Figure 2-27 *Breakaway wall panel failed to function as designed because continuous sheathing was installed across pilings. No structural damage was observed; however, note damage to utility components installed on breakaway wall panel.*

Figure 2-28 *Use of anchor bolts through the sill plate of a breakaway wall is improper. Even though this bolt does not have a nut and washer, it prevented the wall from breaking away laterally.*

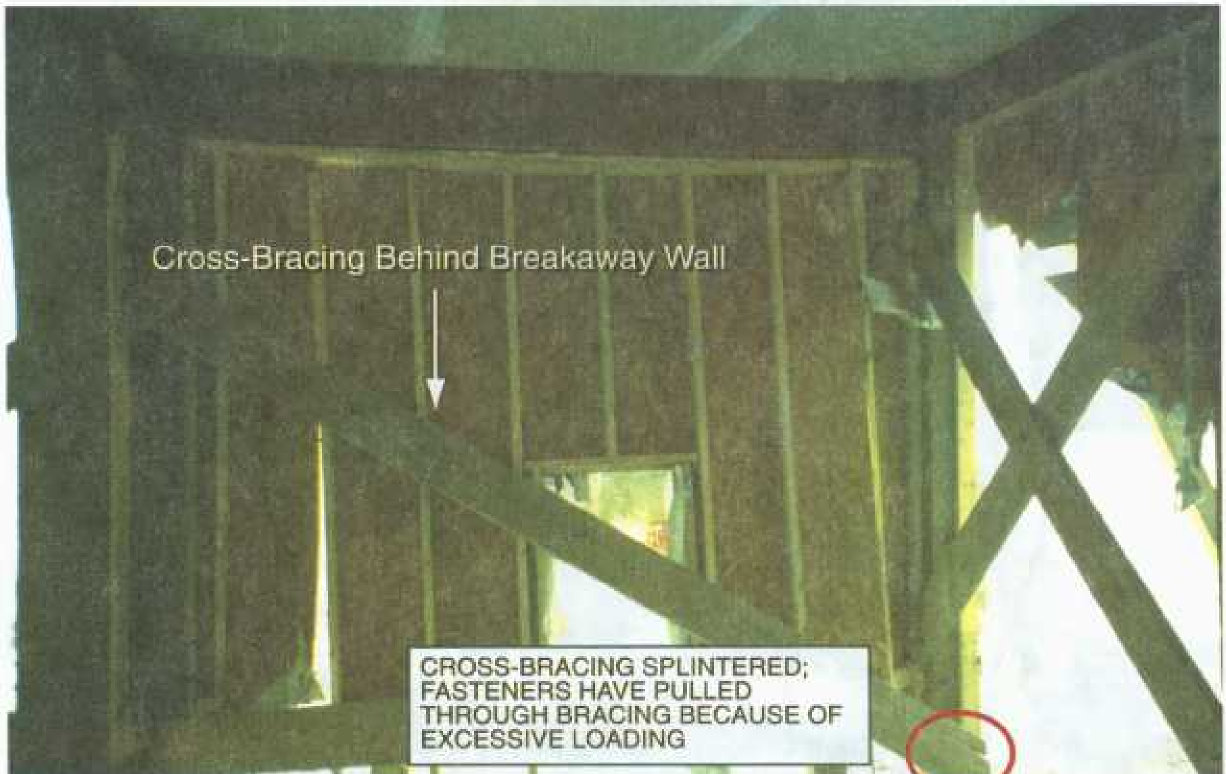

Figure 2-29 *Improper installation of breakaway walls (on the seaward side of cross-bracing) resulted in failure of cross-bracing. Note breakaway wall pushed against cross-bracing.*

2.5 Below-Building Concrete Slabs

With some minor exceptions, below-building concrete slabs generally performed as intended. Because some of the exceptions resulted in building damage, they are worth noting.

2.5.1 Slab Thickness

Slabs thicker than 4 inches were observed to have caused two problems:

- The thicker the slab, the greater the force needed to break the slab and therefore the greater the load transferred to the building foundation system until the slab breaks free of the foundation (see Figure 2-30).
- The thicker the slab the more it weighs per square foot of surface area. When a thicker slab breaks apart, the sections weigh more than those of the same size from a thinner slab and they create greater impact loads when they are thrown up against the building foundation by velocity flow and wave action.

