Chapter 9
Special Design Considerations

9-1. I-Walls of Varying Thickness

Different restraint conditions are created with abrupt changes in wall geometry and by encasing steel sheet piles in concrete. Under thermal loads produced by heat of hydration and ambient temperature effects, stress related cracking can occur. The following actions were recommended by the Structures Laboratory, US Army Engineer Waterways Experiment Station (WES), after performing an investigation of cracking in I-wall monoliths in the New Tiger Island Floodwall. The investigation was limited to an I-wall with a lower portion thickness of 2 feet and an upper stem of 1 foot.

a. A 45-degree chamfer should be included at a change in geometry. See Figure 9-1 for details.

b. Generally, the top of the sheet piles should be placed 9 inches below the point at which the concrete section thickness is increased, except at each end of the monolith. Two sheet pile sections at each end of the monolith should be lowered an additional 9 inches, placing these sheets a total of 18 inches below the thickness change. The sheet piles located at the monolith joint should be notched down to 9 inches above the base of the wall. See Figures 9-1 and 9-2 for details.

c. Additional vertical and horizontal reinforcing steel should be placed at the ends of the monoliths to provide for temperature induced loads as shown in Figures 9-1 and 9-2.

9-2. Corrosion

a. General. The corrosion process in sheet piling is highly dependent on the environment in which it is placed. Generally, uncapped exposed sheet pile corrodes at varying rates averaging from 2 to 10 mils per year depending on the surrounding atmospheric conditions, i.e. rural versus heavy industrial. Corrosion rates usually decrease after the first few years of exposure. Sheet pile driven in natural undisturbed soil has a negligible corrosion rate due to the deficiency of oxygen at levels just below the groundline. Increased corrosion rates for piles in organic or fresh fills should be anticipated due to oxygen replenishment. In marine environments, the rate of corrosion is related to the type of water to which the sheet pile is exposed. Typically, fresh water is the least corrosive and salt water the most, with contaminants and pollutants playing a major role in magnifying its corrosiveness. The critical zone for sheet piles exposed to water is the splash zone, the area between the still water elevation and the upper limit of wave action. This area corrodes at a much greater rate than if it remained completely submerged.

b. Methods of protection.

(1) The most common way of protecting steel sheet pile against corrosion is through the use of coatings. Generally, coal tar epoxy has become widely accepted for this application. If the piling is driven in fresh fill, the coating should cover the area in contact and extend a minimum of 2 additional feet. For sheet pile exposed to water, it is critical that the coating cover the splash zone and extend a minimum of 5 feet below the point where the sheeting remains submerged (EM 1110-2-3400).

(2) An additional means of providing corrosion resistance is by specifying ASTM A-690 (1989b) steel. This steel offers corrosion resistance superior to either A-328 (1989a) or A-572 (1988) through the addition of copper and nickel as alloy elements.

(3) Another effective method of protecting steel sheet pile is through the use of cathodic protection. The corrosion process is electrochemical in nature and occurs wherever there is a difference in electric potential on the piles surface. In an effort to provide electrical continuity, particularly in capped walls, a continuous No. 6 rebar should be provided atop the piling. The rebar should be welded at each section and terminate at monolith joints where a flexible jumper is required. If subsequent inspections show a rapid loss of material, the system can be externally charged to halt the flow of electric current, thus suppressing the corrosion process. See Figures 9-1 and 9-2 for details.

(4) In some cases a larger sheet pile section may be specified to provide for the anticipated loss of section resulting from corrosion.

9-3. Liquefaction Potential During Driving

The potential for liquefaction may exist at any time a dynamic operation takes place upon a granular foundation or a stratified foundation which contains granular soils. The risk of liquefaction should be evaluated on a case-by-case basis using the recommendations of Technical Report GL-88-9 (Torrey 1988). If the foundation

