in proper condition while placing concrete.

2. If material to be excavated is of such nature that neat lines for the curtain wall cannot be maintained, the Project Manager may allow forming and placing the curtain wall to the bottom of the footing. Mud must be prevented from working up into the concrete.

3. Currently, the plans for box culverts show the backside of the wing battered 3/8" in 12", which results in a varying wall thickness. Contractors may be permitted to construct walls using the wall's base thickness, thus eliminating the batter. A plan revision or change order will not be required to effect this change.

B. Placing Concrete and Form Removal

C. Placing Concrete

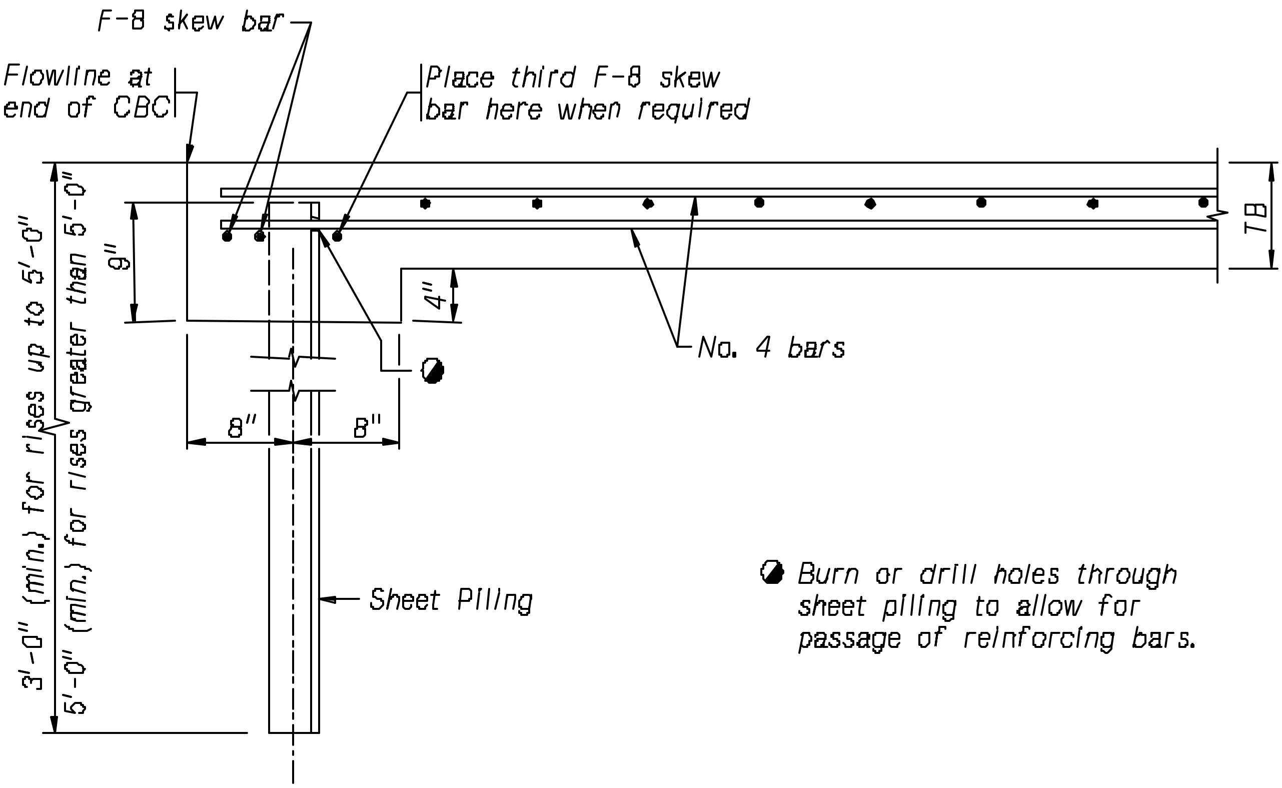
1. Placing Concrete in Walls and Top Slab. *SSHC Subsection 704.03* states that culvert, sidewalls, and top of slab may be constructed as:

    a. A monolith unit or,

    b. Concrete in sidewalls may be placed and allowed to harden before the top slab is placed.

2. If the contractor chooses to use the hardened concrete method, keyways will have to be installed to anchor the cover slab.