2.5.2 Slab Joints

Three general types of joints are used in concrete slabs under elevated buildings: tooled and sawcut contraction (crack control), expansion, and isolation:

- Contraction joints are cut into the surface of the slab after the slab is poured and floated level. The joints become vertical planes of weakness that are intended to control cracking. These planes of weakness can serve a dual purpose by creating a frangible slab, since they are also the planes along which the slab is expected to break during a coastal erosion and scour event such as a hurricane or Nor'easter.

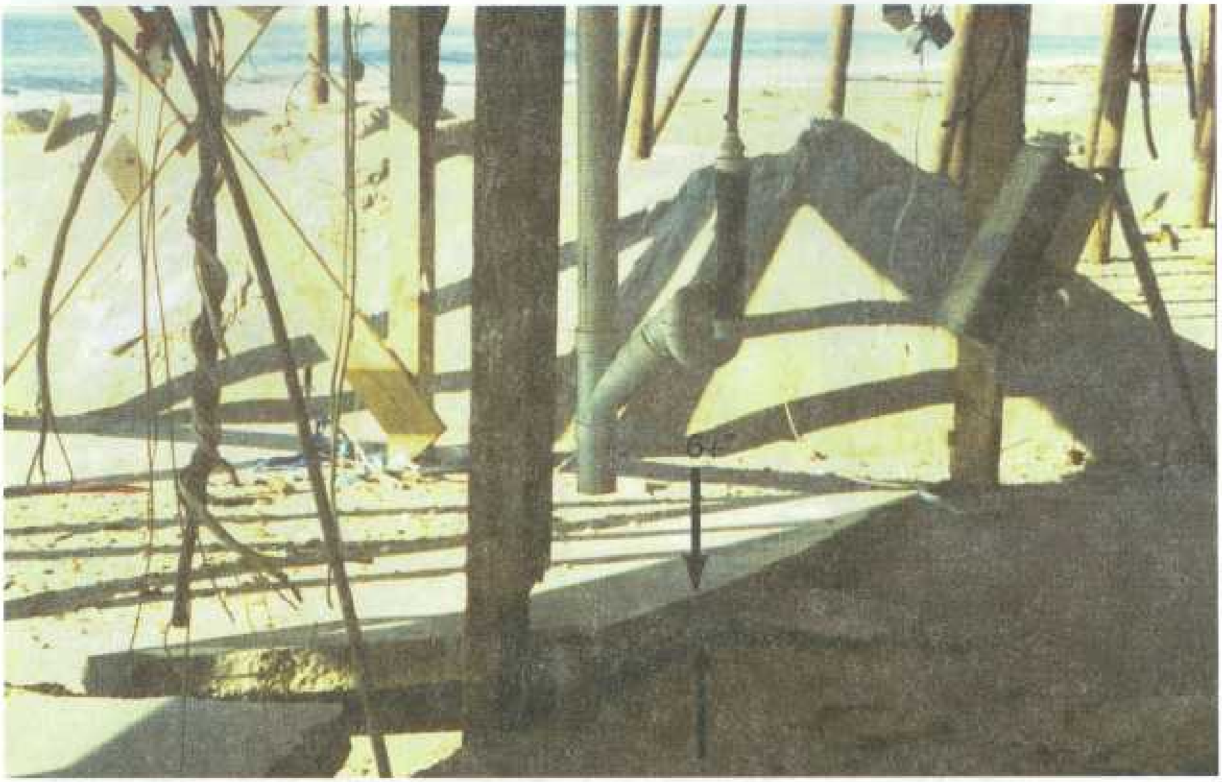

Figure 2-30 Example of unnecessarily thick slab.

- Expansion joints are set in place before the slab is poured. They separate independent slab sections and are filled with a compressible material that allows the sections to expand and contract in response to changes in temperature. They also help create a frangible slab.
- Isolation joints are used to separate the slab from structural members, such as vertical foundation members, and other slab penetrations. These joints are similar to expansion joints in that they are filled with a compressible material and are set before the slab is poured. When used in frangible slabs, they help ensure that the slabs will break away cleanly from the vertical foundation members and other slab penetrations such as sewer riser pipes.

