SECTION 500 – STRUCTURES

501.00 Structures.

General. The term “structure” is a general term used to refer to a variety of features commonly found on ITD construction projects. Typical structures include such features as bridges, retaining walls, dams/impoundments, buildings etc. Generally structures are major features that have been carefully designed to carry forces or loads in an economical and efficient manner. They are usually constructed of a combination of materials including: concrete, steel, wood, composites and other materials both natural and man-made.

Each structure is generally unique with its’ own special design, materials and construction requirements. Buildings are usually designed by consultants and have their special provisions included in the contract documents. Retaining walls, dams or impoundments may have been designed as part of the contract plans or these tasks may be contractually assigned to the contractor to perform. In addition, the contractors may design temporary dams or impoundments as part of their selected method of operation.

Projects that involve the construction of bridges may differ significantly depending on the type of bridge being built. Bridges are generally designated as to type by the nature/material of the principal, horizontal, load carrying members (stringers/girders) comprising the superstructure. Hence, a bridge with steel stringers/girders is designated as a structural steel bridge (CA Section 504). Whereas a bridge with pre-stressed concrete stringers/girders is designated as a pre- stressed concrete bridge (CA Section 506). Most bridges on the State Highway System will be composed in part of structural concrete (CA Section 502) with metal reinforcement (CA Section 503). Many types of bridges can involve bearing pads (CA Section 507) under the stringers/girders where they rest on the abutments/ pier caps, but these are more common on steel bridges.

The Engineer and the Inspectors should become familiar with the bridge type being built, as well as the nomenclature and basic function of each of the bridges principal components. In addition, the Engineer should use great care in making any field adjustments or changes on structures without the proper consultation.

Inspection. Inspection of the construction of structures is highly technical and demands that the inspector be completely informed on all phases of the operation. The inspector should be thoroughly familiar with the plans, specifications, and special provisions pertaining to a particular phase of construction before construction operations begin. The inspector should be aware of the reasons behind each of the provisions listed in the specifications that have been developed through years of experience and research designed to obtain a quality product. A review and discussion of the specification and the appropriate sections of this manual with the contractor, subcontractor, and/or supplier will eliminate many misunderstandings.

The first step in inspection is careful checking of the plans for errors. This should begin as soon as plans are available. Sub-dimensions must be compared to overall dimensions and clearances and tolerances checked. Bearing elevations and anchor bolt locations must be carefully verified. A check should be made from a distance to see that the item is in the correct place and proper position:

- Does the footing cover the piling?
- Does the skew angle fit conditions?
- Is there room for the other portions of the structure?
- Does the structure span the waterway or feature as intended?

When questions, unusual conditions or problems are encountered, the Engineer should document the situation and seek guidance from the consultant designer (if applicable) or the ITD Bridge Section, or both.

Staking. The responsibility for setting construction control stakes is outlined in the specifications. A question usually arises regarding the amount of staking that should be performed for the contractor on structures. Grades and lines that have been set by the contractor must be checked. The Engineer may elect to set all of the necessary structure grades for the contractor, but this practice should be avoided for two reasons:

- First, the Engineer has created a definite area of responsibility for errors, which may result on the structure.
- Second, while performing this work the Engineer obligates personnel to duties, which should be performed by the contractor.

Adequate control staking for the structure will greatly assist the contractor and provide a means of rapid checking by the Engineer's personnel. Control stakes should be located out of the area of operation of both the structure and roadway contractors as much as possible. The Contractor's personnel should be shown the location of these stakes and their purpose explained. Incomplete or vague marking may cause unnecessary delays or expensive corrections.

When setting grades, complete the circuit to a second bench mark thereby checking the elevation. A disturbed bench may not be discovered unless the grade is checked on a second bench.

Foundations. The design of a structure assumes an unyielding foundation. Any settlement will affect the grade line and riding surface. Minor settlement can cause overstress of material, serious cracking and failure. The structure foundation must be inspected to ensure adequate bearing capacity (i.e., bearing values and foundation data shown on the plans should be compared to field conditions). Loose, disturbed material must be removed from the excavation and replaced with backfill in accordance with the specifications. When excavation extends through stratified soils containing unsatisfactory materials, special probing or test holes may be required to check the material below the bottom of footing. This is especially true if layers above the bottom of footing do not conform to the test boring data. **Always compare the actual material that is found against the boring information.** Resolve any differences with the Engineer and HQ's Materials geotechnical specialists, and keep the HQ's Construction/Materials Section advised.

Special care should be exercised in the placement of fills beneath structures. The use of granular fills material and the special control of compaction or compaction procedures may be required by the plans to attain the required density.

The material to be used behind abutments, retaining walls, etc., must be free draining granular material. Refer to plans or special provisions for placement of this material and possible special drain requirements.

Any required shoring and cribbing should be designed to allow sufficient space for placement of forms. Water must be channeled outside the forms for pumping. Underwater foundations requiring cofferdams should also provide adequate space for placing of forms and for handling water outside the footing. They should provide for a possible lowering of the footing elevation and be high enough to prevent overflowing of the cofferdam during high water. The Contractor should be reminded that any restriction in the channel due to forming may result in raising the water elevation, making it necessary to deepen or re-channel the flow to avoid flooding. **Do not allow stream channels to be altered without first consulting with the District Environmental Planner.**

A material log should be included in the daily diary, together with work accomplished and unusual occurrences or materials encountered. Photographs of conditions and the operations, identified as to time and location, are valuable additions to the record.

When foundations are at a considerable depth below water, it may be necessary to provide a seal of concrete before attempting to de-water the cofferdam. This is done after the piling has been driven and/or the excavations to the final footing elevation have been completed. The purpose of the seal is to act as a counterbalance to the pressure created by the head of water on the outside of the cofferdam.

Documentation for Structures. Diaries are intended to provide a record of unusual or controversial happenings and to provide a detailed record of each phase of construction. The diary may be used in planning and organizing the work and for computation of quantities and may prove to be valuable references in connection with the performance or failure of some phase of work or may be used as evidence in court action to settle disputes between the Department and the Contractor. The inspector's diary should include a record of all tests, measurements made and samples taken during the shift, as well as the weather conditions. Any communications with contractor personnel should be noted in detail, and the notes should reflect compliance with the specifications. General observations should be made concerning weather conditions, water elevations, materials sources, and related information. Any incident affecting the progress of the work should be recorded (including cause, time, place, duration, number of men, and equipment made idle). It should keep in mind that there is always the possibility that a claim might arise. The diary should be written completely before the end of each shift and nothing concerning the job should be considered too unimportant. Field notes should not be copied but should be kept exactly as they are originally recorded.

502.00 Concrete.

General. Unlike other materials used in highway construction, concrete is seldom removed and replaced. Therefore, it is essential that every precaution be exercised to insure that the initial placement is correct. To ensure a quality product, the inspector must be thoroughly familiar with placing concrete and should have completed the appropriate inspector training and be current in the appropriate sampling and testing (WAQTC) requirements.

The district materials sections should have a list of approved aggregate sources (QAMS) for concrete rock. Before new sources of aggregate can be used, the source must first be tested and approved. High classes of concrete (Greater than class 45) may not be obtainable from all "approved" aggregate sources.

Concrete itself is a composite material. The fine and coarse aggregates act as the reinforcement while the cement, water, and admixtures act as the matrix. Concrete behaves best when the matrix and reinforcement are in continuous contact with each other and are mixed in the right proportions.

Steel reinforcement can interrupt this continuity when the bars are placed too close together. If there is not sufficient room for the coarse aggregate to help fill the space between the bars, there is no longer reinforced concrete, but reinforced mortar. Mortar is more prone to shrinkage and cracking than concrete.

To avoid this situation the maximum size aggregate in the concrete should be limited to the least of the following:

- 2/3 of the clear spacing between reinforcing steel bars or bar bundles
- 1/5 of the narrowest form dimension
- 1/3 the depth of the slab.