D. Sheet Pile Turndown. Option to Use Steel Sheet Piling in Lieu of the Planned Turndowns at Box Culvert Ends.



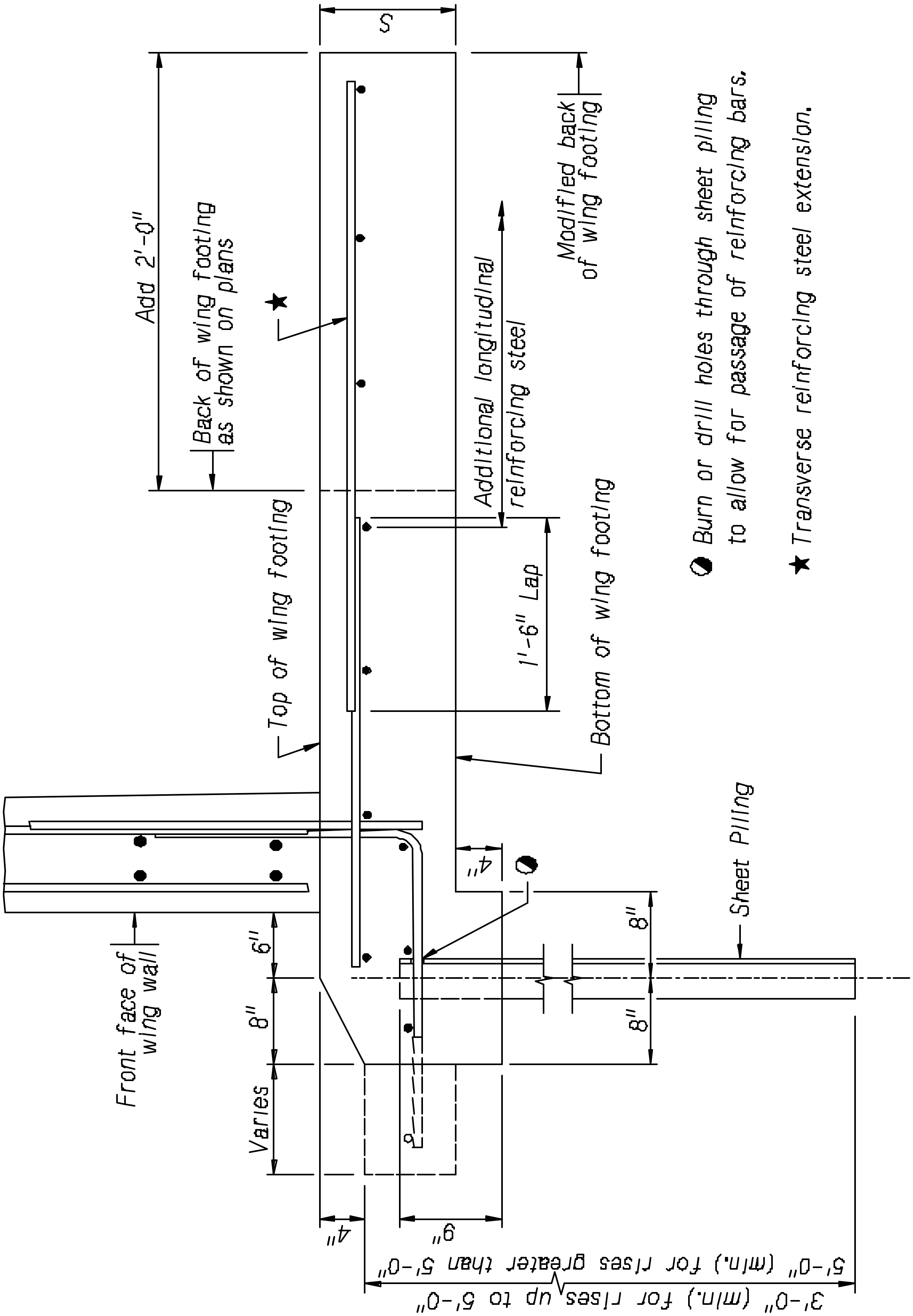
OPTIONAL SHEET PILING TURNDOWN AT END OF BARREL FLOOR

(Longitudinal section taken at midspan)

NOTES

The wing footing width, including the horizontal taper (dimension P to dimension Q), must be increased at the same footing thickness by an additional 2'-0". Additionally, the distance from the top of the wingwall footing to the bottom of the sheet piling turndown shall be 3'-0" for rises up to 5'-0", and, 5'-0" for rises greater than 5'-0". This option shall include the extension of the transverse reinforcing steel, placement of additional longitudinal reinforcing (same spacing as the No. 4 bars in the top of the footing), and the placement of additional concrete. The wing footing extension shall be poured monolithically with the rest of the wing footing. All sheet piling, additional concrete, reinforcing steel, preparation, equipment, tools, labor and incidentals necessary to complete the work shall be supplied at no additional cost to the Department.

All sheet piling shall be interlocking. Steel sheet piling shall have a 7 gage thickness (minimum). Plastic sheet piling may be used with permission from the Bridge Division.



OPTIONAL SHEET PILING TURNDOWN AT WING FOOTING
(For concrete box culvert wings)

E. Removal of Wall Forms

1. On large culvert jobs, it is a distinct advantage for the contractor to remove wall forms before the top slab has attained sufficient age to remove supporting forms. This will be permitted under the following conditions:

   a. Vertical forms may be removed as provided in *SSHC Subsection 704.03*.

   b. Slab forms must be supported independently of the wall forms.

   c. Vertical supports for the slab forms must be capped with timbers. Longitudinal spacing of supports with 4x6 inch (100 x 150 mm) caps on edge should not exceed 4.5 ft (1.4 m). With 4x8 inch (100 x 200 mm) caps, spacing should not exceed 6 ft (1.8 m). Rows of supports must not be over 4 ft (1.2 m) apart. There must be at least two rows of support, with the outside rows not more than 2 ft (0.6 m) from walls. Variance from the above suggested spacing should be reviewed by the Project Manager.

   d. Vertical posts shall not be smaller than 4x4 inches (100 x 100 mm), but may be built up of two 2x4 inches (50 x 100 mm) pieces of lumber. Lateral bracing will be required. A vertical clearance of ¼ inch (6 mm) must be provided between the wall form studs and the slab form joists.

NOTE: Lumber may be sized in metrics using actual, not the conventional nominal sizes.

   e. The slab form must remain in place as provided in *SSHC Subsection 704.03*.

   f. The interior walls of the culvert must be coated with white pigmented curing compound as provided in *SSHC Subsection 704.03*.

F. Flume Reinforcement

1. Regarding Type I, II, IV, and V Flumes, welded wire fabric reinforcing is now required on the Special Plan C (4341, 4342, 4344, 4345 – both E & M) for the flume and spillway areas. This wire can be awkward to place and keep in position. Contractors may place **intersecting No. 3 rebar at 12" centers** as an alternative to the welded wire fabric.

G. Backfilling Culverts – Typical Grading

1. The plans define the area used to calculate plan quantities for flowable mortar and granular backfill. (Flowable mortar plan quantities should include 30% additional for anticipated consolidation of the granular backfill and shrink due to loss of water.) If the Contractor opts to excavate a larger area than assumed for plan quantity, additional excavation, backfill, and flowable mortar will not be considered for pay. We will however, require additional excavation to be backfilled in a manner as identified by the plans or typicals.

2. Placement of flowable mortar shall always be computed from "top down." This means allow for:

a. Pavement thickness.

b. 1 foot (0.3 m) of special backfill, if required.

c. Variable thickness of earth fill where cover heights are over 8 ft (2.5 m).

H. Joints (*SSHC Subsection 704.03*)

1. The location and dimensions for construction joints will generally be shown on the plans.

2. In cases where the pour is larger than can be accomplished at one time, or for some other reason it is necessary to make a construction joint not shown on the plans, approval should come from the Construction Engineer.

3. When an emergency arises, construction joints shall be placed as directed by the Project Manager. If there is some doubt as to the proper location of the joint, the District Construction Engineer should be contacted.