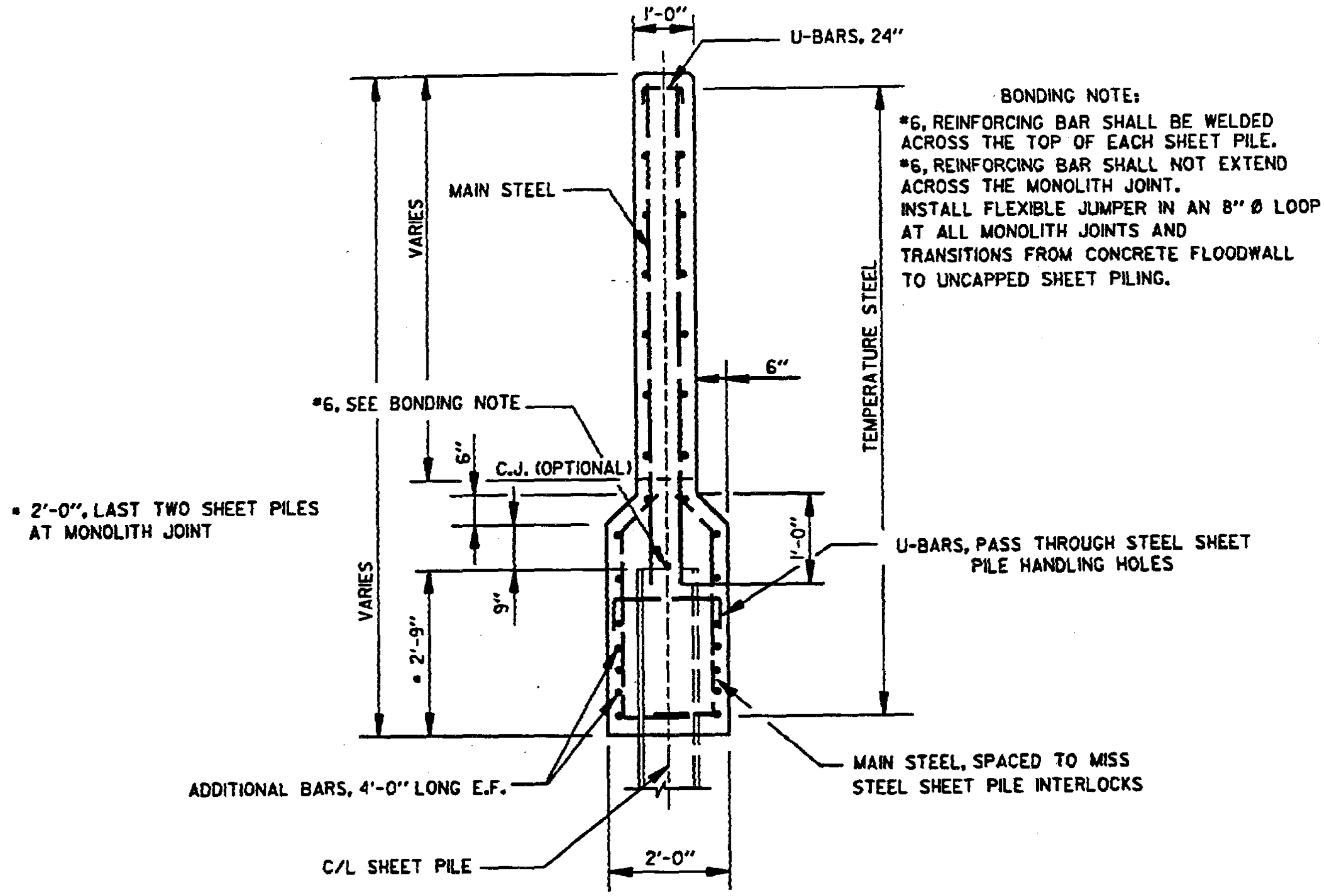


Figure 9-1. Typical section through I-wall of varying thickness

soils meet the criteria of this report, the assumption may be made that during pile driving the acceleration of soil particles will be sufficient to induce liquefaction, and therefore, a potential for damage exists. Limitations should then be set on pile driving, such as: maximum water stage during driving; minimum distance to the deposit of liquefaction prone soil; and size of pile driving hammer and its rated energy. A total ban on driving may be warranted. Limits on pile driving have been successfully applied along the levees of both the Mississippi and Atchafalaya Rivers. Pile driving is prevented or limited based upon the potential for liquefaction at a stage when the water level is above the landside ground surface and pile driving is planned within 1,500 feet of the levee or flood protection works. The extent of any limitations placed on pile driving should be evaluated against the potential for damage to the public.

