11.20 FOUNDATIONS

11.21 STAKING AND CHECKING LOCATIONS OF STRUCTURES

The staking of a culvert or bridge is a highly responsible task and requires a thorough study of the layout of the structure. The utmost precision is necessary to avoid mistakes.

The following steps are very important to ensure clearly understood staking control and correct use of the staking provided throughout the construction process:

- Review the plan staking layout to understand the control information provided in the plans and determine how this control can be established on the project site for use during construction. If the plan information is not clear, now is the time to discuss the intent of the plan representation with the designer. The Office of Construction can assist in providing answers to any questions of intent.
- Include a discussion of the staking control at the Preconstruction Conference. This discussion should include a specific review of the control information provided in the plans, how the contractor proposes to use this control during construction, any requests from the contractor regarding staking control needs, and how the staking will be provided in the field.
- Immediately following completion of staking control in the field, the contractor, inspector, and surveyor should meet on the project site for a complete review of all staking and elevation control. The locations and identification of all controls must be clearly understood prior to initiating any construction. THERE CONTINUES TO BE INSTANCES OF INCORRECTLY IDENTIFIED SURVEY CONTROL. THIS IMPORTANT VERIFICATION SHOULD BE PERFORMED PRIOR TO BEGINNING CONSTRUCTION TO AVOID ANY CONFUSION REGARDING SURVEY CONTROLS.
- Once staking and elevation control have been established in the field, the contractor is responsible for preservation and correct use of the control provided. During construction, multiple checks should be made with respect to alignment, position, and elevation before each placement of work is initiated. After placement, re-verification of alignment, position, and elevation should be made prior to subsequent placements. **NEVER PRESUME THAT STAKING AND ELEVATION CONTROL HAVE REMAINED UNDISTURBED SINCE THE LAST USE. ALWAYS CHECK CONTROL AGAINST PREVIOUSLY COMPLETED WORK BEFORE PROCEEDING.**

Check and Double Check

- 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. As a final check for bridges, all span lengths must be measured to verify that all girder line distances are correct. Prior to initiating construction and during construction, span lengths must be monitored to ensure correctness and accuracy of construction of substructure.
- 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.

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. The **"INSPECTOR'S HANDBOOK for CONSTRUCTION SURVEY"** is a good reference for layout and staking procedures.

Documentation
A staking diagram for each structure must be recorded in a permanent survey field book. This sketch must show 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.

Common Survey Errors to Avoid
A. Turning the wrong skew angle
B. Errors in measuring from piers to abutments (This should be detected by an overall check from abutment to abutment.)
C. Centerline of bridge is not always on centerline of road (This is quite common on interstate bridges.)
D. When using a bench elevation, confirm elevation on prior completed work before setting elevations for new work. This can eliminate the potential error resulting from incorrect instrument setup, incorrect instrument readings or the possibility that the bench control has been disturbed.

Encountering Old Substructures
Specification 2401.03 requires the removal of old structures that 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 extra work order (EWO) to remove that portion in conflict. Payment will "NOT" be made if plans indicate the new substructure would hit the old.

Setting Bench Marks (Post Construction)
During construction many bench marks may be destroyed, and new ones must be set for future use. Reestablishing bench marks after construction is a responsibility of the project engineer's survey party. These bench marks must be placed in accessible and readily seen locations. Best results are obtained by delaying this work until after initial settlement has occurred. It is recommended to wait for up to one year after construction.
A. Bench Marks for Bridges

It is recommended to position permanent bench marks on the abutment upper wingwall. Location of the bench mark should be on the right side at the approach end of the bridge. Placing permanent bench marks on superstructures is not recommended and shall be avoided if at all possible.

B. Bench Marks for Culverts

Bench marks should always be set in the inlet parapet near the centerline of a culvert and set nearly flush with the headwall. It shall be our practice to spread the split bottom wings of the plug before setting. This will help to assure it staying in place.

Inspectors must either physically set the bench mark during parapet finishing or make arrangements to have it set.

11.22 PILING AND PILE DRIVING

Pile Driving

A. Driving Constraints

Piles shall not be driven within 15 m (50 feet) of freshly placed concrete. Normally piles may be driven the next day.

Plans may specify a waiting period after berm construction is completed before driving abutment piling. The length of this specified waiting period may be contingent on the analysis of settlement plate readings prior to allowing abutment piling to be driven. The grading plans for the bridge berm construction should be reviewed to determine whether settlement plates were installed. Refer to Construction Manual Section 6.43 for information on settlement plates.

B. Cap Weight

Latitude is allowed for minor variances in the cap mass (weight) listed on the "HAMMER DATA" sheet. Sometimes there are field situations which arise necessitating a change in the cap. Therefore, a variance of ± 70 kg (±150 lbs) is allowable before calling the Office of Construction to validate a driving graph.