The problems associated with slab joints involved the number of contraction joints and the effect of reinforcing wire mesh. In the slabs beneath many structures, the number of contraction joints was observed to be insufficient to make the slabs frangible. When the slabs broke up, the pieces were too large and generated unnecessary impact loads on the foundation system. Occasionally, the lack of an adequate number of contraction joints prevented the slab from breaking up. Figure 2-31 shows a large, unbroken section of a below-building slab-on-grade that was flipped up, probably by wave action, and came to rest against two vertical foundation members. The flipped slab created an obstruction that increased the flood loads on the foundation. In fact, the vertical foundation members behind the slab in Figure 2-31 were found to be leaning landward.

2.5.3 Wire Mesh

The BPAT observed that wire mesh was used in most slabs. The mesh is laid out before the concrete is poured. It usually extends across contraction joints but usually does not extend across expansion joints . The BPAT observed that where wire mesh was present , it usually had been

Figure 2-31 *Concrete slab-on-grade flipped up, probably by wave action, came to a rest against two foundation members, generating large, unanticipated loads on the foundation. Note slab is supported on concrete collars around piles and contains wire mesh.*

installed improperly (i.e., at the bottom rather than in the middle of the slab). Even so, the team observed that when reinforced slabs broke apart, broken sections were held together by the wire and came to rest against , or became wrapped around, vertical foundation members. As a result, large, unanticipated loads were transferred to the foundation system.

2.5.4 Connecting the Slab to the Vertical Foundation Members

Some engineers and architects may have specified, or contractors chose to use, dowels to connect concrete slabs-on-grade to vertical foundation members. The dowels, intended to help prevent the differential settlement of the slabs, were inserted into or through the vertical foundation members before the slab was poured. They caused serious problems when the slabs broke apart under flood loads. The dowels made it more difficult for the slab to break into small pieces and separate cleanly from the vertical foundation members. Even when the slabs broke into small pieces, the dowels acted like pins in a hinged connection, keeping the slab connected to the vertical foundation members (see Figure 2-32). As a result, unnecessary and unanticipated flood loads were transferred to the vertical foundation members.

Although the BPAT was unable to define a cause-and-effect relationship, several buildings with this slab-to-foundation pin detail were found to be leaning. The team members believe that the inability of the slab to break free of the vertical foundation members was at least partially responsible the failure of the vertical foundation members to remain plumb.