9-4. Settlement

a. Effects on tie rods. Tie rods placed above loose granular or soft cohesive soils can be subjected to loads greater than that computed by conventional methods. As the underlying soils compress, either due to volume changes, distortion, or consolidation, the weight of the overlying soils induces additional loads as the rod deflects. Where excavation is necessary to place an anchor, the backfilled material should be a select soil, compacted to at least 90 percent of standard proctor maximum dry density. If soil conditions warrant the consideration of settlement, methods used in eliminating the effects include supporting the tie rod or encasing it in conduit.

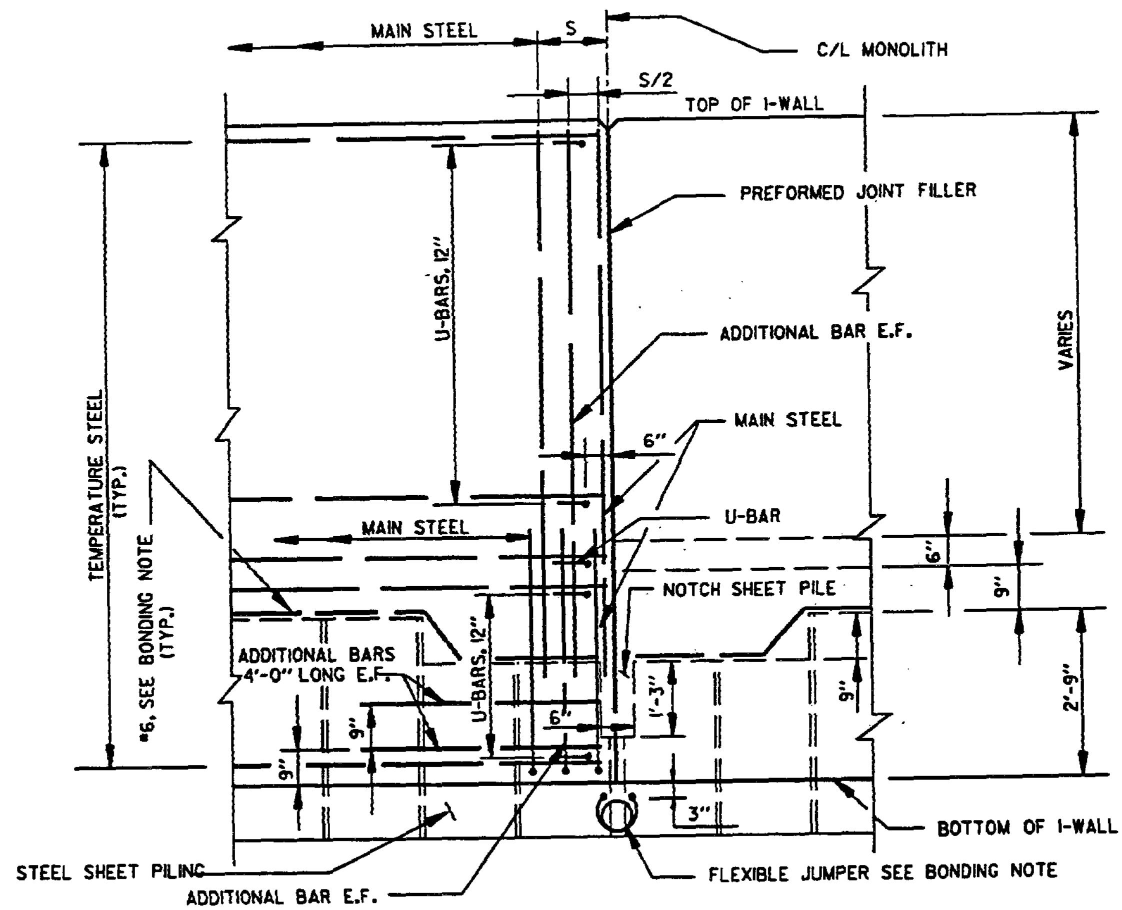


Figure 9-2. Detail of I-wall of varying thickness

b. Effects on walls. Wall settlement is a very serious concern in the overall system stability of the floodwall, earth retaining wall, or tied backwall. In most cases the wall will settle along with the soil mass into which it is embedded. The consolidation method used for predicting wall settlement should be the one with which the designer is most familiar, whether it is the classic Terzaghi prediction or one of the hindcast-forecast methods. Since the wall cannot easily be modified in grade, the designer should consider the confidence level of the settlement prediction and overbuild the wall sufficiently to prevent settlement of the wall below grade. Concrete capping should be delayed until a major portion of the settlement has occurred. The "after settlement" configuration is used in the wall overturning analysis. Additionally, as the loads applied to the foundation by the wall are essentially horizontal the designer has to be cognizant of the fact that lateral consolidation will occur with sustained loading. This should be evaluated and the wall system should be capable of compensating for this movement.

9-5. Transition Sections

a. Sheet pile to levee. When a sheet pile wall terminates within a levee, the piling is typically extended a minimum of 5 feet into the full levee section.

b. I-wall to T-wall. When a concrete capped I-Wall abuts a T-Wall, consideration must be given to the difference in deflections likely to occur. The relative movement may tear any embedded water stops. To accommodate these large movements between walls, a special sheet pile section with an L-Type waterstop is suggested. A typical detail is shown in Figure 9-3.