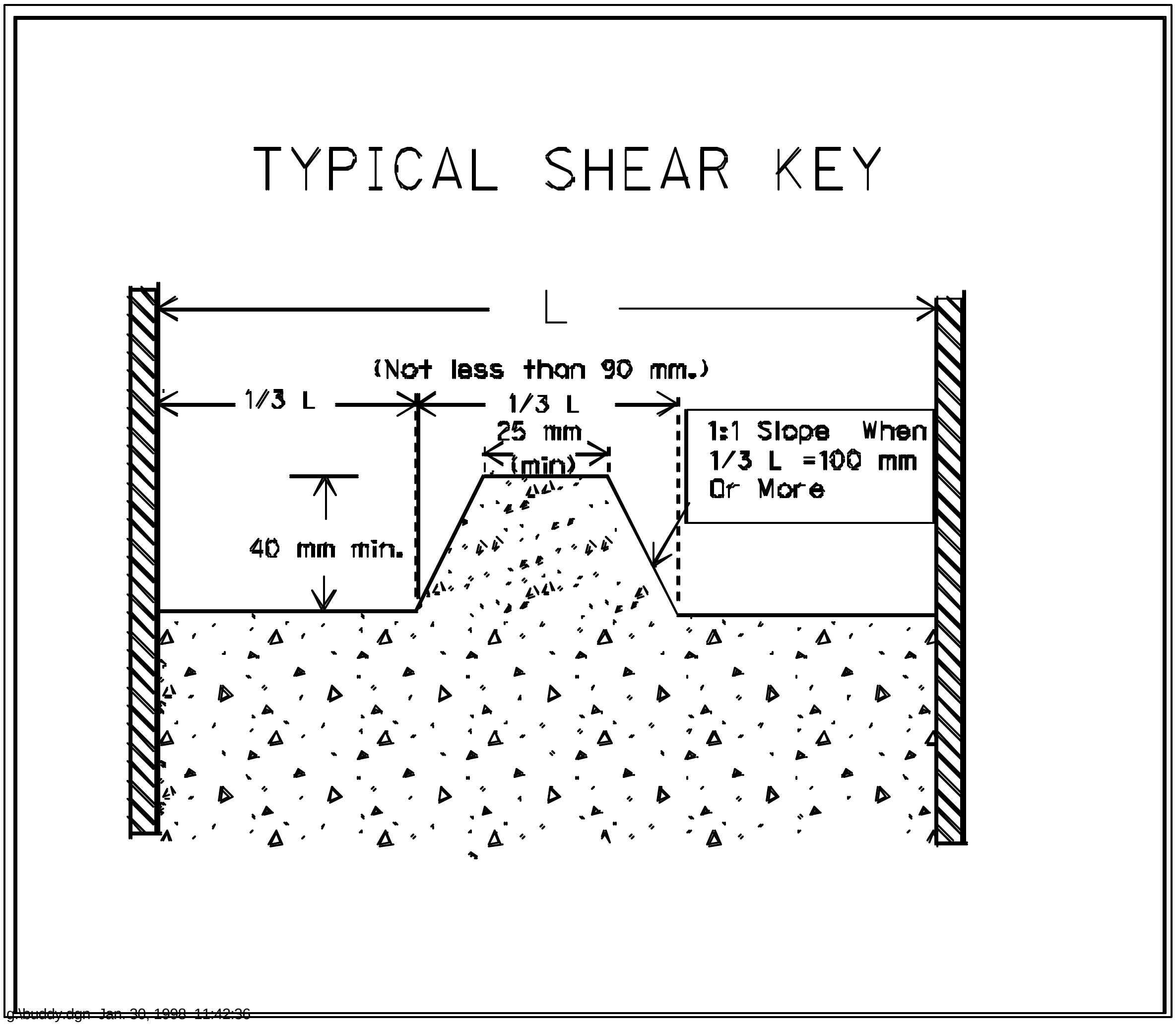
4. Construction joints shall be paid for as outlined in SSHC 704.04.

5. Where it is necessary to transfer shear, shear keys or inclined reinforcement shall be used. It should be pointed out that in practically all cases, shear transfer is essential and therefore shear keys or inclined reinforcement will usually be required. When inclined reinforcement is used as a means of shear transfer No. 5 bars at 1 foot (300 mm) centers should be considered a minimum. The angle of inclination should be approximately 15 degrees from the direction of shear and the length of bar should be at least 2'-3" (685 mm) in order that 20 bar diameters can be placed in both sections of the pour.

6. Shear keys should be formed with beveled strips or boards at right angles to the direction of shear. Typical dimensions for a shear key are shown in the following sketch.

7. If the volume of concrete culvert pour is greater than can be placed in a normal day's operation, or in case of emergency, construction joints located in accordance with the details shown in the drawing "Construction Joints for Box Culverts" may be constructed. Construction joints between roadway shoulder lines are not shown in this drawing since they are not to be so constructed unless authorized by the Construction Engineer.

8. Construction joints in box culverts should be located as follows: Vertical floor joints, wall joints and top slab joints should be constructed in accordance with the sketches in this article and should be staggered by approximately 3 ft (1.0 m). When the walls and top slab are placed simultaneously, the top slab should be stopped and jointed approximately 3 ft (1.0 m) before ending the wall. (Refer to sketch "Construction Joint for Box Culverts".)



[The side slopes of the key will be less than one to one until the widest dimension of the key reaches 4 inches (100 mm).]

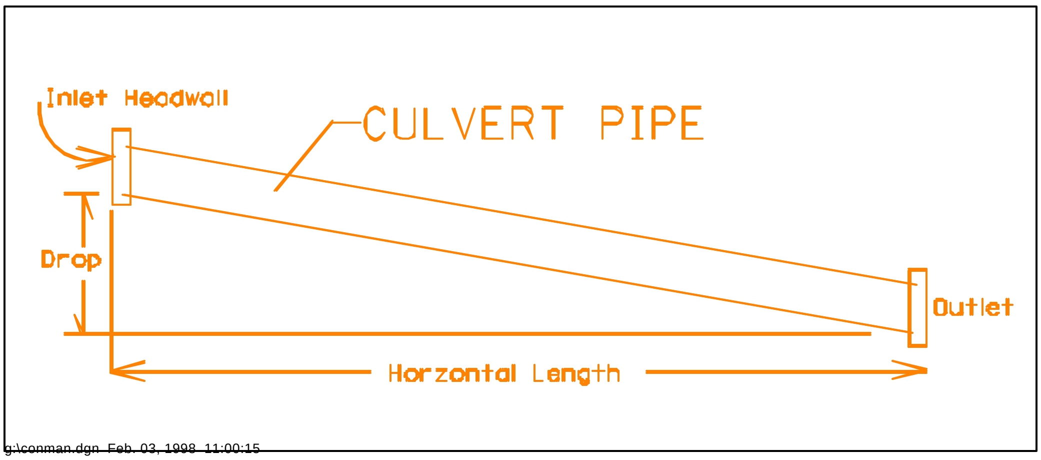
716.00 CULVERT PIPE (*SSHC Section 718*)

716.01 DESCRIPTION

A. This work shall consist of furnishing and installing culvert pipe. The contractor has the option to furnish any of the types of culvert pipe listed in the specifications.

716.02 CONSTRUCTION METHODS

A. Culvert List. The contractor is not permitted to order or deliver culvert pipe until a "culvert list" listing the correct sizes and lengths of pipe is furnished to him/her by the Project Manager.



B. Pipe Bedding

1. Pipe bedding is explained in the special plan for "Pipe Policy".

2. The following soil classifications are necessary to use the pipe special plans to determine correct bedding materials.

ASTM D 2487 Description and Identification of Soils			
		SIEVE RANGE	
GRAVEL	COURSE	Passes 3-inch	Retained on ¾-inch
	FINE	passes ¾-inch	Retained on No. 4
SAND	COURSE	Passes No. 4	Retained on No. 10
	MEDIUM	Passes No. 10	Retained on No. 40
	FINE	Passes No. 40	Retained on No. 200

C. Temporary Culvert Pipe

1. The Districts will be responsible for making a determination (presumably during the plan-in-hand inspection) regarding whether or not to ask for new pipe.

2. Logistics Division maintains a list of pipe values which can be used to determine damages to the Department when pipe is not returned to us in usable condition.

D. Salvaged Culvert Pipe. The following listed examples and rules are given to help clarify removal and salvage of culvert pipe.