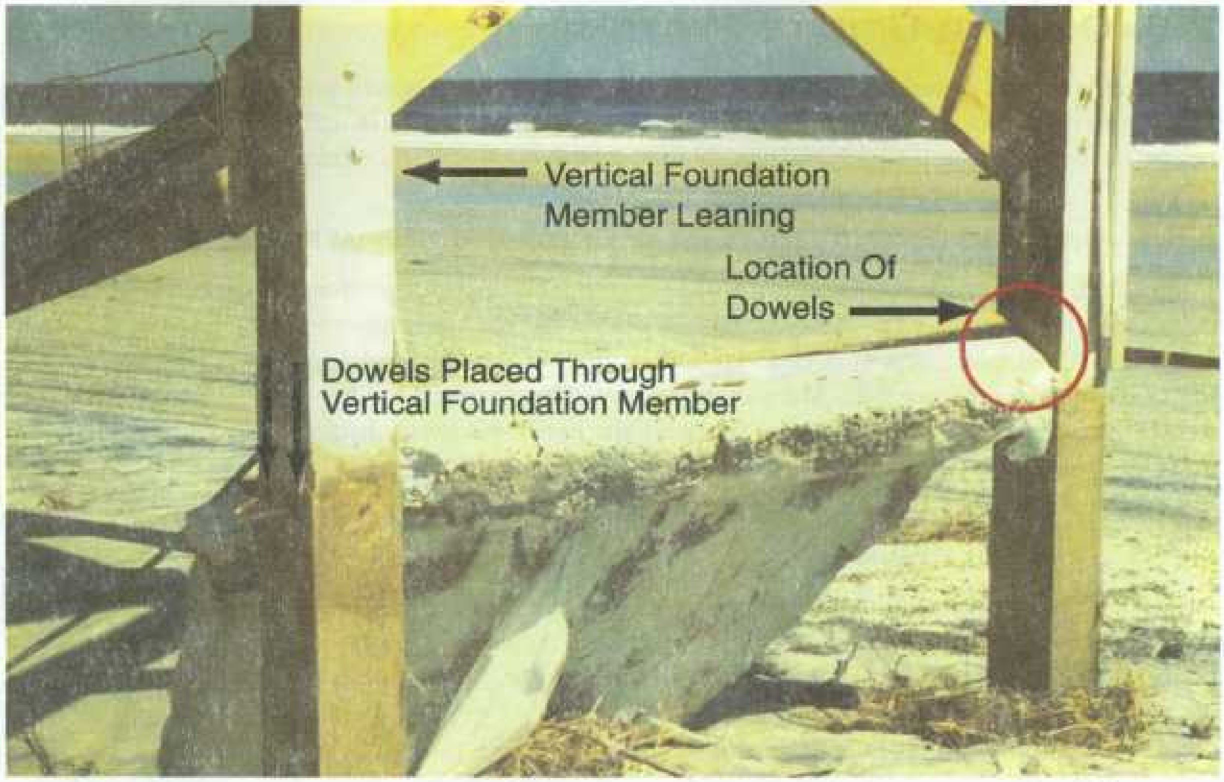

Figure 2-32 *Use of steel dowels to tie slabs to vertical foundation members prevented the proper breakup of slab. A portion of the slab was left attached to the piling, resulting in large, unanticipated loads on foundation members. Note leaning vertical member, on right.*

2.5.5 Casting Concrete Grade Beams and Slabs-On-Grade Monolithically

Some concrete grade beams and slabs-on-grade were poured monolithically in a continuous concrete pour. As a result, large loads were transferred to the foundation system when velocity flow, breaking waves, and debris forces were applied to the sections of slabs attached to the grade beam. Although the BPAT was unable to define a cause-and-effect relationship, several buildings with this monolithic grade beam and slab detail were found to be leaning. The team members believe that the inability of the slab to break free of the vertical foundation members and grade beam was at least partially responsible for the failure of the vertical foundation members to remain plumb.

2.5.6 Concrete Collars

The BPAT observed that concrete collars were often poured around foundation pilings in conjunction with the construction of below-building concrete slabs (see Figures 2-14 and 2-31). Although intended to provide stability, these collars presented a large obstruction to flow, therby increasing flood loads on, and scour around, the pilings to which they were attached. the increased scour resulted in a loss of sand supporting the foundation (see Figure 2-31). As shown in Figure 2- 14, collars did not prevent piling failure.

2.6 On-Site Utility Systems

Building performance issues concerning on-site utility systems usually involved air conditioning / heat pump compressors and their supporting platforms, the placement of utility system components in relation to breakaway wall panels and vertical foundation members, and septic tanks.

2.6.1 Air Conditioning / Heat Pump Compressor Platforms

The majority of air conditioning and heat pump compressor platforms supported by posts collapsed when acted on by flood forces. The posts were generally observed to be embedded only 1 to 2 feet. Once platforms were dislodged, they often collasped, leaving compressors submerged in flood water (see Figure 2-23. Many compressors were observed to have become waterborne debris. Occasionally, when a platform survived, the compressor was insufficiently elevated and was inundated with salt water and sand. Once inundated, the compressor is no longer salvageable and must be replaced.

Oceanfront Residential Buildings

When post-supported platforms adjacent to oceanfront houses collapsed, the cause was almost always erosion and scour combined (see Figure 2-33). Erosion in the areas where the platforms were set was generally 2 to four 4 feet in depth, often exceeding the embedment depth of the support posts. Cantilevered platforms, which do not depend on vertical support members, escaped the scour- and erosion-induced damage incurred by post-supported platforms. Compressors installed on adequately elevated cantilevered platforms were not subject to flood-related damages, including inundation, but were still subject to wind damage when they were not adequately anchored (see Figure 2-34).

