The Building Performance Assessment Team Process

In response to hurricanes, floods, earthquakes, and other disasters, the Federal Emergency Management Agency (FEMA) often deploys Building Performance Assessment Teams (BPATs) to conduct field investigations at disaster sites. The members of a BPAT include representatives of public sector and private sector entities who are experts in specific technical fields such as structural and civil engineering, building design and construction, and building code development and enforcement. BPATs inspect disaster-induced damages incurred by residential and commercial buildings and other manmade structures; evaluate local design practices, construction methods and materials, building codes, and building inspection and code enforcement processes; and make recommendations regarding design, construction, and code issues. With the goal of reducing the damage caused by future disasters, the BPAT process is an important part of FEMA's hazard mitigation activities.

About the Cover

THIS PHOTOGRAPH WAS TAKEN ALONG THE GULF COAST IN THE CITY OF PENSACOLA BEACH, FLORIDA, AFTER THE PASSAGE OF HURRICANE OPAL. IN THE FOREGROUND ARE THE REMAINS OF A STRUCTURE BUILT BEFORE THE CITY ADOPTED THE FLOODPLAIN MANAGEMENT ORDINANCE REQUIRED FOR PARTICIPATION IN THE NATIONAL FLOOD INSURANCE PROGRAM (NFIP). THE STRUCTURE IN THE BACKGROUND WAS BUILT AFTER THE ADOPTION OF THE REQUIRED ORDINANCE AND WAS THEREFORE REQUIRED TO MEET NFIP STANDARDS FOR CONSTRUCTION IN THE COASTAL HIGH HAZARD AREA. THE DRAMATIC DIFFERENCE BETWEEN THE POST-STORM CONDITIONS OF THESE TWO STRUCTURES UNDERSCORES THE IMPORTANCE OF PROPER CONSTRUCTION IN COASTAL AREAS SUBJECT TO HURRICANES.

Hurricane Opal in Florida

A Building Performance Assessment

August 30, 1996

FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

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Executive Summary

On October 4, 1995, Hurricane Opal made landfall on Santa Rosa Island, Florida, near Navarre Beach, at approximately 6:00 p.m. c.d.t. (central daylight time.) As a result of the damage caused by Hurricane Opal, President Clinton declared 15 counties in the Florida Panhandle and Lee County, on the southwest Florida coast, Federal disaster areas (see Figure 1-1).

The Federal Emergency Management Agency (FEMA) deployed a Building Performance Assessment Team (BPAT) whose mission was to evaluate structural damage and recommend mitigation measures that will enhance the performance of buildings in future storms. The team was composed of engineers and building construction specialists from FEMA, the State of Florida, and the private sector (see the Appendix for a list of the team members). The BPAT conducted its evaluation in the area where most of the severe damage was concentrated: along a 200-mile stretch of Florida's Gulf of Mexico shoreline, between Pensacola Beach, in Escambia County, and St. Joseph Spit, in Gulf County (see Figure 1-1). The BPAT's observations focused on the performance of buildings during the hurricane, including both successes and failures. These observations and the BPAT's recommendations are documented in this report.

Preliminary estimates by the insurance industry indicate that Opal may be one of the most costly natural disasters to affect the United States (ranking only behind Hurricane Andrew; the Northridge, California, earthquake; and Hurricane Hugo). According to State of Florida estimates, more structures were damaged or destroyed by the effects of flooding and erosion during Hurricane Opal than in all other coastal storms affecting Florida in the past 20 years combined.

Most of the structural damage associated with the storm appeared to have been caused by coastal flood forces — storm surge, wind-generated waves, flood-induced erosion, and floodborne debris. Wind damage along the coast was confined primarily to roof damage, sign damage, tree damage, and similar impacts and was judged by the BPAT to be less severe and less extensive than flood damage

Construction along and near the shoreline in the study area was generally governed by one or more of the following:

- The Standard Building Code, enforced by local or county governments
- National Flood Insurance Program (NFIP) construction requirements — in identified Special Flood Hazard Areas — enforced by local or county governments
- State construction requirements for structures seaward of the Coastal Construction Control Line, enforced by the Florida Department of Environmental Protection