C. Pile Length

It has been observed that a difference of ± 3 m (±10 feet) in pile length typically does not affect the driving graph. Therefore, extensions over 3 m (10 feet) will need to have the driving graph verified by calling the Office of Construction.

D. Production Pile Driving

Prior to driving piling, all equipment to be used should be verified with the driving equipment that was used in the Wave Equation Analysis and development of the respective production driving graphs. This should include inspection of the hammer cushion (and pile cushion when applicable) condition, both at the start and throughout the pile driving process.

Driving of piling (i.e: concrete, steel H-pile or wood) should typically progress from the interior (center) of the foundation to the outside. This is to reduce the effect of displaced soils becoming trapped and compacted in the center of a pile group. This increasingly compacted soil could cause problems with driving the piles in the center of the group.

Vibratory Hammers

There has been an increase in the number of requests from contractors for approval to use vibratory hammers to expedite pile installation. *Specification 2501.09, Paragraph D* states that vibratory hammers shall not be used unless approved in writing by the engineer.

Office of Construction and Soils Design have defined the following general criteria to be used in their evaluation of requests for approval of vibratory hammers:

- Use of vibratory hammers will only be considered for steel piling.

- Vibratory hammers will not be permitted in clays where the driven pile capacity is dependent on friction and end bearing in clay.
- Vibratory hammers may be reviewed for use in sands where driven pile capacity is based on friction in sand.
- Vibratory hammers may be reviewed for use in clays and sands where the driven pile capacity is based primarily on end bearing into bedrock.
- All requests for approval to use vibratory hammers shall be forwarded to the Office of Construction for review.
- If request is approved, the vibratory hammer can be used only after the pile tip elevation has been established as required by *Specification 2501.09, Paragraph D.*

Gravity Hammers
Gravity hammers have been given an upper limit of 2,700 kg (6,000 lbs) by *Specification 2501.09, Paragraph A*. Minimal latitude is allowed, therefore, check the Hammer Data sheet for completeness before forwarding a request for wave equation development.

A good check for size of gravity hammer is provided in *Specification 2501.09, Table "J."* Use this table as a guide when checking maximum and minimum size of hammer being requested by the contractor.

For a listing of Gravity Hammers and Caps for both gravity and diesel hammers, refer to *Appendix 11-1*.

Diesel Hammers
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.

One manufacturer of hammers uses one size hammer barrel and places different sized rams inside. This hammer barrel height has been increased on newer model hammers (ie: Serial Number 911203 and after). 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 based on the hammer name and serial number as follows:

MKT DE 33/30/20		Prior to S/N 911203		Including & After S/N 911203	
Ram Mass		Ram Distance±		Ram Distance±	
(kg.)	(lbs.)	(mm)	(in.)	(mm)	(in.)
907	2000	1880	74	1955	77
1270	2800	1220	48	1320	52
1497	3300	790	31	890	35
1814	4000	180	7	280	11

MKT DE 42/35		All Serial Numbers	
Ram Mass		Ram Distance±	
(kg.)	(lbs.)	(mm)	(in.)
1 587	3 500	1371	54
1 905	4 200	736	29

A good check for size of diesel hammer is provided in *Specification 2501.09, Table "J."* Use this table as a guideline when checking maximum and minimum size of hammer being requested by the contractor.

Bearing and Penetration

A. Penetration Requirements

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. A second factor which enters into the calculation is the pile resistance to uplift. ***For these reasons "full penetration" is extremely important*****.**

A depth of expected scour is typically shown on the Bridge Situation 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.

When doubt exists concerning the amount of probable scour or minimum pile penetration required, the Office of Construction 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.

B. Practical Refusal

Quite often Steel H piles are driven to practical refusal in rock. Practical refusal will be achieved when at least the design bearing is reached, AND scour penetration and resistance to uplift are satisfied, AND one of the following criteria are met:

- Driving blows per 0.25 meter (blow per foot) reach the values listed in the ** **DO NOT EXCEED** ** column on the driving graph
- When a particular ram rise reaches the right side of driving graph
- When the pile no longer moves

Note: If the resulting pile cutoff length after driving will be greater than 3 meters (10 feet), contact the Office of Construction for review of driven pile length.

C. Bearing is Not Achieved

When design bearing is not achieved, first check to be sure you have the correct equipment and driving graph. Then call the Office of Construction after a retap has been completed. When calling have the following information available:

- Information from the "logged pile"

- Bearing values of surrounding pile
- Observed "blows per minute"
- Bearing values achieved during production driving as well as bearing value after retap

Refer to the Flow Sheet in *Appendix 11-2* for information on evaluation of low bearing pile.

Retaps

A retap will be required any time pile do not achieve design bearing. (Refer to *Specification 2501.13, Paragraph E for retap procedure and number of retaps required*). A retap is taking the bearing on pile with the lowest driving resistance after it has "set" for a period of time. Twenty-four (24) hours is required, however, overnight is acceptable and sufficient in most cases.