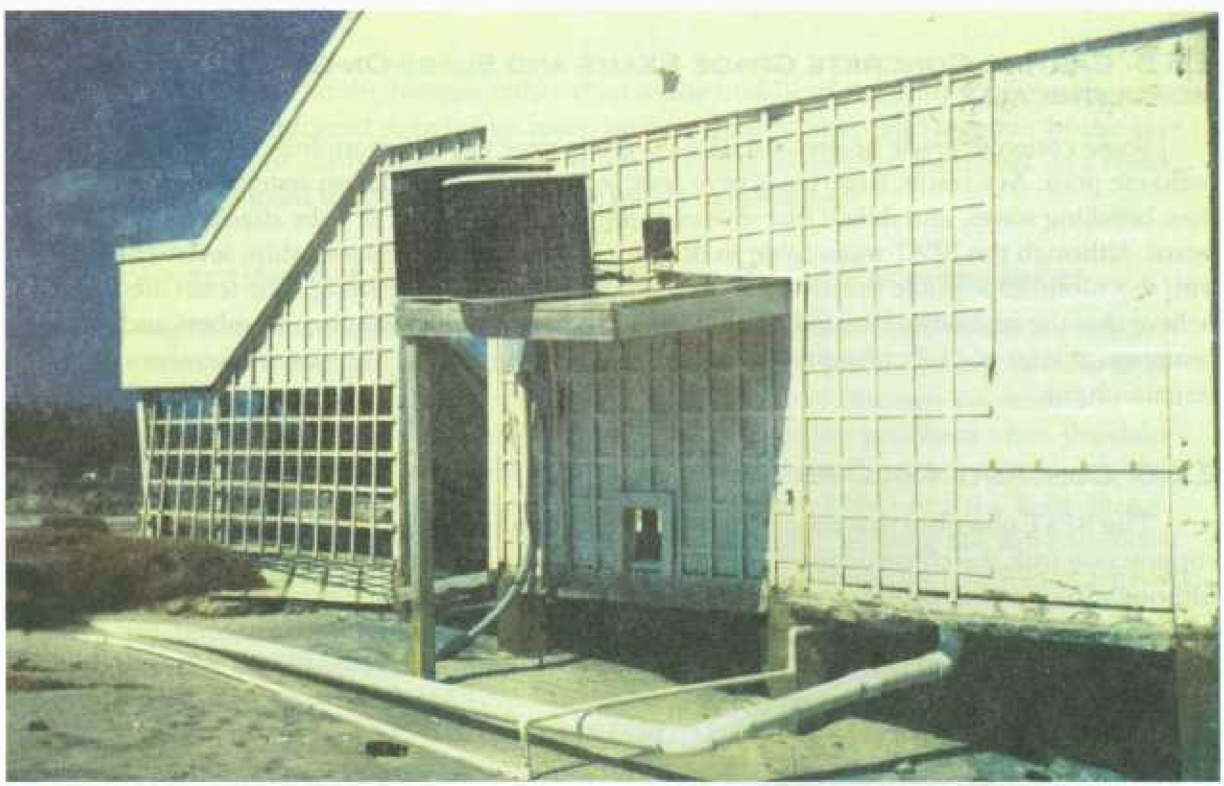

Figure 2-33 *Air conditioning / heat pump compressor platform leaning because erosion and scour caused loss of one supporting column.*

Figure 2-34 *Although the air conditioning/heat pump compressor platform on this oceanfront house was adequately elevated with cantilever bracing, the compressor was almost pushed off the platform by wind because of the lack of the necessary attachment.*

Landward Residential Buildings

Many of the post-supported compressor platforms adjacent to homes landward of the oceanfront row collapsed as a result of localized scour due to velocity flows (see Figures 2-23 and 2-35). Localized scour of approximately 1 foot in depth was generally observed. Where posts were embedded only 1 to two 2 feet, localized scour allowed the velocity flow and debris impact forces to dislodge the platform. Platforms with properly embedded posts performed much better. Often, the only damage sustained by landward residential buildings was the loss of the compressor unit due to water or wind damage.