To participate in the NFIP, a community must adopt and enforce a floodplain management ordinance based on the Flood Insurance Rate Map (FIRM) issued for the community by FEMA. The communities in the study area include structures built before the adoption of the floodplain management ordinance and structures built after the adoption of the ordinance. The former are referred to as "pre-FIRM" structures, the later as "post-FIRM." Typical pre-FIRM structures in the study area are one-story concrete block or wood-frame structures built on slab-on-grade

foundations, one- to three-story concrete block structures, and one- to three-story wood-frame structures founded on timber piles. Many of these structures were behind concrete sheetpile seawalls. Typical post-FIRM structures in the study area are one-, two-, and three-story wood-frame structures elevated on timber or concrete pile foundations. Post-FIRM structures, although sustaining damage, performed much better than the pre-FIRM structures.

Flood Damage and Vulnerable Components

Because most of the structural damage observed by the BPAT along the Gulf of Mexico shoreline appeared to have been caused by flood forces rather than wind forces, the team focused on flood-induced damage. The observations of the team presented in this report address following issues:

- storm-induced erosion and scour
- debris flow and impact
- slab foundations
- pile and pier foundations
- framing systems
- connections
- bracing
- breakaway construction and enclosures below elevated buildings
- stairs, decks, and porches
- utilities
- seawalls
- drainage and drainage structures

Other issues discussed in this report include (1) the incorporation of pre-FIRM construction into new construction during the improvement of existing structures and (2) structures that appear to have been built without the aid of detailed plans prepared by a design professional. The BPAT found that poor workmanship frequently accompanied the lack of professional design in such instances.

Recommendations

The BPAT developed recommendations that address observed damages and vulnerabilities for both new construction and substantial improvements to existing structures in areas subject to coastal and hurricane storm forces. These recommendations include the following:

- Restudies and FIRM revisions now underway for the affected communities will use updated V-Zone mapping procedures and may result in more extensive areas being shown as V-Zones. Consequently, until such time as revised FIRMs are completed, the affected communities should consider studying local coastal flooding conditions that occurred during Hurricane Opal to determine whether areas shown as coastal A-Zones on the current FIRMs, as well as areas within several hundred feet of the Gulf of Mexico shoreline, are actually subject to V-Zone flood forces. If such areas are identified, the affected

communities should strongly encourage the owners of new construction and substantial improvements to existing structures within those areas to conform with V-Zone construction standards. In addition, if areas shown as A-Zones on the current FIRMs are determined to be subject to V-Zone forces, the BFEs shown for those areas are likely to increase. Therefore, communities should also strongly encourage the owners of new construction and substantial improvements to existing structures in such areas to construct the lowest floors of their structures several feet above the BFEs shown on the current FIRMs.

- For all areas known to be subject to high-velocity wave action, strong currents, erosion, or combinations thereof — regardless of flood zone designation — the embedment depths specified for pile foundations should be sufficient to ensure that the foundation will withstand anticipated erosion and storm forces. Foundations for masonry columns should be designed to withstand all anticipated flood, erosion, debris, and wind forces. Shallow footings should not be used to support masonry columns where the risk of undermining exists.

- In areas subject to storm-induced erosion, regardless of the flood zone designation, any slabs serving as floors for habitable spaces should be designed and constructed as structural slabs, to withstand all anticipated erosion, scour, and storm forces, and attached to sufficient foundation systems that do not rely on underlying soil for support.

- In areas subject to storm-induced erosion, regardless of the flood zone designation, slabs used solely for parking should not be attached to structural members and should be designed and constructed to break into small pieces in the event of undermining, thereby minimizing potential transfer of flood loads to the structure.

- All materials should meet or exceed the minimum requirements for building materials in the Standard Building Code and FEMA's Technical Bulletin 2-93, *Flood-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas* (FEMA 1993b).

- Repairs of damaged structures should be completed in accordance with applicable Federal, State, and local codes and regulations and should be inspected to ensure conformance with building codes and floodplain management requirements.

- Engineered plans signed and sealed by a registered design professional should be provided for both new construction and substantial improvements to existing structures in areas subject to coastal storm forces. Siting and construction in 100-year coastal flood hazard areas must meet (and, if possible, exceed) setback and elevation requirements.