1. Rules

   a. The decision to salvage or not to salvage the culvert pipe at each location must be made by the Inspector or Project Manager prior to beginning removal work on the culvert pipe, and the contractor must be advised of your decision prior to his/her commencing work on the removal.

   b. Culvert pipe ordered salvaged and carefully removed by the contractor will be paid for as per the specifications even though after removal it is apparent that the removed pipe has no salvage value.

   c. The contractor must carefully remove the culvert pipe to prevent damage to the culvert pipe.

2. Examples

   a. The contractor is ordered to salvage the culvert pipe. The contractor carefully removes the culvert pipe. The culvert pipe has almost rusted through from the outside and really has no salvage value. The length of pipe removed will be included for payment.

   b. The contractor is ordered to salvage the culvert pipe. After the pipe has been uncovered, it is apparent that it has very little salvage value. <u>If the contractor is agreeable</u>, the Inspector or Project Manager can rescind their salvage order and the contractor can complete the removal any way possible. The length of pipe removed under these conditions will not be included for payment.

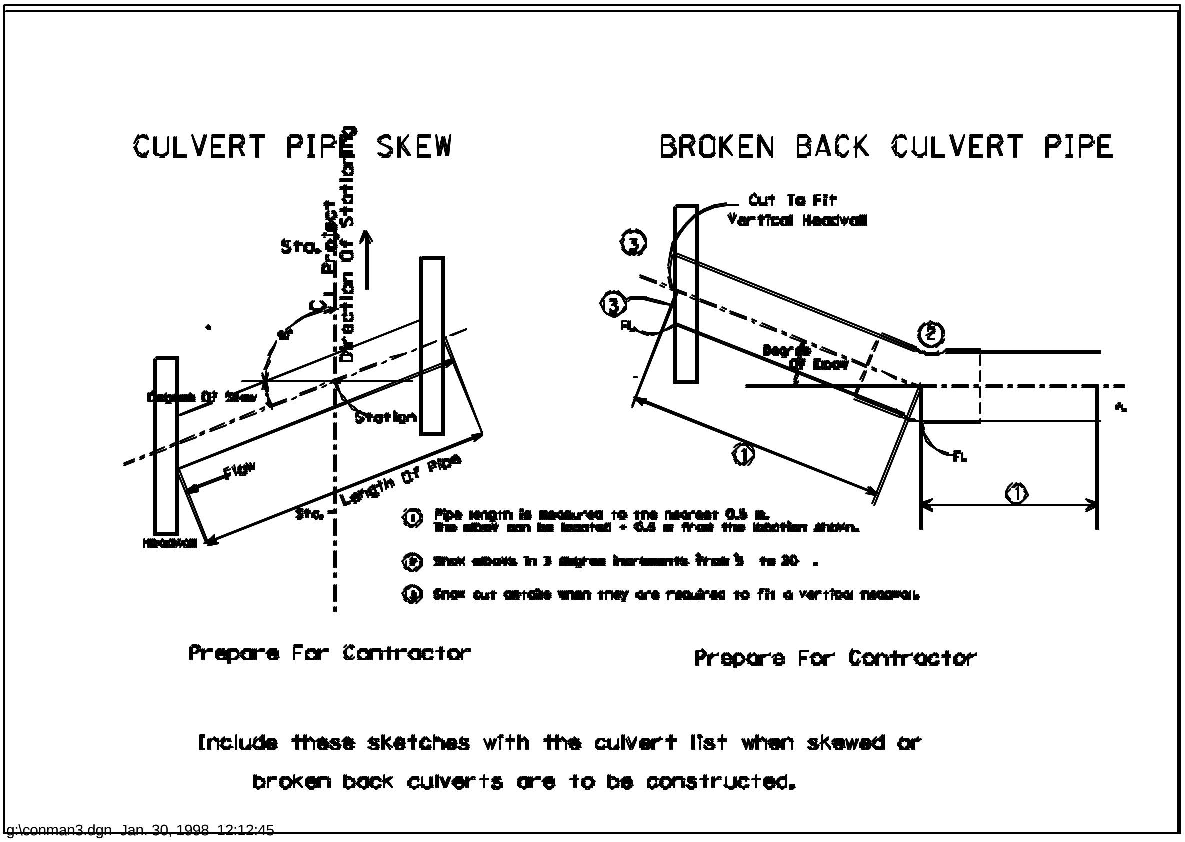
   c. The contractor is ordered to salvage the culvert pipe. The contractor is careless in removing the culvert pipe and damages it. The length of pipe removed less the damage length may be included for payment, or the Inspector or Project Manager may determine that there is no salvage value left in the culvert pipe and no payment will be made for salvaging the culvert pipe at this location.

   d. The contractor is ordered to not salvage the culvert pipe. The contractor removes the culvert pipe and disposes of part of it. The contractor advises that the remaining removed pipe may be picked up by the Department. The Department may refuse to pick it up, inasmuch as all such material is the property of the contractor and it is his/her responsibility to properly dispose of such material. If the Department picks it up the lengths may be included for payment as salvaging culvert pipe or they may be picked up without payment being made. The Inspector or Project Manager shall determine what is fair and just.

3. Decisions and Documentation

   a. There will undoubtedly be conditions arising which are not entirely covered by these rules or examples but the Inspector or Project Manager should be able to make the proper decision within the spirit of these guidelines.

4. The project records must include pertinent notes explaining and detailing decisions made on salvaging culvert pipe.



ADDITIONAL EXCAVATION FOR EMBANKMENT OR BACKFILL
(Left in English Units for Your Convenience)

The following charts may be used for computing Additional Excavation for Embankment or Backfill for circular culvert pipe, arch culvert pipe or elliptical culvert pipe (pages 450C, D, E, F). "Y" is the distance from natural ground to the center of the pipe or in the case of arch pipe to the widest part of the pipe. The numbers in the columns under the different size pipe diameters are the end area in square feet of the backfill required by the specification.

Example: A 24" circular culvert pipe is laid at Station 17+30 with Flowline Lt. 2416.60 at 47' and Flowline Rt. 2415.00 at 51': The field design cross-section is 16.6 at 50' Lt., 16.3 at 35' Lt., 16.2 at

18' Lt., 16.2 at CL, 16.0 at 5' Rt., 16.0 at 10' Rt., 15.3 at 15' Rt., 15.0 at 27' Rt., 15.7 at 42' Rt. and 15.5 at 55' Rt.