For example: if 5/8 inch coarse aggregate is used:

- The minimum clear spacing between bars would be 5/8 ÷ 2/3 = 15/16 ˜= 1 inch
- The narrowest form dimension would be 5/8 ÷ 1/5 = 25/8 = 3 1/8 inches
- The minimum slab depth would be 5/8 ÷ 1/3 = 15/8 ˜ = 2 inches.

Inspectors need to know the size of the coarse aggregate used so they can check for adequate rebar spacing and form size. It is not uncommon in areas where bars are lap spliced to find a spacing problem. Pier caps often have rebar spacing problems especially where the vertical pier steel penetrates into the cap beam.

Rebar spacing and cover problems should be brought to the attention of the Contractor and Designer. Both have the responsibility to ensure that the Standard Specifications are followed.

The quality of the project work should always come first in the Inspector's mind. Quality is the main reason why Inspectors are assigned to a project. Inspectors must not worry about the schedule when it comes to compromising the requirements of the contract plans and specifications. Stay focused on the contract plans and specifications, and help the Contractor to achieve 100 percent compliance. Inspectors need adequate time to inspect structural concrete forms, falsework, and steel reinforcement prior to concrete placement. This amount of time will vary from just a few minutes for a concrete catch basin to a few hours for a large bridge deck.

Contractors on the other hand want to place concrete the moment the forms are up and the last piece of reinforcing bar is tied in place.

The Inspectors and the Contractor's foreperson shall meet prior to the activity to discuss concrete placement schedules, steel placement activities, steel and formwork inspection requirements, and traffic and safety issues. The Contractor's foreperson is often under enormous pressure to meet deadlines and stay on schedule. When there is finite amount of time to place forms and steel the foreperson may try to make up for any delays by trying to shorten the inspection time. Inspectors then feel rushed and pressured to accept sub-standard work in an effort to help out their "partner." Partnering was never meant to allow relaxation of the contract specifications.

Here are some "DO's" and "DO NOTs" to help the Inspector and the Contractor get through these tough situations:

DOs:

- Perform frequent inspections as forms are going up and steel is placed to catch errors early on.
- Meet with Contractor's foreperson daily to discuss quality issues and progress.
- Point out recurring non-compliance issues to the Contractor no matter how unpleasant it becomes.
- Keep the Contractor informed of your inspection time requirements.
- Adjust your inspection schedule if the Contractor experiences delays (be flexible).
- Build a relationship based on cooperation and professional courtesy.
- Escalate chronic, un-resolvable, noncompliance issues no matter how small they are.
- Develop a feel for how the foreperson plans and executes the work, and adjust your daily work hours accordingly.
- Go through the contract plans with the various trade forepersons to verify they haven't missed some important details you may have noticed.
- Keep ahead of the Contractor by looking through the contract plans and specifications to see what could get the Contractor into trouble later on.
- Always be willing to help the Contractor clarify and interpret the contract plans and specifications.

DO NOTs:

- Allow the Contractor to rush you by cutting short your inspection time.

- Close the lines of communications between you and the Contractor no matter how tough things become.
- Take the Contractor's lack of attention to the contract specification requirements personally.
- Delay inspections to the very last minute.
- Keep to yourself defects you see in the Contractor's work.
- Compromise yourself or the specifications just to meet a schedule (escalate instead).
- Get into a power struggle with the Contractor over pour scheduling versus inspection time.
- Become reactionary if the Contractor ignores you or does not take you seriously.
- Direct the Contractor how to perform the work.

Weather and Temperature Limits. The Resident Engineer may suspend a pour due to weather limitations. Like other types of concrete, structural concrete has both temperature restrictions and precipitation limitations. Subsection 105.01 of the ITD Standard Specifications can be used by the Resident Engineer to suspend work if it is in the best interest of the Department. Keep in mind that only the threat of precipitation is needed to justify suspending the work. You don't have to wait until it is actually raining or snowing. The temperature restrictions for cast-in-place concrete are clearly stated in the Standard Specifications.

The standard specifications also require an accurate thermometer for measuring. The temperature measuring device shall be capable of measuring the temperature of freshly mixed concrete to ±1°F (±1°C) with a range of 0°F to 212°F (-18°C to 100°C). When heating water and aggregates, the approximate resulting temperature for a batch of concrete can be estimated from the following formula:

$$X = {(Wt + 0.22MT)}/{(Wt + 0.22M)}$$

Where:
X = temperature of the batch in degrees F
W = weight (mass) of the water
M= weight (mass) of the aggregates and cement
t = temperature of the water in degrees F
T = temperature of the aggregates and cement in degrees F

Sampling and Testing. The ends of concrete cylinders must be smooth. Tests have proven that rough irregular cylinder ends cause a reduction of up to ten percent (10%) compressive strength. The reductions appear to become greater as the compressive strength increases. There is no substitute for careful workmanship in preparing concrete cylinders. The inspector is cautioned against poor practices resulting in irregular ends. Two of the most common are as follows:

- Denting the bottom of the mold with a tamping rod. Placing the mold on a firm foundation can prevent this.

- Improper finishing of top. Either too much or too little concrete results in an unsatisfactory surface. Too little concrete is difficult to trowel finish properly. Too much material, if allowed to come in contact with the mold lid, can result in an irregular or convex surface depending on the lid or a nonparallel surface if the lid is placed improperly.

With the mold on a level surface, trowel finish the cylinder flush with the top of the mold. Lightly place the mold lid on the mold (overnight), if possible, until the concrete is partially set. Then place the lid on firmly. Sealing of the lid too soon results in the concrete sticking to one side of the lid but not the other giving a nonparallel surface.

Concrete Acceptance. Subsection 502.03 of the Standard Specifications require the Contractor to submit all proposed concrete mix designs along with appropriate samples of all ingredients for the Engineer to review and confirm. The Engineer will submit the proposed mix design and all ingredients to the District Materials Engineer to confirm in accordance with the directions outlined in Section 260 of the Quality Assurance Manual.

The Engineer will promptly notify the Contractor of the acceptance or rejection of the proposed mix design. If the mix design is accepted the letter should remind the Contractor that final acceptance of the concrete is based on field compliance of all contract specifications requirements. If rejected, the Engineer will explain why and direct the Contractor to correct the deficiency(s) and re-submit.

Concrete acceptance is based on supplied concrete meeting the minimum requirements specified in Subsection 502.01 of the Standard Specifications and the results of the 28-day compressive strength tests. Concrete failing to meet the intended strength but meeting the allowable strength will be subject to a penalty per Subsection 502.01 B. Concrete not meeting the allowable strength will be removed at no expense to the Department. Plastic concrete not meeting the requirements of Subsection 502.01 of the Standard Specifications will be rejected prior to placement.

Concrete that has subsequently been damaged through neglect by the Contractor by not following specifications will be removed and replaced at no expense to the Department. If the damage is tolerable, the concrete may be left in place with an appropriate penalty (Subsections 105.03 and 502.01 B of the Standard Specifications).

A. Proportioning. The Contractor must submit a concrete mix design for all concrete classes. Each mix design, except Classes 15 and 22, must be supported by test results indicating the design, under production conditions, will consistently provide average compressive strengths equal to or exceeding the minimum specified strength (concrete class times 100) multiplied by the appropriate Strength Factor(s) or Strength Value. These factors and values shall be determined as described in Subsection 502.03.A of the Standard Specifications. Recent state project concrete compressive strength test reports may be used to support mix designs in lieu of furnishing special samples and lab test reports. If the mix design is acceptable and the laboratory results indicate the mix will consistently meet the intended strengths, the Engineer should write the Contractor authorizing the use said mix design. This approval is only for the mix design that the supportive data demonstrates. Acceptance of the concrete is still based on the 28-day concrete cylinder breaks.

Samples of cement, water, additives, sand, and coarse aggregate must be submitted at the start of the job, and as required by the minimum test schedule.