This report includes photographs taken by the BPAT during the site visit. Also included are engineering design drawings that provide details which can be used to enhance building performance under hurricane and coastal flood conditions.

1 Introduction

1.1 Purpose

This report presents the findings of the Building Performance Assessment Team (BPAT) regarding building successes and failures during Hurricane Opal and recommends mitigation measures that will enhance the performance of buildings in future storms. The Appendix lists the BPAT members.

Typical construction types are defined for structures built prior to and after the affected communities' adoption of the floodplain management ordinance required for participation in the National Flood Insurance Program (NFIP). Because the ordinance is based on flood hazard information shown on the Flood Insurance Rate Map (FIRM) issued for each community, these structures are referred to as "pre-FIRM" and "post-FIRM," respectively. The BPAT's observations regarding flood and wind damage caused by the storm are described in detail, and recommendations are presented regarding design and construction of new structures and substantial improvements to existing structures; permitting, plan review, and inspection; construction materials; and repair and retrofit of damaged structures.

1.2 Background

Hurricane Opal made landfall on Santa Rosa Island, in Santa Rosa County, Florida, near Navarre Beach, at approximately 6:00 p.m. c.d.t. (central daylight time) on Wednesday, October 4, 1995. Fifteen counties in the Florida Panhandle were declared Federal disaster areas (see Figure 1-1). Most of the damage was concentrated in six counties: Escambia, Santa Rosa, Okaloosa, Walton, Bay, and Gulf. Lee County, along the gulf coast in southwest Florida, was declared a Federal disaster area because of rainfall-induced flooding associated with the same storm system.

The most severe damage caused by Opal was concentrated along a 200-mile stretch of Florida's Gulf of Mexico shoreline, between Pensacola Beach (Escambia County) and St. Joseph Spit (Gulf County). This is the area where the BPAT conducted its field inspections (see Figure 1-1). The results of these inspections and the BPAT's review of post-storm video taken by the Florida Department of Environmental Protection (FDEP), Bureau of Beaches and Coastal Systems, led to the conclusion that most of the structural damage associated with the storm was caused by coastal flood forces — storm surge, wind-generated waves, storm-induced erosion, and floodborne debris. Flood damage also occurred along the shorelines of Santa Rosa Sound, Choctawhatchee Bay, and other inland waters.

Wind damage along the coast was confined largely to roof damage, sign damage, tree damage, and similar impacts and was judged by the BPAT to be less severe and less extensive than the flood damage. However, wind damage extended throughout the affected counties. Newspaper accounts indicated that approximately 18,000 dwelling units (e.g., homes, apartments, hotel/motel units) in 10 panhandle counties were rendered uninhabitable by Hurricane Opal and approximately one-fifth of these units were destroyed (*Panama City News Herald* 1995). The BPAT was unable to confirm these estimates.