To conduct a retap with a diesel hammer, the hammer should be warmed up on another pile before setting on the pile to be retapped. After two blows to set the cap, count the next 10 blows and measure the distance driven. Convert this to blows per 0.25 m (blows per foot) and determine bearing from the graph. If this meets or exceeds the required design bearing, that pile may be accepted. Indicate on the Log of Piling form a retap value in the appropriate column. There is no need to compute a "set" value and apply this to other piling in that particular foundation. In no case should an average set value be computed and applied to all piling in that foundation. If a retap is conducted on a pile with the lowest driving resistance and it achieves at least design bearing, then all other piling in that foundation may be accepted based on the retap. However if any piling fail to achieve design bearing during retap, the Office of Construction shall be notified.

Dynamic Pile Analyzer

The Office of Construction has a pile analyzer available for driving evaluations. This equipment has been recently upgraded to include the most current technology in pile analysis. The pile analyzer will evaluate pile bearing, based on energy delivered to a pile, through the analysis of soil and pile properties during production pile driving. It will be used not only to verify the driving graph and hammer system, but also to collect field data to be used to better understand soil conditions during driving. Refer to *Appendix 11-2, Flow Sheet.*

There are two situations where the analyzer should be used:

> Case 1. Contract documents require pile to be driven with the analyzer. This will become more frequent as projects with specific pile types and soil conditions are selected for testing to collect field data.
> Case 2. Pile does not achieve bearing and there are unresolvable questions or conditions observed during driving.

In Case 1, the project engineer needs to contact the Office of Construction to arrange for the analyzer. This contact must allow adequate time (typically at least one week) to schedule the work.

In Case 2, the Office of Construction will determine a need for the analyzer during discussions with the project engineer to resolve low bearing values. If the analyzer is needed to verify driving results, the contractor will be paid a lump sum of $250.00 for each pile evaluated. This will be by extra work order to cover any delay in driving and any extra work needed to help hook up the analyzer to the pile.
A. Mounting Analyzer Sensors

In order to measure the energy transferred from the hammer and wave speed within the pile, special sensors need to be physically attached to the pile. Mounting these sensors requires holes to be drilled. For concrete pile, anchors must be set in the pile. To save time, predrill holes prior to having the analyzer arrive at the site. Refer to Drilling Templates in *Appendix 11-3*.

B. Summary

If visible damage does occur, driving should be discontinued before the pile is damaged to the point that it can no longer be incorporated into the structure. If penetration is adequate and the design bearing has been attained, the pile may be incorporated into the structure. If there is doubt concerning penetration and bearing, the Office of Construction should be consulted.

Static Load Tests

The use of Static Load Tests has become almost nonexistent since the Office of Materials purchased the Dynamic Pile Analyzer and since the Office of Construction switched driving control to the Wave Equation. However, the only "true" way to know a pile's capacity is to conduct a static load test.

Today the load test is used to develop comparative data on something new. In 1994, the Office of Bridges and Structures investigated the use of 305 mm (12 inch) concrete pile. Plans where these pile were used had specific directions for location, tip elevation, and driving criteria. For situations where a load test is required that has not been included in contract documents, the Office of Construction will provide guidance for location and driving conditions.

A. Performing Load Test

Conducting a static load test is requested through the Office of Materials, Special Investigations section. For all situations, DO NOT be too hasty to cut the piling off because about 1.5 m (5 feet) needs to protrude above the ground to conduct a load test. This section allows attachment of the jacking beam and instruments required for the test. (Refer to *Appendix 11-21* for information about load testing.)

When a load test is completed, the Office of Materials will provide a test report. Interpretation of the results and any recommendations for the piling will be made by the Office of Construction.

B. Payment for Load Tests

Load tests ordered by the project engineer will be paid for as extra work and will be paid for as a lump sum of $3,000.00 as per *Specification 2501.21, Paragraph J.*

11.23 SPLICING PILE

Welding Steel Pile

Specification 2408.13 requires that all welds conform to the Structural Welding Code ANSI/AWS D1.1 of the American Welding Society.

A. Field Welding

All welding must be done by a certified welder. When a welder is qualified by the Office of Materials, a certificate is issued showing the types of welds which they are qualified to perform. Inspectors should ask to see the welder's certificate, and note: (1) certificate number, (2) date issued, and (3) qualified positions on the "Log of Piling" form. Certificates are good for one year and must be renewed annually, except requalification will only be required every two years for field welders who have successfully passed their qualification tests without failure for three consecutive years.

Only Shielded Metal Arc Welding (SMAW) and Flux Cored Arc Welding (FCAW) will be permitted for welding steel piles.

The welding electrode must be on the approved list published by the Office of Materials semiannually or be specifically approved by the Office of Materials.