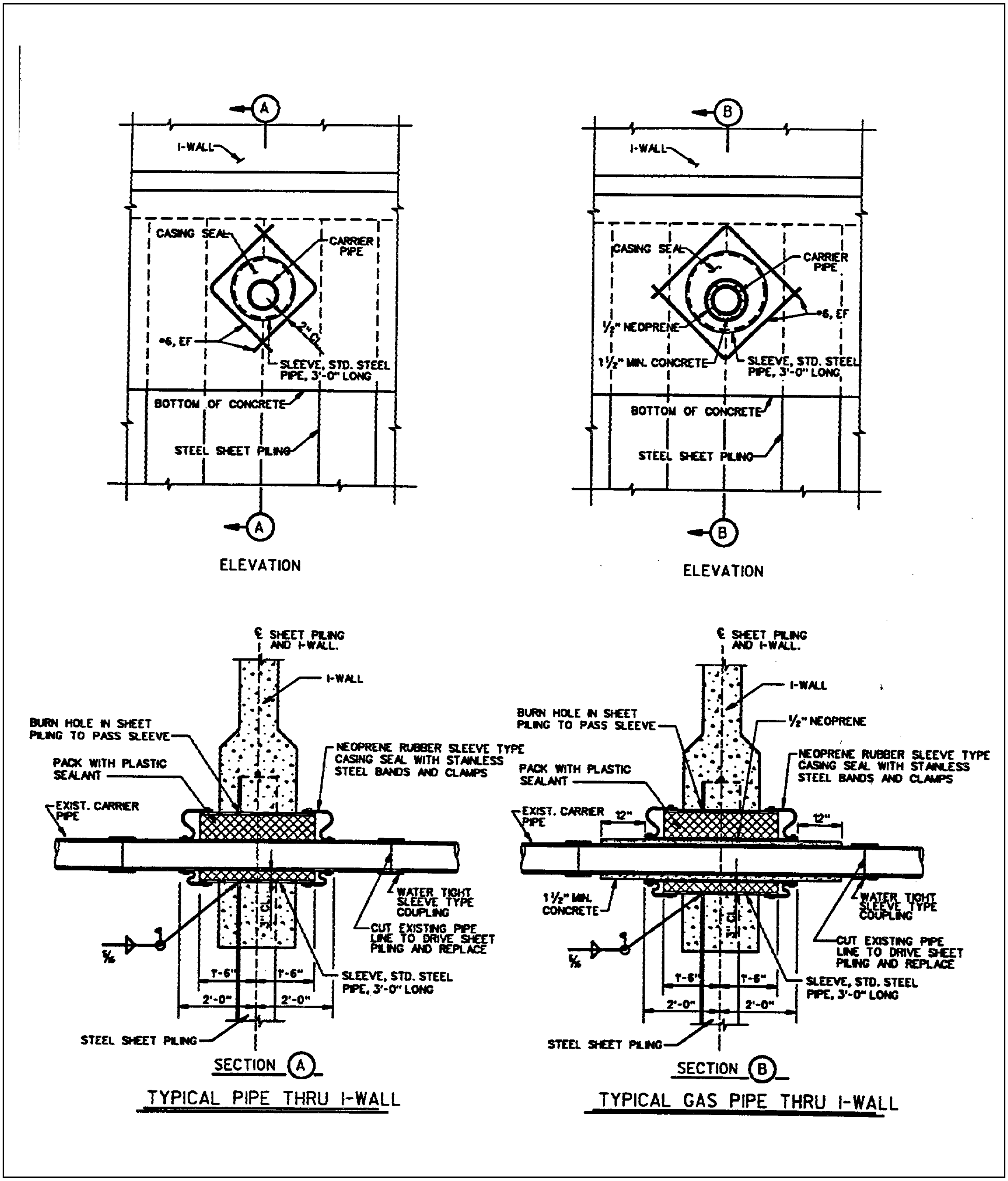


Figure 9-3. Typical