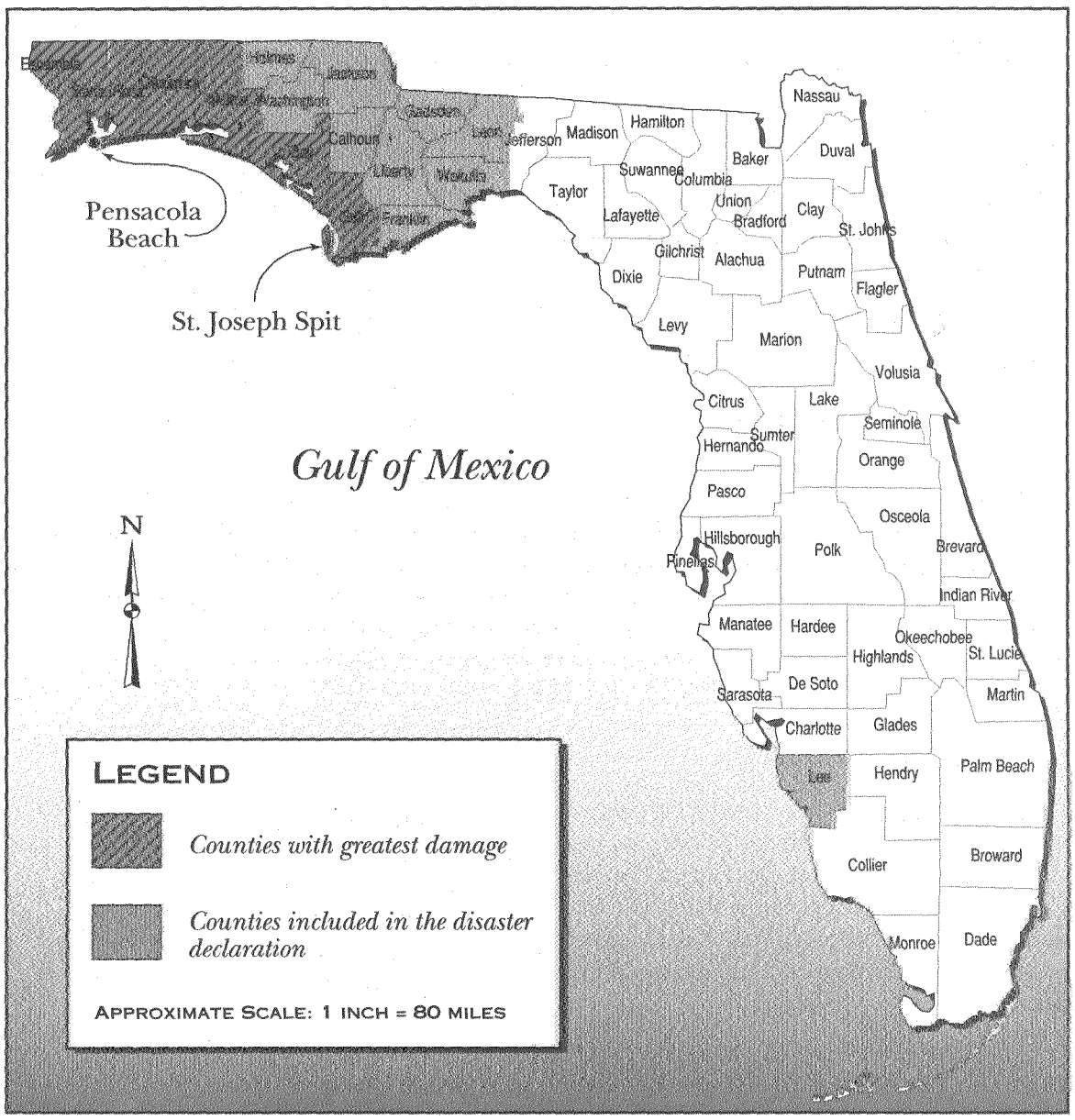

Figure 1-1 Florida counties included in the Hurricane Opal Federal disaster declaration.

Data from the FDEP (1995) indicate that approximately 990 coastal structures along the Gulf of Mexico shoreline incurred 50 percent or more damage (i.e., substantial damage). This total includes over 500 single-family dwellings and over 300 multi-family structures (containing 1,000 dwelling units and 800 motel/hotel units). The FDEP data also show that over 3 miles of concrete and timber bulkheads and retaining walls were damaged or destroyed. According to State of Florida estimates, more structures were damaged or destroyed by the effects of flooding and erosion during Hurricane Opal than in all other coastal storms affecting Florida in the past 20 years combined.

Preliminary estimates from the insurance industry show total insured losses from wind damage from the storm to be approximately $2 billion, making Opal one of the most costly natural disasters to affect the United States (ranking only behind Hurricane Andrew; the Northridge, California, earthquake; and Hurricane Hugo).

1.3 HURRICANE OPAL — STORM CONDITIONS

Hurricane Opal was classified as a Category 3 storm on the Saffir-Simpson scale at the time of landfall, with a central pressure of 940 millibars (mb) and recorded sustained wind speeds of approximately 110 to 115 miles per hour (mph). Recorded wind speeds rapidly decayed to 86 to 92 mph just inland. The storm was moving north-northeast with a forward speed of 22 mph at landfall (National Oceanic and Atmospheric Administration 1995).

Water level data from a National Oceanic and Atmospheric Administration (NOAA) tide gage on the Panama City Beach pier show a peak water level of approximately 8.5 feet above Mean Lower Low Water (MLLW) at 6:00 p.m. c.d.t., nearly 8 feet above the predicted astronomical tide. Water level data from the NOAA gage at Apalachicola show a peak water level of approximately 6.6 feet MLLW at 7:30 p.m. c.d.t., approximately 6 feet above the predicted astronomical tide.