2.6.2 Placement of Utilities on, Through, or Adjacent to Breakaway Wall Panels

In the vast majority of structures with breakaway wall panels observed by the BPAT, utilities were improperly placed on, through, or adjacent to breakaway wall panels.

The BPAT observed electric meter boxes, telephone service boxes, cable TV boxes, sewer service lines, and domestic water service feeds all mounted on breakaway wall panels (see Figures 2-27 and 2-36). Utilities placed through breakaway wall panels included telephone and cable TV lines, the electric feed from the back of the meter box to the electric panel box, and water service feeds (see Figure 2-37). Under the effects of flood forces, these utilities either were torn out or prevented breakaway wall panels from breaking away cleanly. Another deficiency observed was the placement of utilities adjacent to or near breakaway wall panels (see Figure 2-38). These utilities were damaged when flood forces caused the panels to break away.

Figure 2-35 *Air conditioning / heat pump compressor platform leaning because scour caused loss of two supporting posts.*

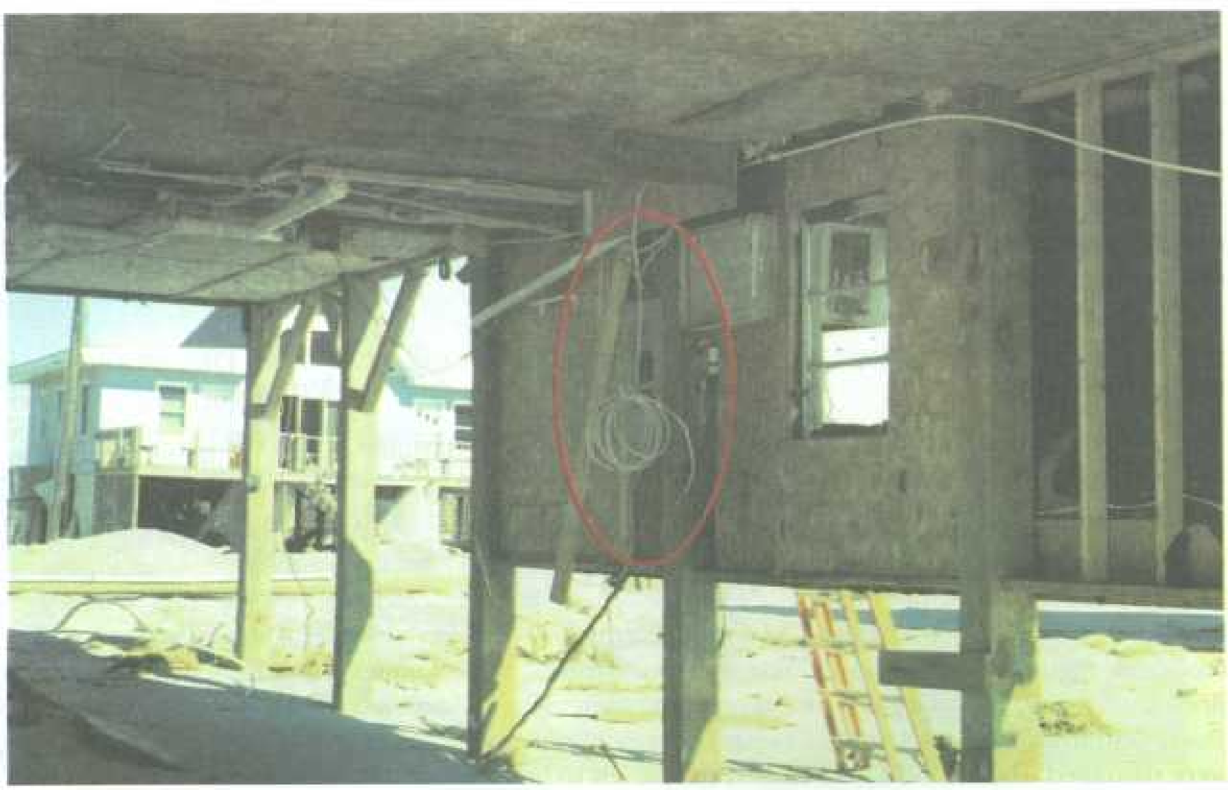

Figure 2-36 *Example of utility component (electric panel box) installed on a breakaway wall panel.*