utility crossings (Sheet 1 of 4)

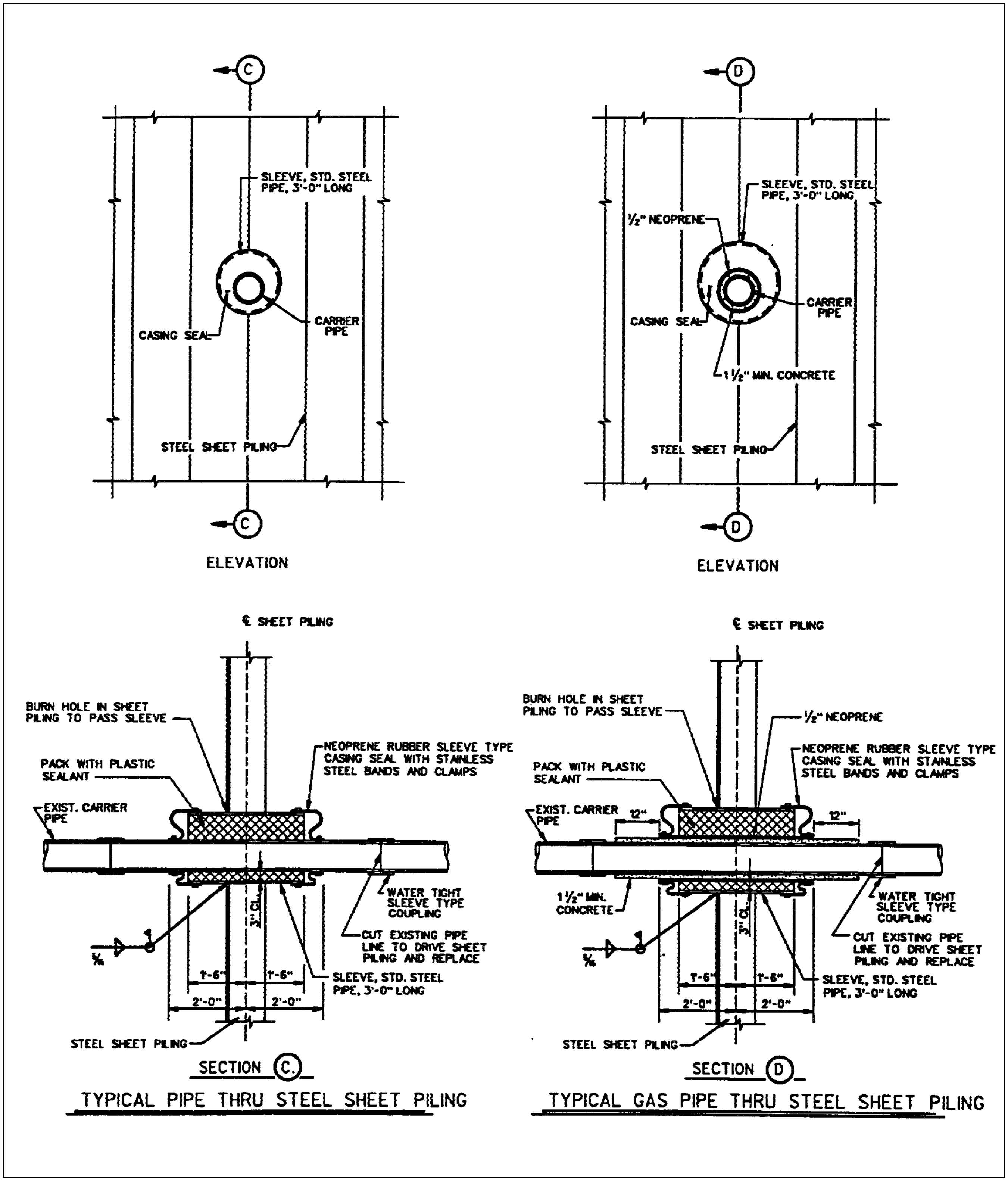