Slump and air tests must be run on the first concrete delivered to verify that specifications are being met. A yield test must also be run on this concrete to determine primarily if the batched concrete contains specified minimum cement per cubic yard. Concrete which over- or under-yields indicates that either the mix design is not being followed or adjustment in the design is necessary. Under yielding usually results in higher strengths and over-yielding in lower strengths. The ideal condition is when the yield is 100 percent.

Once a mix design has proven satisfactory, inconsistencies between loads can usually be traced to one of the following causes:

- Failure to make the proper moisture content correction for the aggregate at the mixing plant. Changes in the stockpile moisture results in changes in the mix. Specifications require aggregates to be stockpiled or binned for drainage at least 12 hours before being batched.
- Indiscriminately adding water to the mixture. The Contractor may make minor adjustments to the mix proportions to improve workability as long as all basic concrete specifications are maintained. The minor adjustments should be approved by the Engineer prior to implementation. If the Contractor wants to add water on site, a batch ticket will be required to show how much water will be added to reach the maximum allowable water/cement ratio. Extremely hot weather and extended mixing time may stiffen the concrete mix. When necessary, the cement may have to be added at the job site to help concreting operations.
- Failure of the mixing or measuring equipment or the improper operation of this equipment. The specifications clearly outline the requirements that equipment must meet. The inspector watch for any shortcomings in the equipment and that the contractor takes corrective action before batching.

B. Equipment. Each batch plant which furnishes concrete to the project must be inspected for full compliance with the specifications. Document the inspection on the ITD-0893 form. At least one plant inspection report must be in the project files before work is performed. Inspection reports are interchangeable between projects but must be done yearly.

C. Handling, Measuring and Batching. Check the procedure for batching, charging mixers, mixing, delivery and discharge to insure that properly batched and mixed concrete is placed. Also check that the scales have current certifications and the accuracy of the water metering devices. This checking should be done at the beginning of the job and as often thereafter as conditions warrant. Document the checking by a diary covering the day or days on which it was done.

D. Mixing and Delivery. Whenever ready mix concrete is used on the project, the Inspector shall be alert to the condition of the trucks being used for delivery. All trucks shall have operational counters and a device to measure the amount of water added at the site. All trucks are required to be operated within the rated capacity stated on the manufacturer's data plate. When necessary, the Inspector will inspect the drums of the delivery trucks for the condition of the fins and buildup of hardened concrete.

E. Falsework and Forms. In essence, the field engineer's rule for falsework inspection is to ensure that the falsework, as it is constructed, complies with the following requirements:

Falsework must be designed and stamped by an engineer licensed in the State of Idaho. The drawings and computations must include design loadings and type of materials to be used. Falsework drawings and computations must be submitted to the Engineer for review.

The falsework is constructed to substantially conform to the falsework drawings.

The materials used in the falsework construction are of a quality necessary to sustain the stresses required by the falsework design.

The workmanship used in falsework construction is of such quality that the falsework will support the loads imposed on it without excessive settlement or take-up beyond that shown on the falsework drawings.

Experience shows that details give the most trouble. Falsework failures are seldom, if ever, a result of faulty design; rather, failures usually can be traced to the oversight of some minor detail. Construction details should be given special consideration, with particular attention to connections and details that contribute to the stability of the falsework system.

Falsework specifications require that construction of falsework may not begin until the Engineer has reviewed and approved the falsework drawings.

This requirement shall be enforced on all projects, without exception.

The leveling of ground is not interpreted as "falsework construction" for this specification; but the placing of timber pads or the driving of falsework piles is "falsework construction" and will not be permitted in the absence of checked falsework drawings.

Falsework is usually erected on timber pads or sills set on the surface of the existing ground. Occasionally, soil conditions are such as to require construction of concrete footings or driving of piles to ensure an adequate foundation for the falsework. In most cases, falsework is composed of either steel or timber members, or a combination of these two materials. Frequently encountered combinations of falsework materials are:

- Timber posts and caps with timber or steel stringers and timber joists. This type of construction is often referred to as "conventional" falsework.
- Tubular steel pipe-frame components assembled together to form towers. This system utilizes steel or timber stringers between towers with timber joists between the stringers.
- Structural steel bents constructed from I or WF rolled shapes or from welded tube sections, supporting steel or timber stingers with timber joists. Steel bents are usually supported by and securely fastened to concrete footings or steel sills anchored to the pavement.

Timely inspection as falsework construction progresses is essential, and the Contractor should be informed immediately when deficiencies are discovered.

Prior to the start of construction of any falsework over or adjacent to the traveled way, the Contractor must consider the safety of the public. The Engineer has the responsibility and the authority to demand that all aspects of falsework construction, including workmanship and erection procedures, conform to the best engineering practice in any situation where public safety is involved. The Engineer should not hesitate to require additional work or to direct or stop any construction procedures if such action is warranted to ensure public safety.

Conversations with the Contractor concerning falsework construction should be recorded in the daily diary. If there are conditions that are critical and the Contractor does not take corrective action, a written order should be given. The letter should state specifically what conditions need correcting, but should not dictate how the correction is to be done. No predictions should be made. The falsework cannot be loaded before satisfactory repair has been made. In addition to routine falsework photographs, close-up photos of details should be taken in all cases where the falsework has required extensive repair or upgrading in order to meet contract requirements.

The inspector should become familiar with the foundation phase of falsework inspection. Regardless of how well constructed the falsework may be, its ability to carry the imposed loads is no better than the foundation upon which it rests. Typically, falsework may be supported on soil, which may consist of native or imported material, or on rock, pavement, or driven piles. Foundation problems most often occur when falsework is supported on soil. However, it should not be assumed that because falsework is supported on rock or piles, no inspection of the foundation is necessary.

Falsework footings are to be designed to carry the loads imposed upon them without exceeding the assumed soil bearing values or anticipated settlements. The soil bearing value assumed in the falsework design for both wet and dry conditions must be shown on the Contractor's falsework plan. Actual values and soil condition must agree with the assumptions.

An inspection of the foundation materials should be made before the pads are set in place. The supporting capacity of the soil may be roughly estimated by probing with a piece of reinforcing bar. The bar may penetrate 1 ft. or more in loose material, but will penetrate only 1-2 in. in compact material. The weight of an average-sized man concentrated on the heel of one shoe exerts a force of approximately 21 lbs./in^2 or 1.5 tons/ft^2. Consequently, if the material is firm to walk on without indentation, it should be capable of supporting a falsework loading of this magnitude. These simple field tests are only indicators and should be used with judgment. The true bearing capacity of a given soil is not easy to determine. The Engineer should not hesitate to require a soil bearing test if there is doubts as to the ability of the foundation material to support the falsework load without settlement.

Falsework pads are often set on abutment fills, or on top of backfilled material around piers and columns. Additional care is particularly important in the case of backfill around piers or columns in stream channels or where traffic will be some distance away. Many falsework failures are actually attributed to excessive settlement of pads placed on improperly prepared soil. Falsework pads should not be placed on the sloping surface of a cut or fill slope where the pads may be undermined or subjected to sliding downhill. Pads should be set on horizontal benches cut into firm material, with the pad set well back from the edge of the bench. Many soils lose their supporting capacity when they become saturated. Adequate falsework construction provides for drainage to protect pads from being undermined or ponded in water.

The Construction/Materials Section is available for consultation and advice as to the suitability of load tests in a given field situation, as well as interpretation of test results.

Falsework and Form Materials.

Timber. -- The inspector’s primary responsibility is to prevent the use of materials which obviously do not meet the falsework design criteria, not become a lumber grader. The Contractor is not permitted to splice or block posts in bents adjacent to railroads or roadways; because the falsework must be stable at all times, including times when no appreciable dead load is acting. No bracing of any type should be fastened to the temporary rail that protects the falsework adjacent to traffic.