B. Shell Pile

Shell pile manufactured by Union Metal require splices to be fillet welded. The fillet weld should be equal in size to the thickness of the shell wall. The pile extension must be telescoped into the pile to be extended a minimum of 150 mm (6 inches). For splicing pile manufactured by Armco, a butt joint and square groove weld must be used as shown in Figure A, *Appendix 11-4*.

C. Pipe Piles

Pipe pile may be extended using Figure A, or B, or C *(Appendix 11-4)* depending on wall thickness and pile position at the time of splicing.

D. Steel H-Piles

Specifications require that field extensions of Steel H-piles shall be made only by approved welding procedures involving the use of backing plates. Steel H-piles are extended with a butt joint requiring a single-bevel groove weld when welded in the horizontal position (Figure B, *Appendix 11-4*) and a vee groove weld in the flat position (Figure C, *Appendix 11-4*). The backing plate must be at least 6 mm (1/4 inch) thick, 38 mm (1-1/2 inches) wide and of the required length to extend full width of web and flanges. Note: HP 360 mm x 174 kg (HP 14 x 117) steel H-piles require a special welding procedure due to flange thickness.

If a backing plate thickness of more than 10 mm (3/8 inch) is used, weld the backing plate all around with a fillet weld. A backing plate 6 mm to 10 mm (1/4 to 3/8 inch) thick may be tack welded in place. Backing plates must be bent or ground to fit snug against the flanges, web, and have chambered corners to fit between the flanges and web. The required root opening is 6 mm (1/4 inch) with a tolerance of plus 6 mm (1/4 inch) and minus 2 mm (1/16 inch).

The top of the pile being extended must be cut square with flat ends; the lower end of the extension, both flanges and web, must be beveled to a 45^{o} angle (Figure B, *Appendix 11-4*). The groove angle in the flat position is to be cut to a 45^{o} included angle as shown in Figure C, *Appendix 11-4*. The tolerance of a groove angle joint is $\pm 5^{o}$. The root face of the weld joints in Figures B and C shall be no greater than 2 mm (1/16 inch). When welding H piles, the web must be welded first.

E. Surface Roughness

Grinding will be required on all free hand oxygen cut joints to achieve the proper angles and surface smoothness. The roughness of oxygen cut surfaces shall not

be greater than 25 micrometers (1,000 micro-inches) as compared to a Surface Roughness Scale. The inspector should occasionally spot check joint preparation for roughness, prior to welding.
Rule-of-thumb: The "feel" of scraping your fingernail over the edge of a used penny or nickel will approximate the maximum roughness allowed on oxygen cut surfaces.

F. Pile Alignment

Sections of piles to be joined by butt welds shall be carefully aligned. Should the end of the pile to be extended be bent from driving, the bent portion of the pile shall be cut off. In aligning the piles for welding, the webs shall be brought into alignment first. If there is some slight dimensional variation due to fabrication, the pile extension shall be centered so that eccentricity of the flanges is reduced to a minimum.

G. Welder Certification

Welders qualified to work on Iowa DOT projects are qualified on 10 mm (3/8 inch) plates. The maximum thickness of plates that may be welded from one side under our normal certification is 19 mm (3/4 inch). If material thicker than 19 mm (3/4 inch) is to be welded, for example an HP 360 x 174 (HP 14 x 117), qualification tests on 25 mm (1 inch) plates will be required.

H. Welding Electrode and Preheat Requirements

The requirements regarding procedures for welding electrodes and preheating temperatures for the various types of steel piling are as follows:

NOTE: Preheating of electrodes requires an "electrode oven" to be on-site and used!

1. Welding must be done with the same process (SMAW or FCAW) used for qualification.
2. If the operator has qualified on welding ASTM 36 steel, that same operator is qualified to weld on steel meeting the requirements of ASTM A572 grade 50 (H-pile), ASTM A328 (sheet pile) and ASTM A252 (pipe pile) grade 2 or 3.
3. A welder qualified for manual shielded metal-arc welding with an E 7018 electrode may also weld with E 7016 and E 7028 electrodes. For welding steel piles, E 7018 and E 7016 electrodes are preferred.

Identifying electrode numbers are as follows:

- The 70 designation shall be understood to mean the 70 series unless an alloy steel of higher strength is to be welded.
- The third digit indicates the position permitted. If the digit is "1," the electrode may be used for welding in any position. If "2," only the down hand position may be used.
- The fourth digit indicates the chemical make-up of the electrode coating. The digit 6 indicates low hydrogen potassium, and 8 a low hydrogen iron powder.