16.6 at 50'		
16.5 at 47'	FL = 16.6 at 47'	Y = 1.1
16.3 at 35'	FL = 16.4 at 35'	Y = 1.1
16.2 at 18'	FL = 16.1 at 18'	Y = 0.9
16.2 at CL	FL = 15.8 at CL	Y = 0.6
16.0 at 5'	FL = 15.8 at 5'	Y = 0.8
16.0 at 10'	FL = 15.7 at 10'	Y = 0.7
15.3 at 15'	FL = 15.6 at 15'	Y = 1.3
15.0 at 27'	FL = 15.4 at 27'	Y = 1.4
15.7 at 42'	FL = 15.1 at 42'	Y = 0.4
15.6 at 51'		
15.5 at 55'	FL = 15.0 at 51'	Y = 0.4

24"×98' Culvert Pipe

Circular Culvert Pipe Embankment Areas
(Y=Height, TC = Center of Pipe)
Pipe Diagram

Y	12”	15”	18”	24”	30”	36”	42”	48”	54”	60”	72”
0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
0.2	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
0.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
0.4	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
0.5	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
0.6	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1
0.7	4.1	4.0	4.0	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8
0.8	4.9	4.9	4.8	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5
0.9	5.7	5.7	5.7	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3
1.0	6.6	6.6	6.6	6.4	6.3	6.2	6.2	6.2	6.2	6.1	6.1
1.1	7.5	7.6	7.6	7.4	7.2	7.1	7.1	7.1	7.0	7.0	7.0
1.2	8.5	8.6	8.6	8.5	8.2	8.1	8.0	8.0	7.9	7.9	7.9
1.3	9.5	9.6	9.6	9.4	9.4	9.1	9.0	9.0	8.9	8.9	8.8
1.4	10.5	10.7	10.7	10.7	10.6	10.3	10.1	10.0	10.0	9.9	9.8
1.5	11.6	11.8	11.9	11.9	11.8	11.5	11.2	11.1	11.0	11.0	10.9
1.6	12.7	12.9	13.0	13.1	13.1	12.8	12.5	12.3	12.2	12.1	12.0
1.7	13.9	14.1	14.2	14.4	14.4	14.1	13.7	13.5	13.4	13.3	13.2
1.8	15.1	15.3	15.5	15.7	15.7	15.5	15.2	14.8	14.7	14.5	14.4
1.9	16.3	16.6	16.8	17.0	17.1	17.0	16.7	16.2	16.0	15.8	15.6
2.0	17.6	17.9	18.1	18.4	18.5	18.5	18.2	17.7	17.4	17.2	17.0
2.1	18.9	19.2	19.5	19.8	20.0	20.0	19.8	19.3	18.9	18.6	18.3
2.2	20.3	20.6	20.9	21.3	21.5	21.5	21.4	21.0	20.5	20.1	19.8
2.3	21.7	22.0	22.3	22.8	23.1	23.1	23.0	22.7	22.2	21.7	21.3
2.4	23.1	23.5	23.8	24.3	24.7	24.8	24.7	24.4	24.0	23.4	22.9
2.5	24.6	25.0	25.4	25.9	26.3	26.5	26.4	26.2	25.8	25.2	24.5
2.6	26.1	26.6	26.9	27.5	28.0	28.2	28.2	28.0	27.7	27.1	26.2
2.7	27.7	28.1	28.5	29.2	29.7	29.9	30.0	29.9	29.6	29.1	28.0
2.8	29.3	29.8	30.2	30.9	31.4	31.7	31.9	31.8	31.5	31.1	29.8
2.9	30.9	31.4	31.9	32.6	33.2	33.6	33.8	33.7	33.5	33.1	31.8
3.0	32.6	33.1	33.6	34.4	35.0	35.5	35.7	35.7	35.5	35.2	33.9
3.1	34.3	34.9	35.4	36.2	36.9	37.4	37.7	37.7	37.6	37.3	36.1
3.2	36.1	36.7	37.2	38.1	38.8	39.3	39.7	39.8	39.7	39.5	38.3
3.3	37.9	38.5	39.0	40.0	40.8	41.3	41.7	41.9	41.9	41.7	40.6
3.4	39.7	40.4	40.9	41.9	42.8	43.4	43.8	44.0	44.1	43.9	43.0
3.5	41.6	42.3	42.9	43.9	44.8	45.5	45.9	46.2	46.3	46.2	45.4
3.6	43.5	44.2	44.8	45.9	46.9	47.6	48.1	48.4	48.6	48.5	47.8
3.7	45.5	46.2	46.8	48.0	49.0	49.7	50.3	50.7	50.9	50.9	50.2
3.8	47.5	48.2	48.9	50.1	51.1	51.9	52.6	53.0	53.2	53.3	52.7
3.9	49.5	50.3	51.0	52.2	53.3	54.2	54.9	55.3	55.6	55.7	55.3
4.0	51.6	52.4	53.1	54.4	55.5	56.5	57.2	57.7	58.0	58.2	57.9
4.1	53.7	54.5	55.3	56.6	57.8	58.8	59.6	60.1	60.5	60.7	60.5
4.2	55.9	56.7	57.5	58.9	60.1	61.1	62.0	62.6	63.0	63.3	63.1
4.3	58.1	58.9	59.7	61.2	62.5	63.5	64.4	65.1	65.6	65.9	65.8
4.4	60.3	61.2	62.0	63.5	64.9	66.0	66.9	67.6	68.2	68.5	68.6
4.5	62.6	63.5	64.4	65.9	67.3	68.5	69.4	70.2	70.8	71.2	71.4
4.6	64.9	65.9	66.7	68.3	69.8	71.0	72.0	72.8	73.	73.9	74.2
4.7	67.3	68.2	69.1	70.8	72.3	73.5	74.6	75.5	76.2	76.7	77.0
4.8	69.7	70.7	71.6	73.3	74.8	76.1	77.3	78.2	78.9	79.5	79.9
4.9	72.1	73.1	74.1	75.8	77.4	778.8	80.0	80.9	81.7	82.3	82.9
5.0	74.6	75.6	76.6	78.4	80.0	81.5	82.7	83.7	84.5	85.2	85.9

Culvert Pipe-Arch Embankment Areas

(Y=Height to Widest Section of Pipe)