Timber posts should be wedged at either the top or bottom for grade adjustment, but not at both locations. Large posts may require two sets of wedges to reduce compression stress perpendicular to the grain. Blocking and wedging should be kept to a minimum. Extending a short post by piling up blocks and wedges is a very poor practice. Wedges should be placed with a surfaced side next to a rough-cut side rather than two surfaced sides together. Full bearing should be obtained between all members in contact. Deficiencies in this respect may be improved by feather wedging with a single shingle. Joints requiring more than a single shingle should be recut. When wood shores are butt spliced, the splice shall be made with square joints adequately secured on all four sides with not less than 2-by _ materials or 5/8 inch plywood of the same width as the post. The scab must extend 2 ft. beyond the joint. Good practice limits splices to one per post.

Structural Steel. -- Steel beams and, particularly, salvaged members should be examined carefully for loss or change of section due to welding, rivet holes, or web openings. If the exact size or section of a used beam is not readily apparent, section properties usually can be determined with sufficient accuracy for verification of beam strength by field measurements. Beams composed of short members which have been welded together to form a longer length should not be used for falsework at any critical location.

Manufactured Products. -- Manufactured products such as tubular steel shoring and overhang brackets are particularly vulnerable to damage by continual reuse. Fabricated units where individual members are bent, twisted, or broken will show 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, re-welded, or have broken weldments 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. Manufacturer's ratings are based on the use of new material or used material in reasonably good condition. The determination as to whether a manufactured product is in "reasonably good condition" is highly subjective and requires experience and judgment. Following is information on the more commonly used manufactured falsework products:

Standard Pipe-Frame Shoring. -- Falsework shoring composed of tubular steel members has gained wide acceptance during the past decade. Two types of frames are in general use: The ladder type frame that has horizontal struts between the vertical legs, and the cross- frame type that provide lateral stability by cross bracing between the legs. This shoring system consists of end frames of various types that are erected in pairs and held rigidly together with pin-connected diagonal cross-braces. The pairs of frames may be stacked one above another to form towers, each tower being 4 ft. wide (which is the frame width) and 8 or 10 ft. long. Frames are also available in 2 ft. widths for special uses. The base frames are 6 ft. in height. Extension frames may be set at various positions to extend the base frame from 1 to 5 ft. Minor vertical adjustments are made with screw jacks located at the top and bottom of the tower.

Deck Overhang Brackets. -- Several types of steel jacks or brackets especially designed to support cantilevered deck overhangs are available commercially. The manufacturer's recommended safe working loads should be followed. If a particular jack or bracket cannot be identified, a test load should be required. Special provisions may require falsework and forms to be so constructed that loads will be applied to the web of steel girders within 6 inches of a flange or stiffener. The loads must be distributed so as to prevent local distortion of the web. In addition, temporary struts and ties must be provided as necessary to resist lateral loads applied to girder flanges and to prevent appreciable relative vertical movement between the edge of deck form and the adjacent steel girder. Lateral loads applied to girder flanges will produce an overturning moment in the girder. To prevent possible overstressing of the permanent end and intermediate diaphragm connections, the temporary struts and ties required by the specifications must be designed to resist the full overturning moment.

Beam Hangers. – Basic hangars are hardware items that are placed transversely across the top flange of a beam or girder. Steel rods or bolts, which are inserted into threaded wire loops at the hanger ends, hang vertically and support the deck slab falsework. Manufacturer's catalog data should be consulted to determine the safe working loads. Note that some manufacturers list total hanger capacity whereas others list values for one bolt or rod. Unbalanced loading (i.e., loading only one side of the hanger) will materially reduce the load-carrying capacity of the hanger, unless it is designed to be loaded on one side at a time or unless special measures are taken to hold the hanger in place. Beam hangers must not be welded to the top flange of a steel girder or to pre-stressed girder stirrups. Welding to shear connectors or studs is permissible, however, if approved by the Engineer.

Steel Joist Assemblies. -- Joist assemblies, a common building construction, are being used more and more frequently in bridge falsework. Joist assemblies are essentially steel beams that can be adjusted to provide a wide range of span lengths. Manufacturer's catalog data should be consulted to determine the safe load-carrying capacity. Joist assemblies that are used to support deck slabs between girders are limited to a design load of the maximum deflection recommended by the manufacturer, which may exceed 1/270 of the span.

<u>Falsework</u> Workmanship Checklists. Workmanship should be of such quality that the falsework will support the loads imposed without excessive settlement or take-up beyond that shown on the falsework drawings. Poor workmanship, particularly in such details as wedges, fasteners, bracing, jack extensions and the like, has been responsible for more falsework failures than inadequate design or overstressed materials. Accordingly, construction details should receive the Engineer's closest attention. The following workmanship checklist is included as a guide to points that may require special consideration:

- The size and spacing of falsework members must agree with details shown on the falsework drawings.
- Falsework pads must be uniformly supported by the foundation material.
- Diagonal bracing, including connections, must agree with details shown on the falsework drawings.
- Diagonal bracing should be inspected after the falsework has been adjusted to grade. Connections must be securely fastened (retighten if necessary to ensure their effectiveness in resisting horizontal forces).
- Posts should be centered over the falsework pad or sill to ensure uniform soil load distribution.
- Posts must be plumb and erected from level and even surfaces.
- The ends of spliced posts must be cut square, and scabs nailed securely on all four sides.
- Blocking and wedging should be kept to a minimum. Too much blocking or too many wedges leads to instability.

- Full bearing should be provided at all contact surfaces.
- Permanently deflected stringers should be placed with the crown turned upward.
- The method of adjustment should be such that the falsework may be readily adjusted to grade.
- Jacks used for adjustment should be plumb and not overextended.
- Abutting edges of soffit plywood should be set parallel to the joists, and continuously supported on a common joist.
- A sufficient number of telltales should be installed to accurately determine the amount of joint take-up and settlement. Telltales should be attached to the joists and as near as possible to the supporting post or bent.

The following inspection checklist is based on information in the "Recommended Standard Safety Code for Vertical Shoring" issued by the National Scaffolding and Shoring Institute. Engineers may use this checklist as a guide when inspecting falsework constructed of welded tubular steel shoring:

- Shoring components should be inspected prior to erection. Shoring, including accessories, which is heavily rusted, bent, dented, or re-welded or which, if otherwise defective, shall not be used.
- A base plate, shore head, extension device or adjustment screw shall be used at the top and bottom of each leg of every tower.
- All base plates, shore heads, extension devices, and adjustment screws shall be in firm contact with the footing at the bottom and the cap or stringer at the top and shall be snug against the legs of the tower.
- Shoring components should fit together evenly without any gap between the lower end of one unit and the upper end of the other unit. Any component which cannot be brought into proper contact with the component into or onto which it is intended to fit shall be removed and replaced.
- Eccentric loads on shore heads and similar members shall be avoided.
- All locking devices on frames and braces shall be in good working order, coupling pins shall align the frame or panel legs, pivoted cross-braces shall have the center pivot in place, and all bracing components shall be in a condition similar to that of original manufacture.
- Shoring shall be plumb in both directions. The maximum deviation from true vertical shall not exceed 1/8 inch in 3 ft. If this deviation is exceeded, the shoring shall not be loaded until it is readjusted within this limit.

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

- Excessive compression at the tops and bottoms of posts and under the ends of stringers.

- Excessive bending of stringers or shores.
- Tilting of joists or stringers.
- Pulling of nails in lateral bracing and movement or deflection of braces.
- Excessive settlement of telltales.
- Rotation of any member because of eccentric or cantilever loading conditions.

If, during the concrete placement, any member deflects unduly or shows evidence of distress, such as splintering on the bottom of stringers, crushing of joints or wedges, etc., concrete placement should be stopped and the affected area strengthened by the addition or replacement of falsework members. One important and often overlooked point is the effect of curing water on falsework foundations. Some means must be provided to prevent curing water from reaching and soaking the foundation material beneath the falsework bearing pads.