Preheating of the base metal means that the surfaces of the parts being welded, within 75 mm (3 inches) laterally and in advance of the welding, must be at or above the following prescribed temperature:

1. For A572 grade 50 steel (H-pile), A328 (sheet pile) and A252 (pipe pile) grade 2 or 3, up to and including 19 mm (3/4 inch) thickness, when welding with low hydrogen electrodes the preheat temperature requirement shall be 10° C (50° F). For thickness over 19 mm (3/4 inch) the preheat temperature requirement shall be 21° C (70° F).

Welding when the ambient temperature is below –18° C (0° F) is not permitted. In inclement or windy weather, suitable shielding must be provided to permit welding in the normal manner.

All electrodes having low hydrogen coverings shall be purchased in hermetically sealed containers or shall be dried for at least two hours between 232° C and 260° C (450° F and 500° F) before being used. Immediately after drying or removal from hermetically sealed containers, electrodes shall be kept in storage ovens of at least 121° C (250° F). Electrodes not used within four hours after removal from the drying or storage oven must be redried before use. For the ordinary field pile welding job, electrodes should be purchased in small packages, allowing for use within the prescribed time limit, unless provision for storage at 121° C (250° F) is made.

Preference of E 7016 and E 7018 electrodes for field welding may now be apparent. The digit 1 permits welding in all positions. These electrode coatings are low in hydrogen, permitting use on A36 and SAE 1010 steels without preheating the base metal unless the temperature is below 10° C (50° F). These electrodes are also required for making the prequalification test.

The restrictions and rules for preheating as outlined above cover the welding of all of our steel piling, since they apply to steel up to 19 mm (3/4 inch) thick. If welding is required on thicker plates, other special rules apply. In such case, the Office of Materials should be contacted for assistance.

Electrodes that are allowed for Flux Cored Arc Welding are E60T-1, E60T-5, E60T-6, E60T-8, E70T-1, E70T-5, E70T-6, or E70T-8. When welding ASTM A588 steel, only the E70 series may be used.

Concrete Pile

A. Extending Concrete Pile

One of the major disadvantages of concrete piles stems from the difficulty of cutoff and extension. If extension of 355 mm or 405 mm (14 or 16 inch) concrete piles is required, the method of extension shall be at the direction of the project engineer. For the purposes of example, the following steps are one method which could be used:

1. Splicing Non-Prestressed Precast Piles

   When a precast, non-prestressed concrete pile must be extended, the concrete at the end must be cut away to expose at least twenty (20) diameters and not less than 0.6 m (24 inches) of the longitudinal reinforcing bar. Reinforcing steel of the same size are spliced by being securely wired to the projecting steel.
2. Splicing Prestressed Precast Piles

If the pile is prestressed, the concrete at the end must be cut away to expose at least 0.6 m (24 inches) of the prestressing tendons. Reinforcing of equal size must be securely wired to the exposed steel. Furthermore, the extension must have 0.53 mm diameter (5 gauge) spiral reinforcing at 75 mm (3 inch) pitch ending with 6 close turns at the top.

After the extension steel is wired securely in place, the forms may be set. Care must be taken to prevent concrete leakage along the face of the pile and to prevent any bulging of the forms. Concrete used in the extension must be of the same quality as used in the original piling. Just prior to placing concrete, the top must have a grout coating to help assure bonding.

B. Splicing 305 mm (12 inch) Concrete Piles

These piling are designed to improve splicing and/or extending by having a steel plate cast into the pile top. If extension becomes necessary, the extension pile also comes with a steel plate cast into its lower end. Splicing then becomes a matter of setting the extension on top and welding the two plates together. (Refer to Figure D, *Appendix 11-4* for welding information.)

Field evaluation conducted in the summer of 1993 indicates the splicing method is very successful.

11.24 PILING ACCEPTANCE

Steel Pile
For acceptance of steel piling refer to *Materials I.M. 467.* This I.M. has undergone a general rewrite. Acceptance for incorporation of steel pile into a project will be based on an approved certified mill analysis of the steel and a satisfactory report on any random sample secured from a project and tested by the Central Laboratory. Approved producing mills are listed in ~~*Appendix A* of this I.M~~ the following Appendices:
Steel H Pile - I.M. 467.01, Appendix A
Steel Sheet Pile - I.M. 467.02, Appendix C
<br Steel Pipe Pile - I.M. 467.03, Appendix A.

Steel piling will not be tested for acceptance on every project. Monitor sampling on a random basis will be coordinated by each District Materials Engineer. Testing of random monitor samples will be processed in the Central Laboratory.

Any random test sample that fails to comply with the requirements and tolerances (dimension and mass) will be handled on an individual basis as directed by the Materials Engineer.

Wood Pile
A. Documentation and Acceptance

At times, wood piling have been delivered to a project from a nearby supplier well ahead of reports for testing and approval. Before the piling are driven, we must assure ourselves that material testing has been completed, and that the District Materials Office has recorded identification markings and/or tags from each lot of piling.