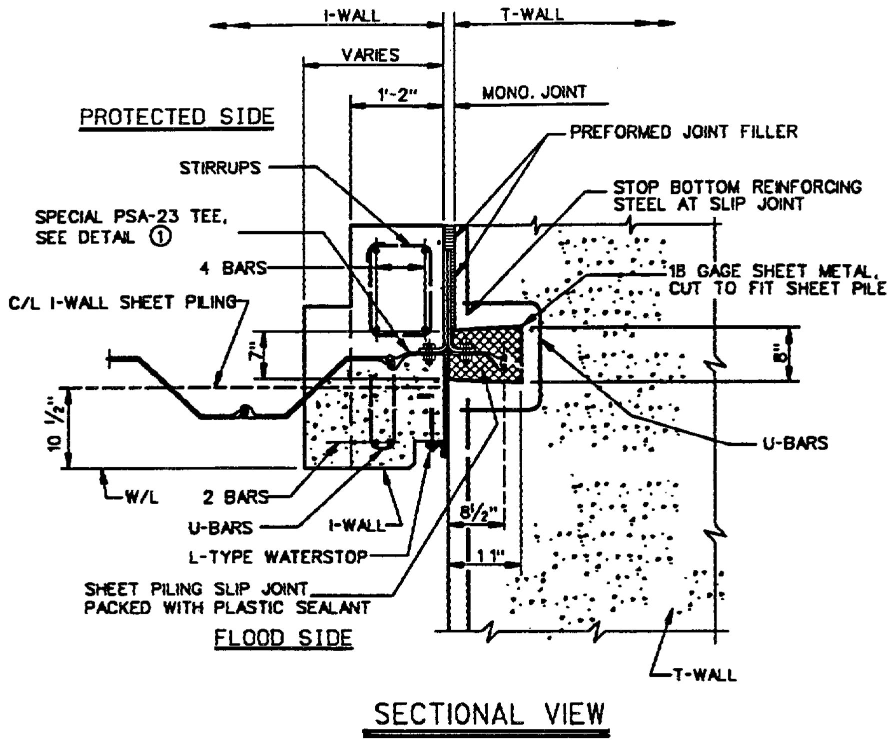