Falsework Field Changes. Some judgment will be required to determine whether the falsework construction "substantially" conforms to the drawings. The following changes will be considered substantial, and must be shown on revised falsework drawings regardless of other considerations:

- A change in the size or spacing of any main load-carrying member.
- A change in the method of providing lateral or longitudinal stability.
- Any change, however minor, which affects the falsework to be constructed over or adjacent to a traffic opening.

Forms. The Standard Specifications require all forms to be designed and to have the seal and signature of an engineer licensed in the State of Idaho, unless otherwise approved by the Engineer.

Extreme pressures are applied to forms by the concrete and during vibration; the concrete becomes fluid that increases the pressures even more. Every forming system must be adequately engineered to prevent failures during concrete placement. Many forms are commercially manufactured. The Engineer should determine the forming system’s structural adequacy. Upon request, most manufacturers will supply all design and allowable loading data for their systems. If the forms are a contractor-built system, the Engineer should determine that the system is capable of performing as intended. If there is any question, do not hesitate to enforce the requirement that the forming system be designed and approved by a licensed engineer.

Deck Forms -- Deck forms should be inspected and approved as above. The most critical point for deck forms is the spacing of span girders, hangers, and overhang braces. Check to assure that proposed loads do not exceed the maximum design load of these components. The forms must not exceed the maximum allowable deflection.

When the forms are approved, the Contractor may proceed with forming of the deck. Care should be taken to insure tight fitting forms. Mortar running through holes in the forms can cause visual damage and in some cases structural damage to the concrete. The form design engineer should calculate all deck grades especially for bridges on curves or variations in width with assistance from the Bridge Design Section. Be sure to adjust all forms to grade before the steel placement begins then check the grade after the steel has been placed.

Before the concrete placement, inspect the forms both from the top and from the underside to insure that all the elements of the system have been properly placed and that no deficiencies exist. Final grade checks should be made on a "dry run" measuring down from the screed of the finishing machine to the mats of the reinforcing steel and to the deck forms.

Permanent Metal Concrete Forms -- The Standard Specifications describe the attachment of permanent metal concrete form supports to the flanges of stringers and girders by permissible welds, bolts, clips, or other approved means. The description goes on to say, "However, welding of form supports to flanges of steel not considered weldable and to those portions of a flange subject to tensile stresses (areas where intermediate stiffeners are welded to bottom flange and are gapped at top flange) shall not be permitted". Welding should be avoided in the tension areas, since arc strikes (which cause gouging) and weld metal deposits (which cause an abrupt change in cross-section) both result in areas of stress concentration. These stress concentrations are considered extremely detrimental to the fatigue strength of the girder or stringer as it flexes through many cycles of loading. The stress concentrations are the first places to develop fatigue cracks. An increase in section due to a weld can therefore have a similar effect to a decrease in section, such as a piece of steel which has been cut or notched will break at that weakened location after a number of repetitious bends. Any welding which has been found in tensile stress areas of girder or stinger flanges must be removed by grinding the weld flush with the original flange surface. Any reduction of the flange cross section due to cutting or gouging must be avoided during this corrective work.

The reference to intermediate stiffeners has caused some confusion that resulted in stringers without intermediate stiffeners receiving welds on the top flange in tensile areas. The intent of this specification is that no welding is permitted for girder or stringer flanges subject to tensile stress, and would also apply to deck overhang supports that have been welded to the girder flange.

Intermittent fillet welds are permissible to attach the form support angle to the girder or stringer flange in compression areas. The Contractor will probably continue to weld directly to the flange in the compression areas and use straps, clips, or some other methods in the tension areas. The approved shop drawings should show the tension areas over supports where welding will not be used. If the shop drawings do not show this, request the information from the consulting design engineer if applicable or the Bridge Engineer for all girders and stringers that are subject to tension before the Contractor begins attaching the forms.

F. Concrete Placement. Prior to each large deck placement, a meeting with the Contractor's supervisor should be held to go over all aspects of the placement. The total number of men available and in particular the finishers and finishing equipment should be adequate for the size of placement.

Placement crews must work over the deck area during the placement operation. The inspector must be particularly watchful to see that reinforcing steel and forms remain in their intended location. The deck finishing machine must be operated over the full length of the deck segment before concrete placement begins in order to check cover on reinforcement and any possible screed rail deflection. All necessary corrections shall be made before the placement is started.

Equipment breakdowns and power failures sometimes occur during concrete placement. Therefore, the inspector should be satisfied that an alternate placement procedure can be implemented and that certain items of standby equipment are available. An extra vibrator can be very valuable when the need arises.

During the placement of concrete, check for any movement or deformation of forms that may exceed the specified tolerance. If the movement or deformation exceeds the specified tolerances, take appropriate action. This action may include halting concrete placement to install additional bracing or changing the rate or sequence of concrete placement to achieve the required lines and grade.

Ensure the Contractor follows the specified order of placing. Also, ensure that concrete for horizontal members or sections is not placed until the concrete in the supporting vertical members or sections has been consolidated and subsidence has occurred. Determining when subsidence has occurred will require judgment based on your experience with various concrete mixes. In general, subsidence has occurred when bleed water at the surface has disappeared.

Through observation, ensure that concrete is placed without causing segregation. Concrete is placed in continuous horizontal layers. Segregation of concrete in the forms may be caused by building up too thick a layer of newly placed concrete and then allowing it to flow or slide down the slope at the end of the layer. Concrete is to be deposited into the forms as close as possible to its final position, without allowing it to flow laterally in the form any considerable distance.

The Specifications provide that concrete not have a free fall of more than 5 feet. The use of an open chute, enclosed chute or tremie will be used otherwise. These handle concrete without appreciable segregation and perform the very important function of keeping the reinforcing steel and forms from being splattered with concrete.

Ensure reinforcing bars are clean when they are embedded in concrete. If they become splattered with mortar from previous placements and it has dried, they need to be cleaned. If the Contractor exercises care and uses the proper methods, there is very little trouble from this source. It is important that the forms be clean and free from dry mortar, otherwise a rough surface will result.

Rate of Placement and Cold Joints. The pour rates should be such to keep cold joints from forming in a structure. A cold joint is formed when fresh concrete is poured against partially set or hardened concrete. Cold joints can form when there is a long interruption during a concrete pour or when the pour rate is too slow to keep each layer of fresh concrete in contact with a previous layer of concrete that is still fresh. Loads and stresses in the structures can cause the concrete to crack or pull apart at the cold joint. Cold joints are dependent on the concrete’s set time that is affected by temperature, admixtures, and the type of cement and secondary cementitious materials used. There is no rule of thumb that says when a cold joint will occur. The Inspector and Resident Engineer must carefully examine the concrete after the forms are removed for any visible layering or discoloring. If you suspect a cold joint does exist say so and reject the pour. The Contractor is then obligated to submit a repair proposal.

At this point the Contractor has several options:

- Core the structure at the cold joint and strength test the cores to see if they will fail at the cold joint.
- Submit an engineering analysis proving the cold joint is not detrimental to the structure.
- Repair the cold joint.
- Remove concrete beyond the cold joint to a place in the structure where a construction joint would be acceptable.

All of these alternatives can be time consuming and costly. Thus it is very important to work with the Contractor to minimize the risks of forming cold joints. It is advisable for the Inspector not to stop a concrete pour when you suspect a cold joint may be forming. Let the Contractor and the Resident Engineer make this call. Usually the burden is placed entirely on the Contractor, and the Resident Engineer will only intervene when the cold joint and its detriment to the structure are obvious.

Bridge Deck Placement. The Resident Engineer must hold a pre-pour meeting with the Contractor before the initial deck pours. The intent is to have the Contractor’s concrete foreperson describe how the deck concrete will be placed, consolidated, finished, textured, and cured.