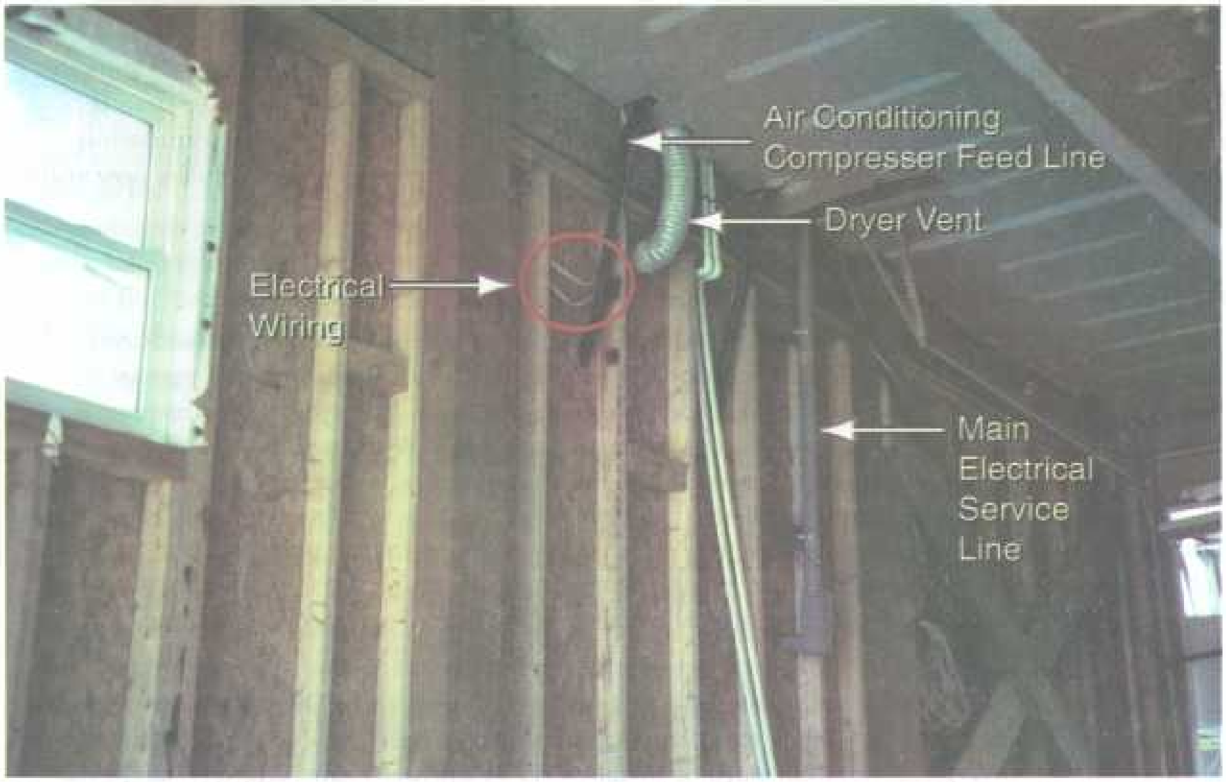

Figure 2-37 Utility components (dryer vent, air conditioning compressor feed line, main electrical service line out of meter box, and electric wiring) penetrating breakaway wall panel.

Figure 2-38 These utility components (wiring, electric panel box, ductwork, and sewer line) were installed adjacent to breakaway wall panel and were damaged when the walls broke away. Note broken sewer line riser pipe on seaward side of piling.

2.6.3 Placement of Utilities Adjacent to Vertical Support Members

Utilities on the vast majority of structures were found to be in locations exposed to velocity flow and debris impact, e.g., mounted to vertical foundation members on sides other than the landward side (see Figure 2-38). Utilities installed on the landward side of vertical foundation members generally survived since the foundation member shielded them from velocity flow and debris impact.