One or both ends of the piling have 3 marks which identify:
1. Treatment charge number (hammer mark or metal tag - could be on the face of a pile)
2. Inspection agency mark
3. Length of piling

Materials IM-462, Appendix B has a list of inspection agencies approved to supply wood piling to Iowa DOT projects. The piles are identified by the initials of these inspection agencies and the inspector's number. It is important that these inspection identification marks be listed in the inspectors field book, along with a record of material and test reports received for the project.

B. Treating Wood Pile

Specifications 2409.05 and 2501.15 require treating cutoff wood pile before incorporating into the structure. A preservative approved by *Specifications 4160 and/or 4161* shall be used.

C. Purchase and Return of Piling

Specification 2501.21, Paragraph A gives a contracting authority the right to purchase unused piling at cost plus 10% as an overhead cost. This would be the cost to the contractor including such items as invoice cost, delivery cost, handling cost at the job site, and any delivery cost to a storage site.

NOTE: *On primary projects, it will be Iowa DOT's general policy not to purchase unused piling.*

Steel Pile Cutoffs
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.

11.25 WAVE EQUATION

Hammer Data Form
Input data for the wave equation program is provided on the "HAMMER DATA" sheet. The blank forms are suggested to be sent to the contractor when arranging for a preconstruction conference.

Completed data sheets shall be returned to the project engineer for forwarding to the Office of Construction at least 20 days prior to driving piling. Prior to forwarding, the project inspector needs to review the forms for completeness. Such screening will help to eliminate delays later. Check the following:

- The hammer data area is fully filled out.
- The piling are listed as indicated on the plans for size, length, and design bearing.
- A hammer cushion is listed. (Cushion #1.) This is required for every hammer.
- If driving concrete piling, there must be a pile cushion listed. (Cushion #2.)
- For gravity hammers, be sure that ram dimensions are given.

If a "HAMMER DATA" form is lacking any of the above information, contact the contractor and obtain the missing data before forwarding the data sheet to the Office of Construction.

Once the driving graphs have been produced, the "HAMMER DATA" sheet will be returned with a graph number added in the "FOR OFFICIAL USE ONLY" column. This ties the data sheet to a particular driving graph. Use the data sheet as a field "equipment" checklist.

NOTE: *It is mandatory that the inspector verify all hammer data prior to beginning pile driving.*

All information is important. Make certain the type, dimension, and thickness of the hammer cushions are correct. If there are doubts about the cushion, check it in the field. Hammer cushions should be inspected periodically during the project to verify thickness and condition. Damaged or deteriorated cushions must be replaced.

Refer to HAMMER DATA forms in *Appendix 11-5*. Since these forms are not in the Office Supply system, please photocopy as needed.

Driving Graphs

The curves of driving resistance versus blow count, and stress versus blow count, are plotted from the summary output generated by a computer analysis. Since the results of analysis depend on 1) pile length, 2) embedded pile length, and 3) the soil "N" values, curves usually are generated for embedded lengths in 3 meter (10-foot) increments. If the addition of pile causes the length to penetrate into a new "N" value, a new graph should be developed. If a variable stroke hammer is to be used, curves will be generated for several stroke heights.

For inspection purposes, the use of driving graphs is extremely easy. Inspectors only need to record the number of blows required to move the pile an equivalent of 0.25 m (1 foot), find that number of blows per 0.25 m (foot) on the "X" axis, read upward to the graphed line representing the appropriate drop height, and record the driven resistance which corresponds on the "Y" axis.

EXAMPLE: Assume:	(Refer to Example in *Appendix 11-6.1*) (Given in U.S. units) 1. Hammer drop = 5' 2. Inspector records 80 blows per foot 3. HP 10 x 42 pile
Question:	What is the driven resistance?
Procedure:	1. Find 80 BPF on the "X" axis (Point A) 2. Move vertically upward to the 5' stroke line (Point B) 3. Move horizontally to the "Y" axis (Point C) 4. Read and record 48 tons
EXAMPLE: Assume:	(Refer to Example in Appendix 11-6.2) (Given in metric units) 1. Hammer drop = 2.25 m 2. Inspector records 98 blows per 0.25 m 3. HP 250 x 62 pile
Question:	What is the driven resistance?
Procedure:	1. Find 98 blows per 0.25 m on the “X” axis (Point A)

	2. Move upward to the 2.25 m stroke line (Point B) 3. Move horizontally to the “Y” axis (Point C) 4. Read and record 712 kN

NOTE: Driving graphs are produced for a particular location, using a specific hammer, and type of pile. In this example, HP 10 x 42 pile are being driven. Since there are no restrictions listed in the upper left-hand corner of the driving graph, the inspector may use the entire graph. The lack of restrictions means that this hammer is not capable of over-stressing the pile for the plotted strokes and listed blows per foot.