As a minimum, the following discussion should be covered:

- The Contractor's pour sequence plan which shall include the location of all construction joints by span and station, the width and quantity of concrete to be placed, the scheduled time for each placement, the direction of placement and orientation of the screed, the proposed screed, and the means of setting and controlling screed grades.
- The equipment to be used for vibrating, finishing, floating, tining, misting, and curing.
- Type of materials used for curing.
- Crew experience and assignments.
- Inspection staffing, procedures and timing.
- Rebar placement and scheduling.
- Material sampling, testing, and certification (concrete, rebar, curing compound etc.).
- Plant operations, inspections and concrete deliveries.
- On-site and off-site traffic control (traffic under the deck pour should be avoided).
- Safety hazards and protective equipment.
- Ladders and walkways for personnel access.
- Illumination requirements, if pour is at night.
- Contingencies for plant failures, pump breakdown, screed stoppages, and inclement weather (rain, snow, dry winds, falling temperatures).

The above points should be used as a basis for developing an agenda for the pre-pour meeting. Bridge deck pours are difficult and expensive to stop once they get started. The idea behind the pre-pour meeting is to ensure both the Contractor's and the Department's field personnel have a clear understanding of how the deck will be poured, and what inspection procedures will be followed. The time to have discussions about good construction practices and specification enforcement is in a meeting room, not on top of the bridge. Thus it is important for the Contractor and ITD to clearly understand all the details of the pour. The project supervisors and inspectors should be free to ask questions so they can fully understand the Contractor's methods. The Resident Engineer should ferret out any hidden agendas on both sides, ask the tough questions nobody wants to ask, and get a commitment from the Contractors staff to do quality work.

Placement Sequence. Bridge superstructures, particularly bridge decks, follow a placement sequence where some portions of the deck or superstructure are placed before others. The placement sequence can be found in the Bridge Plans. The Project Inspector must ensure the Contractor strictly follows the placement sequence.

The placement sequence is intended to place much of the concrete for the superstructure in the mid-span areas before placing concrete over the piers. The placement sequence allows the reinforcing steel over the piers to move as the bridge deflects from the weight of the concrete. If the concrete over the piers were placed first, the rebar would be locked into place as soon as the concrete hardens. Then when the mid-span areas are poured, the concrete over the piers could crack as the concrete tries to restrain the rebar from moving.

Skewed Bridges. All bridges that are built on a skew have special requirements that are sometimes overlooked by contractors and inspectors. Typically the abutments are not perpendicular to the centerline of the roadway. They are set at some angle other than 90 degrees, and can be as low as 45 degrees. However, the girders run parallel to the roadway centerline. As a result, the angle between the abutment and the girders is not 90 degrees.

The concern here deals with the placement and finishing of bridge decks. The bridge deck must be placed and finished in the direction of the skew angle and not perpendicular to roadway centerline.

Pumping Concrete. When concrete is pumped, the Contractor should be advised to have a standby pump in case the primary pump fails. It is not necessary for the standby pump to be at the job site as long as it can be mobilized and placed in operation within 30 minutes of a pump failure.

It is considered good practice on monolithic pours to allow a waiting period from two hours (minimum) to four hours (maximum) following concrete placement in walls, columns, or piers before permitting fresh concrete to be placed on top of these members. This delay can be modified where wall height is 6 feet or less. The delay is necessary to allow most of the settlement and shrinkage in the earlier placements to occur; thus, decreasing the probability of cracking at the junction of the two placements.

In some cases, the Project Plans will indicate the sequence of placing concrete in a structure. When not shown on the contract plans, the Resident Engineer should require the concrete to be placed continuously throughout each section of the structure or between indicated joints. The concrete placement rate should be such that no cold joints are formed within monolithic sections.

Vibrating Concrete. Subsection 502.03.F.2 of the Standard Specifications allows the Contractor to use vibrators for consolidating structural concrete. It is up to the Project Inspector to approve or disapprove vibrators. Inspection of vibrators and other placing and finishing equipment should be done at least one day before the pour, so the Contractor can replace any substandard equipment.

The purpose of vibration is to cause the concrete mix to envelop and bond to the reinforcement, fill voids, and make the structure more waterproof and durable. The concrete vibrator, when properly used, is a good tool for working the concrete under and around closely spaced reinforcement.

Operation of the vibrator requires some skill and considerable physical effort. Workers who are charged with this responsibility should have some experience and instruction in proper methods of vibrating. The vibrator should not be left in any one area of concrete longer than a few seconds.

As soon as the surface of the concrete surrounding the vibrator ceases to settle, it should be pulled out slowly and inserted slowly into a new area. Excessive vibration should be avoided as it tends to cause segregation and increases the lateral pressure on the forms.

If the Inspector suspects the vibrator is not operating at or above the minimum frequency, measure the vibrator's frequency with a portable tachometer or a vibrating reed called a Vibra-Tak. ITD district materials labs or the central lab should have these instruments. The frequency should be measured with the vibrator operating in and out of the concrete. A significant difference between the vibrator's measured frequencies in and out of concrete may indicate that the vibrator is in need of repair or there is an inadequate power or air supply.

Contractors should operate vibrators in accordance with the manufacturer's recommendations. If the Inspector suspects that the Contractor is not using a vibrator properly, the vibrator can be rejected for not being suitable to the Contractors placement methods. Consult the manufacturer's recommendations to make this determination. The depositing of concrete at one point and moving it with the vibrator is not permitted.

Concrete should be placed in approximately horizontal layers not more than 24 inches deep. If concrete movement is necessary it should be done with shovels rather than vibration. Moving concrete horizontally causes the grout to flow while the rocks settle.

Also, ensure that high frequency internal vibrators consolidate the concrete when specified. The method used to vibrate concrete directly affects the structure's strength. Ensure minimum contact between the vibrator and reinforcing steel. Concrete must be vibrated to the point where mortar and water flush to the surface; vibration beyond this point is not necessary or desirable. Insufficient vibration, on the other hand, will leave rock pockets (voids).

Bridge screeds should be equipped with vibrators and often have a tachometer as well. Bidwells and other commercially available screeds can be equipped with external vibrators mounted in front of the rollers. These vibrators must clear the top mat of reinforcing steel and are used to ensure that the riding surface of the deck is properly consolidated for long-term wear.

Joints in Major Structures. There are basically only two types of joints in any reinforced concrete structure: the construction joint and the expansion joint. The contract plans will show all joint locations.

The weakened plane joint (where the concrete is partially sawn to control cracking) is rarely used in reinforced concrete structures. Reinforcement steel acts like a crack stopper so there is no guarantee that the concrete will crack at the weakened plane joint.

Construction Joints. Construction joints are usually oriented and located in areas where load transfer is uniform or at a minimum. With the Designer's approval, the Contractor may add, alter, or relocate construction joints.

The construction joint is a provisional joint used primarily to terminate a concrete placement at a predetermined location. Some structures are so large that it is not possible or desirable to place them all at once. The construction joint is intended to provide a temporary means of ending a concrete placement while still providing structural continuity (that is adequate load transfer across the joint). The installation of construction joints is generally straightforward. A form serves as a bulkhead where the placement is terminated. Usually rebar will protrude through the form and a key is usually formed on the joint face (see Project Plans). The form is stripped the next day except when a stay-in-place form is used. The joint is then cleaned with either sand or water blasting (if more than eight hours old) and the next placement is continued.

Inspectors need to carefully examine construction joints in structures for:

- The correct location and orientation.
- Correct concrete placement procedures (ensure only acceptable concrete is used and that it is properly placed and consolidated—don't use the first concrete out of the chute or pump line).
- Proper cleaning and blasting (don't over blast the joint since this will only loosen the coarse aggregate).
- Smoothness across the joint when placed in a bridge deck or other riding surface (this may require extra straight edging and careful screeding or re-screeding by the Contractor).

Expansion Joints. The expansion joint is intended to allow movement between adjacent structures or between different members within a structure. This movement prevents stress build-up due to creep, shrinkage, or temperature changes that would seriously crack the structure.

Expansion joints create a small gap between two structures or structural members (abutment vs. girders) that allow for movement.