Equivalent Round Size

Y	12”	30”	36”	42”	48”	54”	60”	66”	72”
0.1	0.6	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.3
0.2	1.1	1.1	1.1	1.2	1.3	1.4	1.5	1.7	1.8
0.3	1.6	1.6	1.6	1.7	1.8	1.9	2.1	2.2	2.4
0.4	2.0	2.2	2.2	2.2	2.24	2.5	2.6	2.8	2.9
0.5	2.8	2.7	2.7	2.7	2.9	3.1	3.2	3.4	3.5
0.6	3.7	3.6	3.5	3.4	3.4	3.7	3.8	4.0	4.2
0.7	4.6	4.6	4.5	4.4	4.2	4.1	4.5	4.7	4.9
0.8	5.5	5.6	5.6	5.5	5.3	5.0	4.9	5.4	5.6
0.9	6.5	6.6	6.7	6.7	6.5	6.2	5.9	5.8	5.7
1.0	7.5	7.7	7.8	7.9	7.8	7.5	7.1	6.8	6.7
1.1	8.6	8.8	9.0	9.1	9.1	8.9	8.6	8.1	7.8
1.2	9.7	10.0	10.2	10.4	10.4	10.3	10.0	9.6	9.2
1.3	10.8	11.2	11.5	11.7	11.8	11.7	11.5	11.2	10.8
1.4	12.0	12.4	12.8	13.1	13.2	13.2`	13.1	12.8	12.4
1.5	13.2	13.7	14.1	14.5	14.7	14.7	14.6	14.4	14.1
1.6	14.5	15.0	15.5	15.9	16.2	16.3	16.3	16.1	15.8
1.7	15.8	16.4	16.9	17.4	17.7	17.9	17.9	17.8	17.6
1.8	17.1	17.8	18.4	18.9	19.3	19.5	19.6	19.6	19.4
1.9	18.5	19.2	19.9	20.4	20.9	21.2	21.4	21.4	21.3
2.0	19.9	20.7	21.4	22.0	22.6	22.9	23.1	23.2	23.2
2.1	21.4	22.2	23.0	23.7	24.3	24.7	25.0	25.1	25.1
2.2	22.9	23.8	24.6	25.4	26.0	26.5	26.8	27.0	27.0
2.3	24.4	25.4	26.3	27.1	27.8	28.3	28.7	29.0	29.1
2.4	26.0	27.0	28.0	28.8	29.6	30.2	30.7	31.0	31.1
2.5	27.6	28.7	239.7	30.6	31.5	32.1	32.6	33.0	33.2
2.6	29.3	30.4	31.5	32.5	33.4	34.1	34.7	35.1	35.3
2.7	31.0	32.2	33.3	34.3	35.3	36.1	36.7	37.2	37.5
2.8	32.7	34.0	35.2	36.3	37.3	38.1	38.8	39.3	39.7
2.9	34.5	35.8	37.1	38.2	39.4	40.2	41.0	41.5	41.9
3.0	36.3	37.7	39.0	40.2	41.4	42.3	43.1	43.8	44.2
3.1	38.2	39.6	41.0	42.2	43.5	44.5	45.4	46.1	46.6
3.2	40.1	41.6	43.0	44.3	45.7	46.7	47.6	48.4	48.9

Culvert Pipe-Arch Embankment Areas
(Y=Height to Widest Section of Pipe)
Equivalent Round Size

Y	24”	30”	36”	42”	48”	54”	60”	66”	72”
3.3	42.0	43.6	45.1	46.4	47.8	48.9	49.9	50.7	51.3
3.4	44.0	45.6	47.2	48.6	50.1	51.2	52.3	53.1	53.8
3.5	46.0	47.7	49.3	50.8	52.3	53.5	54.6	55.6	56.3
3.6	48.1	49.8	51.5	53.0	54.6	55.9	57.1	58.1	58.8
3.7	50.2	52.0	53.7	55.3	57.0	58.3	59.5	60.6	61.4
3.8	52.3	54.2	56.0	57.6	59.4	60.7	62.0	63.1	64.0
3.9	54.5	56.4	58.3	60.0	61.8	63.2	64.6	65.7	66.6
4.0	56.8	58.7	60.6	62.4	64.3	65.7	67.1	68.4	69.3
4.1	59.0	61.0	63.0	64.8	66.8	68.3	69.8	71.0	72.0
4.2	61.3	63.4	65.4	67.3	69.3	70.9	72.4	73.8	74.8
4.3	63.7	65.8	67.8	69.8	71.9	73.6	75.1	76.5	77.6
4.4	66.0	68.2	70.3	72.4	74.5	76.2	77.9	79.3	80.5
4.5	68.5	70.7	72.9	75.0	77.2	79.0	80.6	82.2	83.4
4.6	70.9	73.2	75.5	77.6	79.9	81.7	83.5	85.0	86.3
4.7	73.4	75.8	78.1	80.3	82.6	84.5	86.3	88.0	89.3
4.8	76.0	78.4	80.7	83.0	85.4	87.4	89.2	90.9	92.3
4.9	78.5	81.0	83.4	95.1	88.2	90.2	92.2	93.9	95.3
5.0	81.2	83.7	86.2	88.5	91.1	93.2	95.1	97.0	98.4

Elliptical Culvert Pipe Embankment Areas
(Y = Height to Center of Pipe)
Equivalent Round Size

0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
0.2	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.0	0.9
0.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
0.4	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9
0.5	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5
0.6	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
0.7	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9
0.8	4.9	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6
0.9	5.9	5.7	5.6	5.5	5.5	5.4	5.4	5.4	5.4
1.0	6.9	8.7	6.5	6.4	6.4	6.3	6.3	6.2	6.2
1.1	8.0	7.8	7.5	7.4	7.3	7.2	7.2	7.1	7.1
1.2	9.1	9.0	8.6	8.4	8.3	8.2	8.2	8.1	8.1
1.3	10.3	10.2	5.9	9.5	9.4	9.3	9.2	9.1	9.1
1.4	11.5	11.5	11.2	10.8	10.6	10.4	10.3	10.2	10.1
1.5	12.7	12.8	12.6	12.2	11.9	11.6	11.5	11.4	11.3
1.6	14.0	14.1	14.0	13.7	13.3	12.9	12.7	12.6	12.5
1.7	15.3	15.5	15.4	15.2	14.9	14.3	14.1	13.9	13.7
1.8	16.6	16.9	16.9	16.7	16.3	15.9	15.5	15.2	15.1
1.9	18.0	18.3	18.4	18.3	18.1	17.6	17.0	18.7	16.5
2.0	19.4	19.8	19.9	19.9	19.8	19.4	18.7	18.2	18.0
2.1	20.9	21.4	21.5	21.6	21.5	21.1	20.6	19.9	19.6
2.2	22.4	23.0	23.2	23.3	23.3	23.0	22.5	21.7	21.2
2.3	24.0	24.6	24.8	25.0	25.1	24.8	24.4	23.7	23.0
2.4	25.6	26.2	26.0	26.8	26.9	26.7	26.4	25.7	24.9
2.5	27.2	27.9	28.3	28.6	28.8	28.7	28.4	27.9	27.1
2.6	28.9	29.7	30.1	30.5	30.7	30.7	30.4	29.9	29.2
2.7	30.6	31.4	31.9	32.4	32.7	32.7	32.5	32.1	31.5
2.8	32.3	33.3	33.8	34.3	34.7	34.8	34.7	34.3	33.7
2.9	34.1	35.1	35.7	36.3	36.7	36.9	36.8	36.5	36.0
3.0	35.9	37.0	37.7	38.3	38.8	39.0	39.1	38.8	38.4
3.1	37.8	38.9	39.7	40.4	40.9	41.2	41.3	41.1	40.7
3.2	39.7	40.9	41.7	42.5	43.1	43.6	43.6	43.4	43.2
3.3	41.7	42.9	43.8	44.6	45.3	45.7	45.9	45.8	45.6
3.4	43.7	45.0	45.9	46.8	47.5	38.0	48.3	48.2	48.1
3.5	45.7	47.1	48.1	49.0	49.8	50.4	50.7	50.7	50.6
3.6	47.8	49.2	50.3	51.3	52.1	52.7	53.2	53.2	53.2
3.7	49.9	51.4	52.5	53.6	54.5	55.2	55.7	55.8	55.8
3.8	52.0	53.6	54.8	55.9	56.9	57.6	58.2	58.4	58.5
3.9	54.2	55.9	57.1	58.3	59.3	60.1	60.8	61.0	61.2
4.0	56.4	58.2	59.4	60.8	61.8	62.7	63.4	63.7	63.9
4.1	58.7	60.5	61.8	63.2	64.3	65.3	66.0	66.4	66.7
4.2	61.0	62.9	64.3	65.7	66.9	67.9	68.7	69.1	69.5
4.3	63.4	65.3	66.7	68.3	69.5	70.6	71.8	71.9	72.4
4.4	65.8	67.8	69.3	70.8	72.1	73.3	74.2	74.8	75.3
4.5	68.2	70.3	71.8	73.5	74.8	76.0	77.1	77.6	76.2
4.6	70.7	72.8	74.4	76.1	77.5	78.8	79.9	80.5	81.2
4.7	73.2	75.4	77.0	78.8	80.3	81.6	82.8	83.5	84.2
4.8	75.7	78.0	79.7	81.6	83.1	84.5	85.7	86.5	87.3
4.9	78.3	80.6	82.4	86.3	85.9	87.4	89.7	89.5	90.4
5.0	80.9	83.3	85.2	87.2	88.8	90.4	91.7	92.6	93.5

