Material Durability in Coastal Environments

Wood

Wood Foundations

Wood piles are the most widely used foundation material for elevating coastal residential structures. Southern pine and Douglas fir are the principal wood species used. The piles are placed in the ground by impact driving, water jetting, augering, or some combination of these methods. The piles must be durable in a ground-contact environment at least, and a saltwater immersion environment at most.

Because untreated wood has insufficient decay and infestation resistance for these exposures, piles are almost always preservative pressure-treated to at least the required ground-contact level of resistance. Wood piles must have sufficient strength and straightness to carry the weight of the structure, withstand pile-driving forces at installation, and resist the wind and wave forces acting on the building. Both round tapered timber piles and square cross-section timber piles are commonly used.

Round Tapered Timber Piles

Tapered timber piles with a circular cross section are frequently used in coastal areas. These piles are usually available in longer lengths than square piles, and for lengths more than about 25 feet, it may be necessary to use round tapered piles. The larger round piles have a larger cross-section area, and are stronger and stiffer than 8-inch-square and 10-inch-square section piles. The pile size is specified by the tip or butt circumference and length. The wood species can be specified, and the International Building Code (IBC) and International Residential Code (IRC) provide allowable design stresses for each species. The IBC and IRC refer to the American Society for Testing and Materials (ASTM) D25, *Standard Specification for Round Timber Piles* for physical specifications.

The natural form of a round pile is advantageous for pressure treatment. The sapwood, which is easier to treat than the heartwood, naturally occurs around the tree exterior. The sapwood is exposed to the treatment chemicals and absorbs the chemical to some depth, protecting the largely untreated heartwood. There is usually sufficient sapwood thickness to meet minimum penetration requirements.

Round piles should bear both the wood species and the preservative treatment certification in the form of a stamp, brand, or an attached certificate. The preservative treatment certification should include the American Wood Preservers Association (AWPA) name, the level of treatment, and the type of treatment.

In addition, the straightness of a round tapered pile will affect the accuracy of the pile's location after it has been driven. The straightness is determined by the physical warp properties of sweep and crook. ASTM D25 limits the amount of sweep and crook allowed in a pile.

Poles normally have most of their length above grade. They are usually placed with their smaller end up, so that their tapered section is most effective in resisting axial and bending loads. That is, the axial load increases from the top down in the exposed part, and the thicker section is located near grade, where the bending is maximum. Because of this configuration of the taper, poles cannot be driven, but must be placed in a drilled hole and backfilled. It is unlikely that pole construction would be found in Zone V; pole construction would be possible in Zone A.

Square-Section Timber Piles

In some locations, square section piles are preferred over round piles because of cost, availability, and ease of framing and connecting the structural beams to the piles. The most widely used square piles are the full-sized undressed (rough) 10-inch- and 8-inch-square members. The latter is the minimum size generally approved for use in coastal high hazard areas. The 10-inch-square piles provide a greater axial and bending capacity than 8-inch-square piles, and some local jurisdictions require the larger 10-inch-square piles.

Square-section piles are produced and structurally graded under the "post and timber" lumber grading classification. Like all sawn lumber, square section piles are cut from the log section. Knots in the log will either become edge knots or center knots in the pile, depending on their location. With an edge knot, the wood that was wrapped around the knot has been cut away, so the knot presence weakens the member, especially in bending. This will be reflected in the structural grading of the member.

A square-section pile should bear both the structural grade stamp and the preservative treatment stamp. The lower structural grades allow more and larger knots, as well as more grain slope and warp. The structural grade will be Select Structural, No. 1, or No. 2, in order of decreasing allowable design stresses and stiffness. The preservative treatment stamp should include the AWPA name, the level of treatment, and the type of treatment.

In a sawn square-section member, both sapwood and heartwood can be exposed at the surface. The pressure treatment is absorbed better by the exposed sapwood than by the exposed heartwood; preservative treatment for a square pile can thus be less effective than for a round pile. Ordering Marine Framing of Seawall Grade is one sure method of obtaining a sawn member with no exposed heartwood.

Exposed Wood Beam and Girder Construction

Typically, horizontal wood beams and girders are connected to the top of the wood piles to support the floor framing of the building. These members are often fully or partially exposed to salt spray and precipitation, if not saltwater immersion. Selecting strong and durable materials for these members is critical. These members can be solid sawn timbers, glue-laminated timbers, or built-up sections.

The IBC and IRC require that wood having natural resistance to decay or treated wood be used for beams and girders that are exposed to the weather to prevent moisture or water accumulation on the member

surface or at the joints between members. This requirement is excepted when climatic conditions preclude the need for durability, a condition unlikely at coastal sites. Thus, lumber of natural resistance to decay or lumber that has been preservative-treated should be used for exposed wood beam and girder construction.