There are three important things that the Inspector must keep in mind about expansion joints:

- The joint is in the correct location and runs the full depth and length required by the contract plans (the joint must completely separate the two structures or structural elements).
- The gap is set at the correct width.
- There are no obstructions or connections between the two structures (rebar, conduit, utility lines or loose concrete) that would interfere with the opening and closing of the joint.

Only approved fillers and sealant materials should be used. Expansion joints are shown on the contract plans. Expansion joints can be found between abutments and bridge superstructures; between two sections of a long bridge superstructure; between anchor and approach slabs; and between approach slabs and abutments. Near the surface of an expansion joint, a compressible material (such as a bituminous or cellular plastic filler) is placed to prevent rocks, nails, and other incompressible material from entering the joint that would prevent movement. On top of the filler, a joint sealant is placed to prevent water from entering the joint. For expansion joints adjacent to bridge decks, a deck joint assembly is installed and serves as the joint filler and sealant.

Deck Joint Assemblies. ITD most often uses two types of deck joint assemblies. The compression seal joint and the strip seal joint. Both are designed to keep out water and prevent debris from falling into the joint.

The Contractor must submit shop drawings for all deck joint assemblies in accordance with Subsection 105.02 of the Standard Specifications. The bridge designer will review and approve the shop drawings. The inspector must have these shop drawings on hand when the Contractor installs the deck joint assemblies. The shop drawings will describe the installation method. The Inspector should ensure this method is followed. In addition, a temperature correction chart should be included with the drawings. It is very important for the inspector to ensure that the correct gap width for the joint is set prior to pouring the joint. The width is based on the structure temperature (not air temperature) at the time of the pour, which can be read from the chart. Setting the joint at the incorrect gap can create long-term maintenance problems for the Department. A gap that is set too wide can cause the joint material to tear or fall out as the joint expands. A gap that is set too narrow can cause the joint to close, which can severely crack the bridge deck, girders, and diaphragms.

Here are some other inspection checks the Inspector can do to ensure the Department gets long lasting, worry-free deck joints:

- A long-lasting joint is a smooth joint—ensure the steel guard angles on each side of the joint are correctly recessed so that no bump or dip will occur as vehicles pass over the joint (concrete grinding should be done to improve the smoothness).
- Ensure the existing concrete adjacent to the joint is coated only with an approved adhesive.
- Ensure good consolidation of the concrete under the guard angles.
- Ensure bolts in the erection angle are loosened after the concrete has set to allow movement.
- Enforce all the provisions of the contract. They were written to provide the Department with durable, high quality deck joints.

Seal Concrete. Seal concrete calls for extra cement to make up for losses during underwater placement. Special care must be exercised in the placement of concrete below the water surface to keep agitation to a minimum. Bottom dump buckets may be permitted in shallow water. When placing seal concrete with a bucket, it must meet the same general conditions as outlined for a tremie (must be watertight, the outlet buried in the concrete, and no washing of the concrete shall occur). Seal concrete is placed with a higher slump so it will flow out of the tremie or bucket and into final position with little working. The higher slump also aids in preventing foreign water from entering the concrete.

Care should be exercised to assure that the required depth of seal is obtained over the entire area. The excavation should be checked for high areas before the seal is placed and the surface of the placed seal should be checked for irregularities.

After the seal has obtained the required strength to withstand the hydrostatic pressure, the cofferdam may be dewatered. During this operation, the flow of water through the joints in the sheeting tends to seal with solids moving with the in-flow. Slow pumping provides more time for this sealing to take place. When the cofferdam is dewatered, the surface of the seal should be trenched to a sump area for pumping, piling cut to the required elevation and spacing checked. The footing is then formed and construction proceeds in a normal manner.

G. Cold Weather Concreting. Several precautions must be taken when placing concrete in cold weather. If temperatures below 40 F are anticipated within seven days following placing the concrete, the Contractor will normally be required to enclose the structure, and provide heat and moisture so the concrete will obtain its initial strength without freezing. The addition of moisture should be discontinued 24 hours before discontinuing the heat so there will not be an excess of moisture on the surface of the concrete to form ice in case of cold weather following the seven-day protection. If the temperature is below 40F when placing the concrete, the concrete must be heated to at least 50 F by heating the aggregate and/or water in accordance with the Standard Specifications. The temperature of the concrete, as well as the slump, must be consistent from batch to batch. Corners and edges require special attention to prevent freezing such as applying extra insulation.

In summary, the difficulties arising from cold weather concreting may usually be minimized by:

- Not placing concrete against any frozen or ice-coated foundation, forms, or reinforcement.
- Having a pre-approved plan for cold weather placement and curing.
- Heating aggregate and/or water to maintain mix temperatures above 50 F.
- Controlling temperature and humidity after placement by enclosing concrete and/or heating to a 50 F to 80 F for seven days.
- Adding moisture for six days and discontinue 24 hours before heat is stopped.

H. Hot Weather Concreting. When the concrete is being placed in the bridge deck during hot weather, additional precautions must be taken in order to prevent rapid surface evaporation. The Inspector should acquire a current evaporation rate chart which allows one to estimate the rate of evaporation based upon the air temperature, relative humidity, concrete temperature and the velocity of the wind. These charts are generally found in such manuals as the Portland Concrete Associations Design and Control of Concrete Mixtures manual. The district materials sections should have these readily available. Generally tolerable evaporation rates are considered under 0.2 lb./sf/hr.

Water reducing retarder admixture should be used in the concrete so the water-cement ratio and slump of the concrete can be maintained within the specification limits. The mixing time of the concrete should be held to the minimum. Shaved ice may be needed as part of the mixing water to keep the mix temperatures low enough.

The temperature of the concrete at the time it is placed in the forms must be kept under 85 F. Concrete with high temperature loses slump rapidly, and is difficult to place and finish. This temperature can be controlled by shading the concrete trucks while loading and unloading and shading the conveyors or pump lines used in placing the concrete. The forms and reinforcing steel should be cooled prior to placing the concrete. This can be done by covering them with damp burlap and then spraying them with cool water immediately prior to placing the concrete. Care must be taken to see there is no standing water in the forms when the concrete is placed.

The concrete must be placed and finished as soon as possible. If there is a delay in applying the curing compound after the concrete has been finished, a fog spray should be applied to reduce the moisture loss due to evaporation. If plastic cracks form and the concrete is still in a plastic state, they can be eliminated by re-vibrating the concrete and refinishing. Care must be taken to not re-vibrate the concrete after initial set has been obtained. The requirements for curing the concrete shall be enforced.

As soon as the visible bleed water has evaporated from the finished deck, the curing compound should be applied. The curing compound should be applied in two applications to ensure full coverage of the concrete. The second coat should be applied in a direction perpendicular to that of the first application. The amount of curing compound applied in the two applications should meet the minimum amount specified. Immediately after application of the curing compound and initial set, the concrete deck should be covered in accordance with Subsection 502.03.J of the Standard Specifications.

In summary, the difficulties arising from hot weather concreting may usually be minimized by:

- Using cool mixing water.
- Keeping the aggregate temperature as low as is economically feasible.
- Reducing the length of mixing time.
- Placing the concrete as soon as possible after mixing and with a minimum of handling.
- Keeping the surfaces shaded or cool during placing.
- Placing curing compound as soon as possible.

I. Finishing Concrete. All formed surfaces require an Ordinary Surface Finish per Subsection 502.03.I, as a minimum. The intent is to provide a concrete surface that is hard, sound, and reasonably impenetrable to moisture. No steel is allowed within 1 inch of the surface. This is to prevent the establishment of a rust channel that could corrode the reinforcement. A surface finish is just as important below ground as it is above. In fact, the potential for rebar corrosion is much higher underground. When formed surfaces will remain in view of the traveling public, the Contractor must use forms that will provide a pleasing appearance of uniform color and texture.

A Rubbed Surface finish is required when the Contractor's forming system does not produce a surface that is reasonably smooth and uniform in texture and color as required by the Standard Specifications.