Cu. Yds. of Concrete to be deducted from one Headwall because of skew.

Corrugated Pipe 8” Headwalls

Size/Skew	5”	10”	15”	20”	25”	30”	35”	40”	45”	50”	55”	60”
18” Pipe	.000	.001	.002	.003	.005	.007	.010	.013	.018	.024	.032	.044
24” Pipe	.000	.001	.003	.005	.008	.012	.017	.024	.032	.043	.058	.078
30” Pipe	.000	.002	.004	.008	.013	.019	.027	.037	.050	.067	.090	.121
30” Pipe	.001	.003	.006	.011	.018	.027	.039	.053	.072	.097	.130	.174
42” Pipe	.001	.004	.008	.015	.025	.037	.052	.073	.098	.132	.177	.238
48” Pipe	.001	.005	.011	.020	.032	`.048	.068	.095	.128	.172	.231	.310
54” Pipe	.001	.006	.014	.025	.041	.061	.087	.120	.163	.218	.292	.393
60” Pipe	.002	.007	.017	.031	.050	.075	.107	.148	.201	.269	.360	.485
72” Pipe	.003	.011	.025	.045	.072	.108	.154	.213	.289	.388	.519	.698
84” Pipe	.004	.015	.034	.061	..098	.147	.210	.290	.394	.528	.706	.950

Corrugated Pipe 6” Headwalls

Size/Skew	5”	10”	15”	20”	25”	30”	35”	40”	45”	50”	55”	60”
18” Pipe	.000	.001	.001	.002	.003	.005	.007	.010	.014	.018	.024	.033
24” Pipe	.000	.001	.002	.004	.006	.009	.013	.018	.024	.052	.043	.058
30” Pipe	.000	.001	.003	.006	.009	.014	.020	.028	.038	.051	.068	.091
36” Pipe	.001	.002	.005	.008	.014	.020	.029	.040	.054	.073	.097	.131
42” Pipe	.001	.003	.006	.011	.018	.028	.039	.054	.074	.99	.132	.178
48” Pipe	.001	.004	.008	.015	.024	.036	.051	.071	.096	.129	.173	.233
54” Pipe	.001	.005	.010	.019	.030	.046	.065	.090	.122	`.164	.219	.294
60” Pipe	.001	.006	.013	.023	.038	.056	.080	.111	.151	.202	.270	.364
72” Pipe	.002	.008	.018	.034	.054	.081	.116	.160	.217	.291	.389	.523
84” Pipe	.003	.011	.025	.046	.074	.110	.157	.218	.295	.398	.530	.713

Concrete Pipe 8” Headwalls

Size	T	5”	10”	15”	20”	25”	30”	35”	40”	45”	50”	55”	60”
18” Pipe	2½	.000	.001	.003	.005	.007	.011	.016	.022	.030	.040	.053	.071
24” Pipe	2¾	.000	.002	.004	.008	.012	.018	.026	.036	.049	.065	.087	.117
30” Pipe	3	.001	.003	.006	.011	.018	.027	.039	.053	.072	.097	.130	.174
36” Pipe	3½	.001	.004	.009	.016	.026	.039	.055	.076	.103	.138	.185	.249
42” Pipe	4¼	.001	.005	.012	.022	.035	.053	.076	.105	.142	.191	.255	.343
48” Pipe	5	.002	.007	.016	.029	.047	.070	.100	.138	.188	.252	.337	.453
54” Pipe	5”	.002	.009	.019	.035	.057	.085	.122	.168	.228	.306	.410	.551
54” Pipe	5½	.002	.009	.020	.037	.059	.088	.126	.14	.236	.316	.423	.569
60” Pipe	5½	.003	.010	.024	.044	.070	.105	.150	.207	.281	.377	.505	.579
60” Pipe	6”	.003	.011	.025	.045	.072	.108	.154	.213	.289	.388	.519	.698
72” Pipe	7”	.004	.015	.035	.064	.130	.154	.220	.304	.412	.553	.740	.996
84” Pipe	8”	.005	.021	.048	.086	.139	.208	.297	.411	.558	.748	1001	1346

Concrete Pipe 6" Headwalls

Size	T	5"	10"	15"	20"	25"	30"	35"	40"	45"	50"	55"	60"
18" Pipe	2½	.000	.001	.002	.003	.005	.008	.012	.016	.022	.030	.040	.053
24" Pipe	2¼	.000	.001	.003	.006	.009	.014	.019	.027	.036	.049	.065	.088
30" Pipe	3"	.001	.002	.005	.008	.014	.020	.029	.040	.054	.073	.097	.131
36" Pipe	3½	.001	.003	.007	.012	.019	.029	.041	.057	.077	.104	.139	.187
42" Pipe	4¼	.001	.004	.009	.017	.027	.040	.057	.079	.107	.143	.191	.258
48" Pipe	5"	.001	.005	.012	.022	.035	.053	.075	.104	.141	.189	.253	.340
54" Pipe	5"	.002	.006	.015	.027	.043	.064	.091	.126	.171	.230	.307	.414
54" Pipe	5½	.002	.007	.015	.027	.044	.055	.094	.130	.177	.237	.317	.427
60" Pipe	5½	.002	.008	.018	.033	.053	.079	.112	.155	.211	.283	.378	.509
60" Pipe	6"	.002	.008	.018	.034	.054	.081	.116	.160	.217	.291	.389	.523
72" Pipe	7"	.003	.012	.026	.048	.077	.116	.165	.228	.309	.415	.555	.747
84" Pipe	8"	.004	.016	.036	.065	.104	.156	.223	.308	.418	.561	.751	1.010

717.00 CONCRETE PIPE CULVERTS (*SSHC Section 720*)

717.01 DESCRIPTION

A. This work shall consist of furnishing and installing new reinforced concrete culvert pipe (round, pipe-arch and elliptical), reinforced concrete slotted pipe and the relaying of existing reinforced concrete pipe.