Several important aspects of the driving graph should be noted and observed:

- Any driving graph is for a specified design number and foundation unit and is computed based on specific hammer data. The inspector *MUST* be sure all listed hammer data are checked in the field.
- Driving graphs prepared in the Office of Construction account for ultimate resistance. *For City and County projects, be sure the driving graph includes, and lists a "Factor of Safety," and provides information relative to driving stresses."*
- The graphed lines are "best-fit" lines drawn from several computer generated points. Based on the graph scale, reading to fractions or tenths of a ton is most likely inappropriate.
- Any graphed line may be interpolated between given lines.
- Often during final driving or a retap, only blows per fraction of a meter (foot) can be observed. If this is the case, convert to blows per 0.25 m (foot) and evaluate as usual.

EXAMPLE: Assume:	(Given in U.S. units only.) 1. Hammer drop = 5' 2. Retap condition 3. Inspector records 17 blows per 6 inches of penetration
Question:	1. What is the value in "blows per foot?" 2. What is the driven resistance for this retap?
Procedure:	1. Convert to blows per foot (BPF) $\frac{X}{17} = \frac{12''}{6''}$ **X = 34 BPF** 2. Find 34 BPF on the "X" axis and proceed as in previous example to determine driven resistance

- For wood piling, *Specification 2501.16* limits driving of wood pile to 40 ton or less.
- All types of pile have varying driving stress limits. Values given in the upper left-hand corner provide important information to the inspector about driving stresses. By drawing a horizontal line corresponding to a particular maximum value (** DO NOT EXCEED **) and Begin to Monitor, the driving graph provides a convenient way to monitor and check these maximum and precautionary values.

Log of Piling Driven
The "Log of Piling Driven" form is used on all projects to document relevant "as constructed" pile information. This report shows a bearing obtained for each individual pile driven and overall length incorporated into the structure. The project engineer should prepare two photocopies of the original report:

- One copy is to be retained in project files.
- One copy is forwarded to the District Office for their records.
- The original is to be sent to the Office of Construction. This copy will be reviewed and ultimately forwarded to the Office of Bridges and Structures where it becomes a part of the structure's permanent record.

Before signing the report, the project engineer should be sure the report has been verified through an independent check. A copy of the driving graph needs to be included when information is forwarded for future reference. One way to do this is to photocopy the driving graph on the back of each "LOG OF PILING DRIVEN" sheet. The bearing value of the piles should be recorded to the nearest "readable" graphed bearing value.

The length of piles shown on plans or ordered by the project engineer indicates the desired penetration. Although the specified bearing may have been obtained prior to "full" penetration, driving shall be continued until full penetration is secured so long as a pile can be driven without damage. If specified bearing is not achieved or full penetration is not obtained to within 3 meters (10 feet) of the plan pile length, contact the Office of Construction for review of driving results.

Log down one piling in each foundation of every structure. Logging the first pile in each foundation will provide beneficial information for the contractor and inspector during production pile driving. The logged results represent the actual driving resistance for the full length of the pile as it is driven through successive soil layers. This logged pile driving resistance can be compared with the plan soil profile and soil boring sheets to evaluate driving conditions during production pile driving. This logged pile information will also be important when pile capacity and/or pile penetration problems are discussed with the Office of Construction.

The following are general guidelines for logging pile. If driving is hard, record intervals at 0.6 to 1 m (2 to 3 feet) If little resistance to driving is encountered, 1.3 to 1.5 m (4 to 5 foot) intervals would be sufficient. This information should be entered on a separate log of piling form and forwarded with the production "Log of Piling Driven." The logged piling data should include all the usual information required on the regular Log of Piling Driven.

Refer to **"LOG OF PILING DRIVEN"** report in *Appendix 11-7*. These forms are available from Office Supplies (Form 830209). The metric version of the "Log of Piling Driven" (Form 830209M) is included in *Appendix 11-7* and is available from the Office of Construction.

A. Filling Out the Report

Columns for plan length and extensions should be totaled and length measured for payment should be shown on the report as the sample report illustrates. (Refer to example in *Appendix 11-8*.) When it is necessary to extend pile, the length of extension is placed on the "Log of Piling Driven" report in the appropriate column. The number of field splices required shall be reported.

If welding of piling is necessary (i.e., splicing), add the following information to the "Log of Piling Driven" form:
1. Name of certified welder(s)
2. Certificate number(s)
3. Date(s) piles were welded

B. Numbering of Piles on Foundation Sketches

A suggested method of numbering piling on pile log sketches to obtain uniformity and ease of identification is provided in *Appendix 11-9.*

Number piles in abutment footings from left to right when facing up station. Also facing up station, number piles in pier footings starting at the upper left corner from left to right and continuing for each row in the footing. Multiple footings can be numbered in the same manner. Single row pile pier bents can be numbered from left to right.