Figure 9-3. (Sheet 2 of 4)



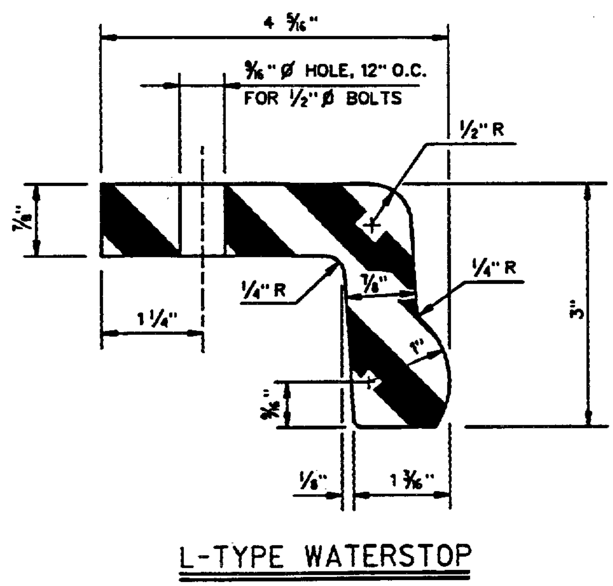


Figure 9-3. (Sheet 3 of 4)

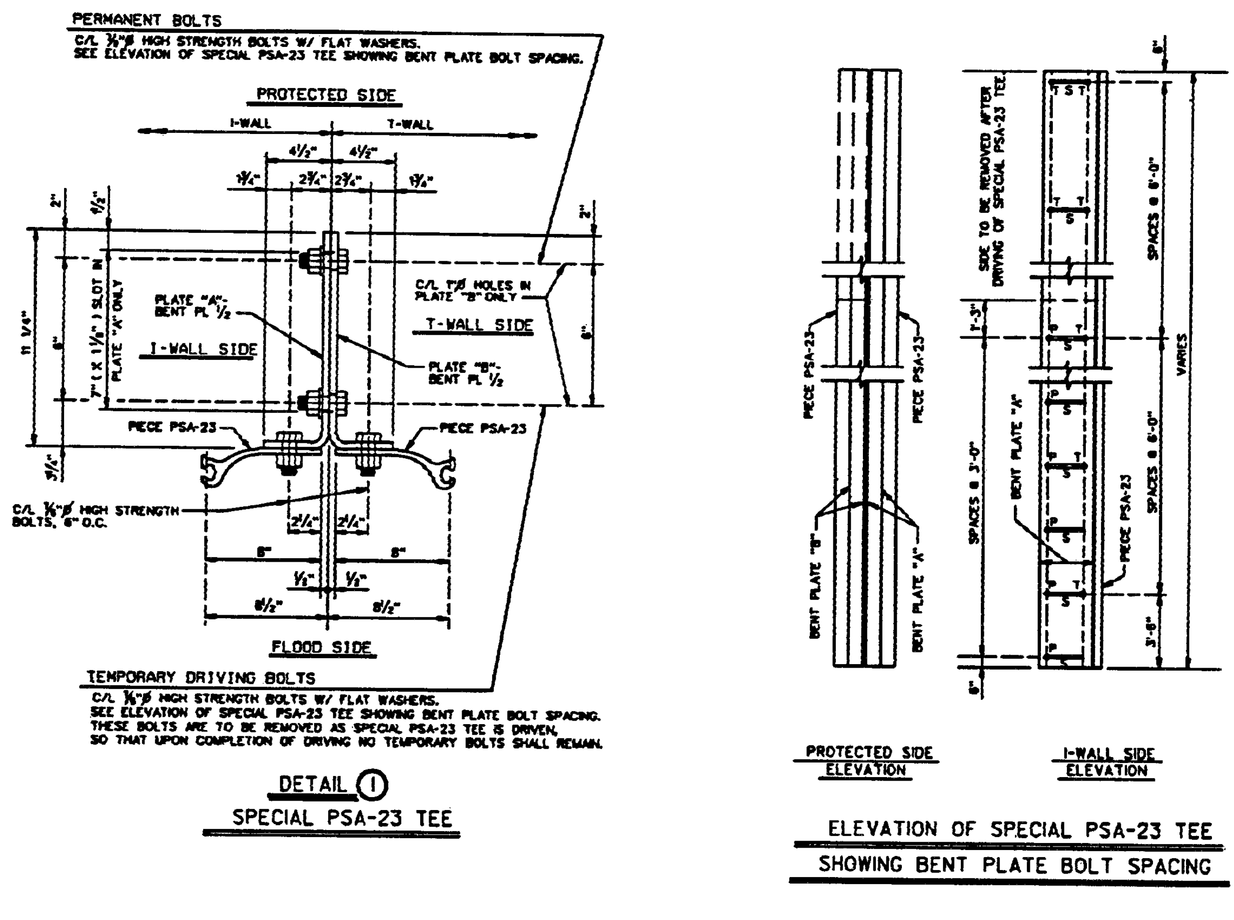


Figure 9-3. (Sheet 4 of 4)

9-6. Utility Crossings

When it is necessary for an underground utility to penetrate a sheet pile wall, a sleeve must be provided to permit relative motion at the crossing. Typically, the utility line is cut and reconnected on either side of the sleeve. The sleeve is then packed with a plastic sealant and covered with a water tight rubber boot. If conditions permit, an alternative method of passing a utility line through the sheet pile can be accomplished without cutting. This method consists of laterally displacing the utility line, driving the sheet piling, notching the sheet piling, and installing the sleeve in halves. See Figure 9-3 for typical utility crossing details.