2.6.4 Septic Tanks

Septic tanks installed near oceanfront homes were often left exposed by storm-induced erosion and scour (see Figure 2-39). Occasionally, thin-walled septic tanks made of precast concrete rings were observed to have become waterborne debris. Concrete ring sections were found dislodged and under elevated structures (see Figure 2-17). When a tank was exposed, the sewer line from the home was usually severed. On many exposed tanks there were openings where the access lid was missing and where the connection to the sewer line from the house was exposed when the pipe broke away. The openings allowed sewage to leak out and flood water and debris to enter the tank. Homes that were otherwise not significantly damaged had been posted "Unoccupiable" by the local building official because of the lack of an operating sanitary disposal system.

The State of North Carolina has established regulations concerning the installation of septic tanks and leach fields in areas subject to coastal flood hazards. When a new building is constructed, the tank and leach field must be installed on its landward side. When repairs to an existing septic system located on the seaward side of a building become necessary for any reason, the tank and leach field must be moved to the landward side of the building.

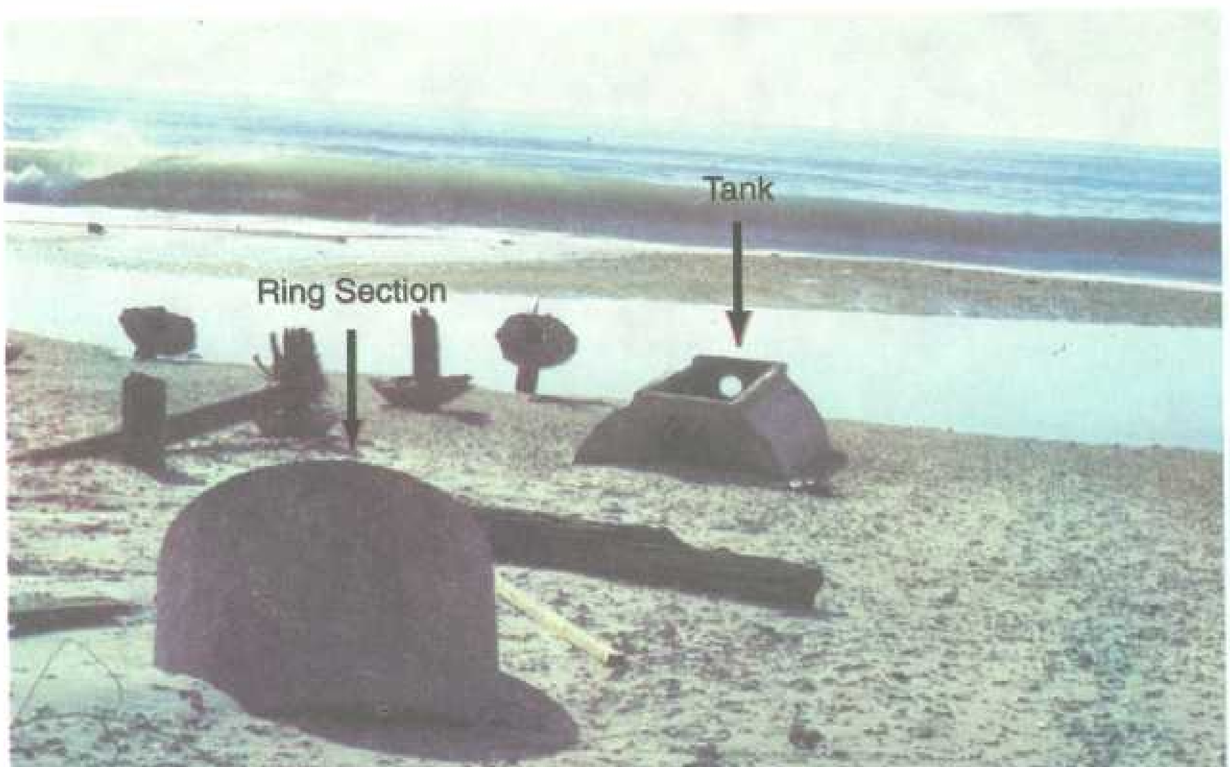

Figure 2-39 *Oceanfront erosion and scour unearthed and damaged septic tanks and systems. Note precast ring section and precast tank.*