11.26 PREBORED HOLES

Often pre-bored holes are required as a preparatory step before driving. Preboring involves an augered hole which is a minimum of 100 mm (4 inches) larger than the maximum pile cross-section. Limits of this hole will be shown on the plans.

Typical Preboring
One purpose of preboring is to reduce and/or eliminate additional load on the pile as a new grade settles. This phenomenon is referred to as "negative skin friction" because it acts to drag the pile down and increases required bearing capacity.

Another purpose is to provide lateral movement at the abutment for thermal differences in a moveable abutment structure. In these situations the prebored hole is to be filled with bentonite.

Special Prebore Situations

- Another application of a type of prebore would be when driving conditions make it difficult to hold piling "on spot" during driving. Example of such a condition could be a previous demolition site where existing foundations are encountered. In this type of situation the holes are to be filled with dry sand.
- Yet another application is when subsurface rock is sloped. At such sites there will be a plan note requiring prebored holes. Often these holes will be drilled into the rock, creating a "socket" for the pile to sit in. In these situations the socket and often a portion of the hole will be filled with concrete.

NOTE: In the two examples above (special situations) the hole will be filled with either sand and/or concrete. When preboring is required for penetration, holes will not be filled with bentonite. Also, it will often be necessary to use some type of casing to maintain an open hole. "Sonotubes" or corrugated metal pipe have been used successfully and are recommended when there is a potential for soil collapse.

Bentonite
There are two approved methods for filling prebored holes in non-collapsing soils with Bentonite:

1. Use powdered Bentonite, mix with water, and fill the hole with a slurry. In this method, the powdered bentonite product used shall be thoroughly mixed with water according to the manufacturer’s recommendations to achieve a minimum of 20 percent solids content.
2. Use granular bentonite and hydrate the material in the hole. Filling the hole with granular bentonite and adding water can be accomplished by one of the following processes:

Process 1
Placing a pipe, extending to the bottom of the hole, on each side of the pile. Filling the hole about one-third full of bentonite chips and pumping (or pouring) water down the pipe until free water comes to the top of the bentonite. Waiting about 10 to 15 minutes before starting the next layer. The time delay allows for initial water absorption. Also the fill pipe can be raised with each repeat process. (*Refer to Appendix 11-10, Cartoon #1*.)

Process 2
Placing water in an empty hole until there is about 0.6 m (2 feet) of standing water. Then add 0.6 to 1 m (2 to 3 feet) of bentonite chips to the standing water. Wait 10 to 15 minutes and repeat the process until the hole is filled with bentonite. *(Refer to Appendix 11-10, Cartoon #2.)*

No matter what method of filling prebored holes is used, the holes should set overnight prior to placing footing concrete. This is to allow time for the bentonite to fully "hydrate" and allow time to check for settling. Holes which have more than 150± mm (6± inches) of settlement will have to be topped off with additional bentonite, while holes which have settled less than 150± mm (6± inches) may be filled with embankment fill.

As per *Specification 2501.19*, the contractor also needs to provide a rigid cover over the bentonite filled hole to prevent concrete intrusion during foundation pouring.

11.27 DRILLED SHAFTS

Drilled shaft foundations are being used for bridges, light towers, and sign trusses. Simply speaking, drilled shafts are holes of "X" diameter and "Y" depth filled with concrete. These shafts carry loads in much the same way as do piling, i.e., through skin friction and end bearing.

Currently, a Supplemental Specification specifies how drilled shafts for bridges are to be constructed.

A. General Types of Drilled Shafts

Cased
This type of shaft is constructed by either first installing a steel casing and removing all soil from within the casing, or advancing a steel casing during a soil removal process.

NOTE: These casings may or may not remain in place after concrete is placed.

Un-Cased
The un-cased shaft can be one of two types:

1. Un-cased in non-collapsing soils. This type is commonly encountered where the shaft is rather shallow in depth and the soil will maintain its sidewall integrity. Here a soil auger is used to drill a hole, required steel is placed, and the hole is filled with concrete.
2. Un-cased in collapsing soils. This type can be encountered in almost any construction situation. To drill a hole in collapsing soils, the contractor has to keep the hole full of bentonite or polymer and water mixture. The mixture, called drilling fluid/mud, has a unit mass (weight)

slightly above that of water and keeps the sidewall from collapsing during construction.

Several special considerations are required when using drilling mud. Some of these are:

- The mud must have a known specific gravity.
- Sand content of mud must be maintained below a specified percentage.
- All concrete must be tremied or pumped.

B. Inspection of Drilled Shafts

Field offices which have a project involving drilled shafts, but no previous drilled shaft experience, may contact the Office of Construction for two videotapes produced by the National Drilling Association.

In addition the Office of Construction has specific reporting forms developed for inspection reporting involving drilled shafts. Blank forms are included in *Appendix 11-11*. Since they are not available through Office Supplies, please photocopy as needed.