9-7. Periodic Inspections

Structures should be inspected periodically to ensure structural integrity and to identify maintenance needs. Methods of inspection usually include visual inspection, magnetic particle inspection, ultrasonic inspection, radiography, and in some cases nondestructive testing. Typically sheet pile structures are visually inspected, relying heavily on the inspector’s experience and knowledge. Ultrasonic measurements have been used to determine the remaining thickness of steel sheet piling. Information concerning frequency and manner of conducting periodic inspections is contained in ER 1110-2-100.

9-8. Maintenance and Rehabilitation

Timbers showing evidence of decay or steel piling significantly weakened by corrosion may require replacement. Concrete capping should be inspected for cracking and sealed as needed to prevent intrusion of foreign materials. Scour problems should be monitored and corrected if the stability of a vertical sheet pile wall is affected. Structures that have sustained major damage from storms or have deteriorated to a point at which normal maintenance is impractical may require total rehabilitation. At this time consideration should be given to alternative types of structures, such as replacing timber with steel.

9-9. Instrumentation

a. General. Instrumentation is usually required to monitor the performance of a sheet pile structure either during or after construction. Measurements of movements and pressures furnish valuable information for use in verifying design assumptions. Most importantly, the data may forewarn of a potentially dangerous situation that could affect the stability of the structure. When a sheet pile wall is constructed on soft or diversely bedded soil, in areas of high or fluctuating water tables, or is frequently subjected to its maximum loading condition, instrumentation is certainly warranted.

b. Types of instruments. The kind of instruments selected should depend on site conditions, type of data required, reliability, durability, and ease of construction.

(1) Piezometers. A piezometer is an instrument mainly used for monitoring pore water pressures in foundation and backfill materials. The most common type is the open tube or open stand pipe piezometer, offering both simplicity and reliability. Pore pressure data can be used in an effective stress analysis, which can indicate a state of impending failure not apparent from a total stress (Q) analysis. Also from these piezometers a general foundation zone permeability can be estimated for use in seepage analyses. Piezometers attached to the sheet pile prior to installation should be protected from possible damage during driving. Installing piezometers, after driving or backfilling the sheet pile, becomes more difficult.

(2) Inclinometers. Inclinometers are generally used for measuring lateral displacement of foundations and embankments but can be used to monitor horizontal movements in sheet pile walls. The more common types employ a casing of either plastic, aluminum, or steel installed in a vertical bore hole or securely attached to the surface of a sheet pile. Normally, the lower end of the inclinometer casing is anchored firmly in rock to prevent movement at this end, thus serving as a reference point. If a rock anchor is not available, the lower end should penetrate a minimum of 15 feet in soil that will not experience movement. Inclinometers attached to sheet piles are limited to the length of the pile if they are to survive driving. This limitation does not permit data collection for movements occurring below the tip. For these cases an additional inclinometer, which penetrates into a nonmoving deep formation, may be warranted.

(3) Strain gauges. The most common strain gauges used for monitoring sheet pile structures are of the electrical resistance and vibrating wire type. These gauges are designed to measure minute changes in a structural dimension, which can then be converted to a stress, load, or bending moment. The electrical resistance strain gauges are made so that they can be easily attached to a surface by means of an epoxy adhesive or by welding. The vibrating wire strain gauge is

usually arc or spot welded to the structural member. The success of these gauges depends highly on surface preparation, bonding, and waterproofing. Field tests have shown that these gauges, when properly installed and protected, will survive pile driving.

c. Data collection and presentation. Initial readings should be made on all instrumentation subsequent to installation, so that an initial data base is established. The person collecting the data should be experienced with the instrumentation devices in use. The frequency of data collection should depend on an established monitoring schedule and should escalate during critical loading conditions or increased wall deflections. Profiles and alignments are typically collected on a yearly basis, while electronic devices should be read more frequently. Weather conditions and any apparent deformities at the site should be recorded. Data should be processed and evaluated by qualified personnel and reviewed by higher authority. Data should be displayed graphically so that various relations and trends can be readily seen.