High-water mark surveys conducted after Hurricane Opal (Michael Baker, Jr. 1995) show that water levels ranged from approximately 8 to 11 feet National Geodetic Vertical Datum (NGVD) along Santa Rosa Island between Pensacola Beach and Fort Walton Beach, approximately 12 to 20 feet NGVD between Destin and Seagrove Beach, and approximately 8 to 12 feet NGVD along Panama City Beach.

1.4 LOCAL, STATE, AND FEDERAL SITING AND BUILDING CODE REQUIREMENTS

Construction along and near the shoreline in the study area was generally governed by one or more of the following: the Standard Building Code, enforced by local or county governments; NFIP construction requirements — in identified Special Flood Hazard Areas — enforced by local or county governments; and State construction requirements for structures seaward of the Coastal Construction Control Line (CCCL), enforced by FDEP, Bureau of Beaches and Coastal Systems (formerly known as the Florida Department of Natural Resources, Division of Beaches and Shores).

FIRMs which show Base Flood Elevations (BFEs) that include wave height effects were adopted by communities in the study area between June 1983 and August 1987. (The base flood, also referred to as the 100-year flood, is the flood that has a 1-percent probability of being equaled or exceeded in any given year and is the basis for the regulatory requirements of the NFIP.) Because the NFIP Flood Insurance Studies on which the FIRMs are based were completed at different times, during which V-Zone mapping criteria were evolving, some of the studies accounted for wave setup, wave runup, and erosion, and others did not.

The Flood Insurance Studies indicate that the predicted 100-year stillwater (or storm surge) elevations along the majority of the Gulf of Mexico shoreline in the study area range from 4 feet to 6 feet NGVD. In the same area, V-Zones generally range from 100 to 300 feet in width and the wave crest elevations in the V-Zone range from 7 to 9 feet NGVD. Higher elevations are indicated for the Pensacola Beach and Perdido Key areas, where the predicted 100-year stillwater elevations range from 8 feet to 12 feet NGVD, V-Zones range from 200 to 400 feet in width, and V-Zone wave crest elevations range from 12 to 15 feet NGVD.

The State of Florida established the CCCL along Florida's sandy beach shorelines to delineate those areas subject to erosion or other adverse impacts during a 100-year storm. Specific elevation and construction requirements are enforced by the State seaward of the CCCL. With the exception of Bay County, the portions of the CCCL in the study area were adopted by the State between 1982 and 1991 and reflect anticipated 100-year storm impact zones. However, the pre-Opal CCCL in Bay County was essentially unchanged from a 50-foot setback line established by the State in 1975 and did not include all areas subject to 100-year storm impacts. After Hurricane Opal, the State adopted a revised CCCL for Bay County on an emergency basis. The new line is 100 feet landward of the pre-Opal line and became effective on October 16, 1995. Reconstruction of many damaged or destroyed structures along the Bay County shoreline will now be subject to CCCL construction requirements.

The FDEP has also completed its own studies that predict 100-year stillwater elevations along the Gulf of Mexico shoreline. FDEP studies for the reach between Escambia and Bay Counties generally show 100-year stillwater elevations ranging between 11 feet and 12 feet NGVD. The 5-foot to 6-foot difference between FDEP and NFIP 100-year stillwater levels is attributed to the inclusion of dynamic wave setup by FDEP.

A comparison of V-Zone boundaries and the location of the State's CCCL had not been completed at the time this report was prepared (a comparison is expected by late 1996). However, the State's foundation and elevation requirements seaward of the CCCL (i.e., pile penetration requirements and lowest floor elevations) are known to be more stringent than NFIP V-Zone requirements. Likewise, the State's wind load requirements seaward of the CCCL are known to be more stringent than the wind load requirements of the Standard Building Code. According to the FDEP (1995), no major habitable structures located seaward of the CCCL and permitted by the State under current standards sustained significant structural damage during Hurricane Opal. In contrast, the FDEP reported that over one-half of the pre-existing major habitable structures seaward of the CCCL (i.e., structures either not permitted by the State or constructed prior to State permitting requirements) sustained structural damage during the storm.