Reinforced Concrete

Reinforced concrete foundations (including walls, columns, piers, piles, and pre-stressed elements) may be used in coastal construction, particularly in Zone A and in areas where wood piles cannot be readily driven or in cases where the superstructure will be constructed of concrete, masonry, or a combination of these materials. As an example, in the Florida Keys, concrete foundations are often socketed into a hole augured into the limestone or other bedrock. The concrete mix selection is an important factor in obtaining durable reinforced concrete in many environments.

Reinforced concrete typically has 1.5 or 2 inches of concrete over the steel reinforcement. This concrete cover, specified by the American Concrete Institute (ACI), must resist both salt-laden and freeze-thaw environments. Usually the steel reinforcement is protected from corrosion by the thickness of the concrete cover and the concrete's natural alkalinity. However, in a coastal environment, chloride ions may penetrate the concrete cover, lowering the alkalinity and allowing the steel to corrode. Expansion of the cracks and spalls in the concrete cover allows more salt penetration and corrosion. Thus, concrete mixes for coastal construction must have superior durability properties to resist this action in addition to the required strength properties.

The IBC and IRC require that the durability of a concrete mix subjected to salt intrusion be enhanced by a higher design strength and a lower water-cement ratio. Admixtures for the mix can be chosen to reduce the water-cement ratio for improved durability while maintaining workability. Both the coarse and fine aggregates should be chosen for even gradation and to avoid chemical reactions. If this durable concrete mix is correctly batched, placed, and cured, it is much less likely that the chloride ions will penetrate the concrete cover and cause the steel to corrode.

Usually, standard bare reinforcing steel is used in coastal concrete construction with acceptable results if the concrete mix is selected in accordance with the guidelines given above and the placement is done in accordance with the guidelines in Chapter 16 of the IBC. The reinforcing steel should be free of loose corrosion and salt at the time of placement. Additional durability may be achieved by using epoxy-coated reinforcing steel as designed and specified by a qualified engineer.

Concrete piles are commonly used in coastal mid- to high-rise structures when higher capacity or longer length is required than is available in round wood piles. In some coastal areas, concrete piles are also routinely used for elevated single-family structures. Concrete piles are also used where termite infestation of even preservative-treated wood piles appears likely. Concrete piles are normally precast off site, with either conventional or pre-stressed reinforcement, and are available in a variety of sizes and lengths. The concrete piles used must be suitable in durability characteristics for a coastal environment. Concrete piles cannot easily be used for elevated structures in the higher seismic zones because the seismic requirement for close stirrup confinement reinforcement in a vertical member is difficult to achieve in a concrete pile.

Steel Foundations

Steel piles and sheet piles are commonly used in industrial waterfront construction, but their use has been limited in residential coastal construction. Most steels corrode in a salt-laden environment, and thus require a protective coating. Even the weathering steels are not immune to corrosion. Certain stainless steels under the right conditions are resistant to corrosion, but their cost and other considerations make them unsuitable for foundation elements. Steel piles may be considered where dense soils or gravels make the placement of concrete or wood piles difficult.

Masonry Foundation, Pier, and Wall Construction

As in concrete construction, salt-laden moisture entering reinforced masonry through cracks, defects, or a thin masonry or concrete cover can cause the steel reinforcement to corrode, leading to spalling and loss of strength. Therefore, the choice of masonry unit, mortar, grout, and reinforcement materials is critical.

For concrete masonry units, choosing Type I "moisture controlled" units and keeping them dry in transit and on the job site will minimize shrinkage cracking. For optimum crack control, Type S mortar should be chosen for below-grade applications, and type N mortar for aboveground applications. Horizontal ladder-type joint reinforcement, when used, is placed close to the wall surface in the mortar joint, and is therefore vulnerable to corrosion. This reinforcement, and other metal reinforcement accessories, should be hot-dip galvanized. Distributed horizontal and vertical reinforcement, which should have at least 2 inches of masonry shell and grout cover, may be of plain steel with all loose corrosion and salt removed. The IBC and IRC require, as a minimum, certificates for the materials used in masonry construction indicating compliance with construction documents.

Reinforced masonry and concrete constructed as foundation walls must be supported by either a concrete footing or pile in order to transfer dead, live, and environmental loads to the soil. When a footing is used, the footing must be placed on undisturbed soil with a bearing capacity sufficient to support the building loads with minimal settlement. The footing should be reinforced with sufficient concrete cover as discussed above.