The intent of Subsection 502.03.I is for the Contractor to produce the proper finish without having to resort to performing a Rubbed Surface finish. In other words, the Contractor cannot use damaged forms or substandard forms and compensate later by performing a surface finish after stripping. The surface finish procedure is merely in the Standard Specifications as a contingency for the unexpected occasion where the formed finish is not pleasing in appearance. It is not a replacement for good concrete forming practices.

If a formed surface does require finishing, Subsection 502.03.I specifies the finishing to begin Immediately upon removal of the forms. Immediately does not mean tomorrow or next week.

Contractors are often anxious to get their forms down as quickly as possible, but may not want to provide the labor necessary to finish and cure the exposed surfaces immediately after removal. Resident Engineers may require the Contractor to leave forms in place until a satisfactory crew could be assembled to finish and cure the exposed concrete. Mortar adheres to young concrete much better than to older concrete and it is easier to obtain a more uniform color and texture. In the long term, the surface will be more durable and uniform in color and texture if the concrete is finished when it is still relatively young.

Finishing Bridge Decks. One area of bridge deck finishing that inspectors and contractors should always pay close attention to is the deck smoothness at the joints. On precast girder bridges, this is especially important since many construction joints are needed to comply with the required pour sequence.

Any irregularities disclosed by the straight edging should be corrected immediately. Attention should be given to finishing the gutter lines on bridges particularly on nearly flat grades in order to preserve good longitudinal drainage.

The Inspector should allow the Contractor to make minor adjustments to the screed grades to obtain the smoothest joint possible while maintaining a deck thickness within allowable tolerances. In some cases, the Contractor may need to back up the screed and re-screed the surface to get the required smoothness. A small uniform roll of concrete should be maintained ahead of the screed. This requires constant attention when the screed is in operation. The smoothness of the deck will be governed to a great extent on how smoothly the screed operates.

Experience is important in the evaluation of straightedge data. Occasionally high spots are really on grade, but the low areas make the high spots look high. When this condition exists, cutting the area to meet tolerances over the low spots may result in removing too much of the surface and reducing the reinforcing clearance.

As one last reminder, Inspectors should spot check the deck thickness behind the screed. Inserting a piece of thick steel wire or rebar into the fresh concrete can do this. The measurement will ensure that the Department is obtaining the correct deck thickness and can alert everyone to potential problems that can be corrected while the concrete is still being placed.

Skewed Bridges. All bridges that are built on a skew have special requirements for finishing the bridge decks. The bridge deck must be finished in the direction of the skew angle and not perpendicular to roadway centerline.

Typically bridge decks have camber built into them to offset the long-term effects of creep. Creep affects the girders under the deck and causes the girders to sag with time. To ensure this sag does not show up in the deck, the Bridge Designer will set the deck elevations higher at the midpoint of the girders than at the ends where the girders come in contact with a pier or abutment. In order to build this camber into the bridge deck, the finishing machine must come in contact with the same point of each girder at the same time. The girders must be loaded uniformly so they all deflect evenly.

The best way to achieve the proper deck camber is to set the finishing machine at the same skew angle as the piers and abutments, not perpendicular to the roadway centerline. On bridges with a slight skew (less than 20 degrees), the Designer may allow the finishing machine to be set perpendicular to centerline. However, the Resident Engineer should obtain the bridge designer's approval before allowing the Contractor to finish in this direction.

Setting the finishing machine to finish along the skew angle requires a longer machine and some rail adjustments on the Contractor's part. Finishing along the skew is usually something most concrete forepersons do not anticipate. Notify the Contractor about this requirement at the pre-operational meeting.

Tining on a Skew. The tining of the bridge deck becomes a problem when the deck is poured on the skew angle. Tining the deck transversely to the roadway centerline can lead to uneven tining on skewed bridges. The tining rake crosses each girder at a different point along its span. The rake may start near the low point of an exterior girder (at a pier for instance) and cross the midpoint of one of the interior girders. This causes uneven contact pressure since the deck is higher at the girder midpoints due to camber.

The solution is to texture the deck at the same skew angle that it was finished. The intent is to get some type of texturing into the deck. The angle of the texture is not as important as its presence.

J. Curing. Proper curing is of major importance. The specifications require that all concrete surfaces are kept completely and continuously moist until a curing method, depending on the type of placement is applied. High temperatures, low humidity, and windy conditions have an adverse effect on curing of concrete surfaces. Each of these conditions, or a combination, will cause shrinkage cracks in the surface of the concrete unless preventative measures are taken. Idaho Test IT-133-07 in Section 530 of the QA Manual shows how to arrive at an evaporation rate. An evaporation rate greater than 0.2 lb./ft^2/hr. will indicate potential problems, and some type of corrective procedures should be considered to change the placement operation. Placement may be required at night or early morning hours when the temperatures are lower and perhaps less windy conditions.

Prior to deck placements a hygrometer and a wind meter should be obtained from the District Materials Section so that the rate of evaporation can be determined during placement. District Materials also has literature available for the prevention of plastic cracking in concrete.

Curing should not be delayed more than one hour after surface texturing or form removal. Any remedial finishing operation should be finished as soon as possible and should not interrupt curing for more than one hour. The bottom line is: Contractors need to have sufficient labor available to begin finishing, and apply curing as soon as the forms are removed—not three hours or three days later.

There are four methods that are acceptable to the Department:

1. The water curing method
2. The membrane formed curing compound method
3. The forms-in-place method
4. The steam cure method.

The curing method type that is used depends on the concrete surface type:

- For formed surfaces, the Contractor has the option of using water curing, curing compound, leaving the forms in place or steam cure.
- For unformed surfaces (such as top of walls, concrete pavements, etc.), the Contractor has the option of using either water curing or curing compound.
- For bridge decks, the Contractor must use water curing with a curing compound.

Curing Bridge Decks. Curing bridge decks requires a combination of wet curing and the application of curing compound. This curing process is more intricate than curing other concrete members.

The generally accepted procedure is to:

1. Finish and texture the bridge deck
2. Immediately spray with curing compound
3. Continuously apply atomized water until curing medium is applied
4. Apply the curing medium within four hours of the finishing operation—usually wet burlap or Burlene, and
5. Continuing wet curing for ten days.

Documentation for Pay Quantities. The concrete inspector shall calculate the concrete quantities before construction begins. The concrete calculations should show the quantity to be paid for in each portion of the structure. Payment is based on plan dimensions except where a change in the plan dimensions was required in the field. If the total concrete quantity for each major structure is within one percent (1%) of the plan quantity, no additional checking is necessary. If the difference is over one percent, the calculations should be rechecked in the residency.

If there is a great difference, the figures may be submitted to the consulting design engineer or the Bridge Section for checking. These computations and checks should be included as part of the project records, and generally will be the source document for final pay quantity of these items. Minor structures should check within one half of a percent (0.5%) of the plan quantity.

If the calculated pay quantities vary considerably from the amount of concrete ordered or batched, the inspector should determine the reason for the variation. Large area placements such as decks will readily consume additional concrete with no visible indication. Any wasted concrete should be so noted and the quantity estimated. By keeping track of the variations throughout the job, the inspector may easily account for the contractor's purchased amount as opposed to the amount paid for. On large projects, the waste can be considerable.

The Resident Office Manager enters the quantity of each item as reported from the field in the field ledger. The office manager may be required to compute or check the quantities.

The inspector may inform the Contractor of the concrete quantities that will receive payment; but, under no circumstances, should the inspector inform the Contractor of the amount of concrete to be ordered. This responsibility must remain with the Contractor.

The diary shall be used to verify the activity, date, and location of the work and measurements. Quantities for concrete shall be computed and reported to the nearest one-hundredth (.01) of a cubic yard. Round off to the nearest 0.1 cubic yard on the estimates is permitted. Stringers shall be reported and paid to plan dimensions. Estimates should be rounded to the nearest LF.

Reports. Concrete Batch Ticket, ITD-0070, is to be completed for each truckload of concrete.