717.02 MATERIAL REQUIREMENTS

A. Pipe Marking. Each section of pipe used should be marked with the fabrication inspector's initial and the class of pipe, when it arrives at the site. The culvert inspector should not permit the laying of any section that does not have these markings. The project manager will receive a copy of the "Report of Shipment of Reinforced Concrete Pipe" (Form DR-420), listing the size, class, length, number of sections of pipe, the inspector's identification mark and stock report number. The inspector will use the information contained in this report to verify approval of reinforced concrete pipe received on the project. The diameter, class, length, number of sections and the pipe identification number shall be recorded in the culvert notebook. Each section of pipe should be examined for damaged ends, cracks and evidence of poor manufacture. All irregularities should be referred to the Project Manager before using of the pipe.

B. Ordering Material

1. The contractor is **not permitted to order or deliver** culvert pipe until a “culvert list” listing the correct sizes and lengths of pipe is furnished by the Project Manager.

2. The Project Manager shall funish a pipe list for driveway and sewer requirements.

3. The District Construction Engineer, and the Project Manager should go over the drainage situation and features in the field to confirm that the structures shown in the plans are adequate to handle the drainage. The cross sections taken at each culvert site should be plotted, the roadway cross section template and the structure plotted thereon at the proper flow line elevations, and the length of the structure thus determined. If the Project Manager includes either a larger drainage structure, or an additional drainage structure in the culvert list, he/she should, if possible, specify the same type of structure, or the same kind of pipe (culvert pipe, concrete pipe or corrugated metal pipe) as is shown in the approved plans for the project for the other structures.

4. In detailing and ordering the pipe culverts, the following rules should be followed for all kinds of culvert pipe (concrete pipe, corrugated metal pipe or culvert pipe):

    a. The overall length of culvert pipe should be given to the closest 2 ft (600 mm).

    b. The minimum distance from either end of the pipe to the break point of a broken back pipe culvert shall be 10 ft (3 m).

c. The dimensions from ends of the pipe to break points, or between break points of a broken-back pipe culvert should be given to the closest 2 ft (600 mm) along the centerline of the pipe. The fabricator will be permitted to locate the elbows 1 foot (300 mm) in either direction from the locations shown in the culvert sketch.

d. Generally, pipe culverts should not be designed or constructed with elbows of less than 5 degrees.

e. Prepare a sketch for each broken-back pipe culvert, designing and detailing the structure using the chart "Slope Data for Pipe Culvert" as a guide, and including dimensions, details and elevations as shown in the sample culvert sketch shown in this Subsection.

f. Pipe arch culverts are to be detailed and dimensioned the same as round pipe culverts. Broken-back pipe arch culverts should be avoided.

g. If flared end sections are to be installed, the pay length shall be the order length shown in the culvert list and sketch. A note should be made as part of the list indicating that order lengths do not indicate the "Y" distances shown in the applicable Standard Plan in the case of metal pipe.

h. The condition, kind of pipe, diameter and lengths right and left of centerline should be carefully checked before ordering extensions for an existing pipe culvert. Careful checking will eliminate ordering extensions which are improper as to length, diameter, kind of pipe, etc.

i. The maximum discharge of the average pipe culvert without head on the inlet will be provided when such pipe are given a slope of between one percent and two percent. Slopes steeper than this will not increase the water carrying capacity of the culvert. The Project Manager should make every effort to use such slopes when they are compatible with other drainage requirements at the individual culvert site. In choosing between a straight and a broken-back culvert pipe, the Project Manager should realize that little, if any, value is gained by installing elbows of less than 5 degrees.

j. If settlement or subsidence is anticipated under higher fills, pipe culverts and box culverts should be cambered. The plans will usually include a "Camber Note" which will state that the pipe culverts should be laid and box culverts constructed on parabolic camber grade as shown in the applicable standard plan, and will state the proportion of fill height which the foundation soil is expected to settle. Settlement of subsidence is generally zero at the toe of the slope, and at a maximum at the shoulder line.

717.03 CONSTRUCTION METHODS

A. Excavation and Backfilling

1. See Section 702 of this manual.

B. Installation

1. Begin laying concrete pipe at the downstream end of the culvert with the groove or bell portion of each section upstream.

2. Irrigation culverts shall be constructed of concrete pipe and must have approved gaskets at the joints. These gaskets shall be installed as per the manufacturer's recommendations and standards. Here is example of how to calculate payment for excavation.

EXAMPLE CALCULATION

Area for 1.25 m depth:
1a
Area for 2.75 m depth:

1b + 2b + 3b
Area for 4.25 m depth:
1c + 2c + 3c

Area for 5.75 m depth:

1d + 2d +3d

Area for greater than 5.75 m depth:
1e + 2e + 3e

718.00 CORRUGATED METAL PIPE CULVERTS (*SSHC Section 719*)

718.01 DESCRIPTION

A. This work shall consist of furnishing and installing new corrugated galvanized metal pipes and pipe arches and the relaying of existing corrugated metal pipe and pipe arches.

718.02 MATERIAL REQUIREMENTS

A. Pipe Marking. SSHC Tables 1035.01 & 1036.01 contain the required minimum gage or sheet thickness for the various pipe diameters. The "Materials and Sampling Guide" provides that the necessary tests for acceptance will be handled by the Materials and Research Division. Material samples need not be taken by project personnel unless a special request is made for samples. The diameter of the pipe and number of sections of pipe covered by each heat number and delivered to each culvert location should be recorded in the culvert notebook. The pipe shipment should be checked against the shipment report and any discrepancy should be reported to the Project Manager. The pipe shipment should also be checked for shipping damage and any damage noted should also be reported to the Project Manager.

B. Ordering Material

1. **The contractor is not permitted to order or deliver corrugated metal pipe or pipe arches until a "culvert list" listing the correct sizes and lengths of pipe is furnished to him/her by the Project Manager.**

718.03 CONSTRUCTION METHODS

A. Excavating and Backfilling

1. Refer to Section 702 of this manual.

B. Installation

1. The culvert inspector should insist on careful handling of the corrugated metal pipes or pipe arches. Corrugated metal pipes or pipe arches should be lifted and moved with a rope sling or similar device which will not damage the galvanized surfaces of the pipes or pipe arches. The contractor should not be allowed to drag the pipes or pipe arches over abrasive surfaces as this will also damage the galvanized surfaces.

2. Corrugated metal pipes and pipe arches shall be laid with the inside circumferential laps lapped downstream so that the water will flow over the lap. The pipe shall be rotated so that the longitudinal laps are horizontal. When joining sections of pipe, the connecting bands should be pulled up as tight as possible. The band should be tapped with a wooden mallet as the bolts are tightened. Excessive pressure on the bolts should be avoided to keep from pulling the steel angle loose from the band. A gap of about 1 inch (25mm) should be allowed between the pipe ends being joined,

CHAPTER NOTES: