PART THREE

# BUILDING AND CONSTRUCTION STANDARDS

# HARVEY CEDARS, NEW JERSEY, FIELD EVALUATION IN RESPONSE TO THE DECEMBER 11-12, 1992 NORTHEASTER: PILOT STUDY ON THE EFFECTIVENESS OF NFIP CONSTRUCTION STANDARDS IN REDUCING COASTAL FLOOD DAMAGE

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## Background

On December 11-12, 1992, the New Jersey and New York coastlines were impacted by significant flooding, damaging thousands of buildings. The losses resulting from the December storm were substantial throughout the New Jersey coastal communities. By closely examining the claims data and building composition of a representative town, it is possible to evaluate the effectiveness of the National Flood Insurance Program (NFIP) building standards. This examination will allow for necessary program modifications that will ultimately lead to the reduction in both NFIP claims and the need for disaster assistance.

## Town Selection

Although storms and flooding are an anticipated hazard on a barrier island, Long Beach Island, New Jersey, has an extensive history of flood problems. The December 11-12 storm was particularly damaging to the community of Harvey Cedars, which is a typical Atlantic Coast barrier island community. Harvey Cedars was selected as the representative town for evaluation of NFIP building standards based on the following:

- The December 11-12 Northeaster approximated the "design" (100-year) flood event at this location based on existing data;

- Flood damage incurred by a similar storm before the implementation of NFIP standards is well documented (the Ash Wednesday, 1962 Northeaster) and provides a meaningful comparison;

- It has a balanced mix of pre-FIRM and post-FIRM construction;
- The percentage of NFIP policies is as high as anywhere in the nation (over 50%); thus, extensive policy and claims data are available; and
- Almost the entire community is in the designated floodplain and the number of structures is small enough to permit a thorough investigation, yet large enough to provide meaningful results.

## Storm Data

One of the worst storms of record in the Long Beach Island vicinity was the Ash Wednesday storm of 1962. The storm resulted in the destruction of beaches, dunes, shore-protection works, houses, and other structures. Several of the houses that did remain, however, were located on pile or column foundations. Thus, in addition to extensive beach repair effort and numerous raisings of street elevations, the majority of the houses that were rebuilt after the storm were elevated above the 1962 flood levels. Even though regulations did not specify these criteria, the houses were rebuilt in a fashion similar to that specified in the NFIP standards, following the example of their surviving neighbors.

Tide crest gage data from nearby towns indicate the December 11-12, 1992 Northeaster (identified by many as the "storm of the century") is comparable in magnitude to the historical March 1962 storm. Although extreme tides were not predicted during this event, the storm occurred between full moon and the moon in perigee. The high tides resulting from these alignment maxima greatly contributed to the overall impacts of the storm surge.

The December 1992 storm resulted in severe erosion of approximately two-thirds of the town's beaches. The majority of the oceanfront homes incurred damage as a result of this erosion. However, structural damage to foundations and supporting elements was very minor. The damage sustained in the remaining structures (non-oceanfront) was primarily the result of flood waters.

Although the two storms were comparable in magnitude, the degree of flooding for the December 1992 storm was slightly less than the 1962 storm. This was due to the shorter duration of the 1992 storm and the additional protection provided via rehabilitation of and improvements to the roads and dunes since the 1962 storm. There was drastically less damage resulting from the December 1992 storm than from the 1962 storm. This is directly related to improvements in the construction techniques typically employed since the 1962 storm. Before 1962, the majority of the residential houses were constructed on conventional slab or crawl foundations. However, as a result of the destruction of many of these homes, elevated construction became prevalent even before the implementation of the NFIP. Deep pilings prevented the collapse of numerous oceanfront structures, which lost up to six feet of soil as a result of the December storm.

## Methodology and Results

### *Methodology*

A quantitative inventory and analytical assessment of NFIP claims data, which compares the degree of flood damage sustained for the December 1992 storm to building types and other parameters, was performed. The major tasks involved included base map development, structure inventory, damage inventory, and comparative analysis. Once initial results were obtained from the inventories and analysis, the definition and content of the tasks were refined to better adapt to these results.

An inventory and thorough examination of 349 structures were performed. Although these 349 structures represent approximately one-third of the buildings in the community, over one-half of the damage is represented. The section of town inventoried represents the portion of Harvey Cedars most severely impacted by the storm. The area is characterized by a relatively low dune elevation and a narrow distance from bay to ocean. For analysis, the area was subdivided into bayside, oceanside (non-front row), and oceanfront (front row). Damage was investigated based on "design" and "actual" first floor elevation in relation to the BFE. The "design" first floor is the first floor of the structure designed as habitable and does not include lower area enclosures as determined by inspection or from NFIP claims data. The "actual" first floor is the first floor as determined by apparent habitable living space, including framed lower area enclosures as determined by *exterior inspections only.*

### *General Structure Data*

All of the structures in the town of Harvey Cedars, New Jersey, are located in an A-Zone with a mixture of pre- and post-FIRM construction. Most of the pre-FIRM structures (over 60% at bayside, 70% at oceanside, and 90% at oceanfront), have first floor elevations above the BFE and thus behave as post-FIRM structures. Therefore, clear differentiation cannot be made between the responses of pre- and post-FIRM construction to the December storm. Of the 349 structures inventoried, 143 are bayside, 152 oceanside (non-front row), and 54 oceanfront (front row). Of these, it is estimated that 78% of the bayside, 84% of the oceanside, and 91% of the oceanfront structures are participating in the NFIP. In addition, based on exterior inspection only, it appears that between two and 15 post-FIRM bayside, two and 10 post-FIRM oceanside, and zero and two post-FIRM oceanfront structures are not in compliance with A-Zone building requirements. Since these generalizations are based on brief exterior inspections of the lower areas only, further investigation of these lower area enclosures is required for a more accurate account of compliance.

### Damage Relationships

***Design and Actual First Floor Elevations: Pre- and Post-FIRM Status.*** The damage sustained was evaluated in relation to the design and actual first floor elevations and the pre- and post-FIRM status. The damage was broken down to general locations: bayside, oceanside, and oceanfront.

Through examination of the damage, it is apparent that there is no correlation in relation to pre- and post-FIRM status. This is evident by the relatively even distribution of damage between the two classifications. The field investigation revealed that the majority of the pre-FIRM structures were elevated to the standards required for post-FIRM construction. Therefore, subsequent analysis of relationships were investigated based on compliance with the "post-FIRM" NFIP building standards, and not the FIRM indication.

As noted, by evaluating the design first floor elevations, it was apparent that numerous structures are elevated at or above the BFE. Several of these structures, though, still incurred damage during the December 1992 storm. When consideration is given to lower areas which appear (by exterior inspection only) to be fully-framed, non-breakaway, and habitable, the number of structures with "actual" first floor elevations above the BFE is reduced. Therefore, it appears that much of the damage sustained was to the lower areas and primarily due to inundation in the bayside and oceanside structures and inundation in combination with erosion for the front row structures.

Based on the study of damage in relation to actual vs. design first floors, subsequent analysis of NFIP claims focuses solely on actual first floor elevations.

***First Floor Elevation and Location Distance.*** The elevation of the first floor in relation to the surge and the distance from the flood source are significant factors in determining damage sustained from the December storm.

***First Floor Elevation.*** An investigation of the first floor elevation in relation to the number of structures damaged revealed that once this elevation is above the BFE in the bayside and oceanside areas, the percentage of structures damaged is reduced significantly. Approximately 23.5% of the bayside structures with first floor elevations below the BFE reported damage, whereas only 3.8% with first floor elevations at or above the BFE reported any damage. Damage was reported for 30% of the oceanside structures with first floor elevations below the BFE, versus 12.4% of those with first floor elevations at or above the BFE. The first floor elevation relationships cannot be summarized as above for the oceanfront structures, since the data pertaining to structures with first floor elevations below the BFE is too limited.

***Claims Paid.*** The damage reported for various structures ranged from $500 to over $70,000. Similarly, the range for the claims paid varied from under $500 to over $60,000. Claims paid for structures in the bayside amounted to approximately $52,057. Of this amount, $36,595 was for structures with first floor elevations below the BFE and $15,457 for structures with first floor elevations at or above the BFE. The claims paid to the oceanside structures amounted to roughly $165,233 with an average of $77,788 going to structures below the BFE and $87,443 to those above the BFE. The average claim paid to these structures was $8,643 for structures with first floors below the BFE and $7,287 for structures with first floors at or above the BFE. It appears that no matter what the relation to the BFE once the house is damaged, the floor height does not appear to influence the value of the claim paid. The floor height does impact, as noted previously, the number of structures damaged. A significantly smaller portion of the buildings was damaged when the first floor elevation was at or above the BFE.

The claims paid to the oceanfront structures cannot be summarized as above, since the sample of structures below the BFE is not large enough to warrant such a comparison.

Although the average claim paid is higher for those structures with first floor elevations above the BFE, further investigation revealed that a large percentage of the damaged structures with first floor elevations at or above the BFE is relatively large and of newer construction, and therefore often more costly.

***Distance from Shoreline Reference.*** When the design related to the distance from the reference baseline is examined, it becomes apparent that the amount of damage sustained to the oceanside and oceanfront structures generally decreases as distance from the baseline increases.

## Conclusion

Harvey Cedars has a history of flooding and suffered severe damage in the 1962 storm. In addition, based on conversations with local officials, insurance representatives, and residences, many of the oceanfront structures were considered to be located in a V-Zone before the 1984 update of the FIRM, which took wave action into account. The combination of the flood history and the previous zone designation has a major impact on the structural composition of this area. The reported damage for the three sub-areas investigated indicates that when structures in the bayside and non-front row oceanside are elevated to the BFE or above, the number of damaged structures is reduced. Only three out of almost 100 post-FIRM structures suffered any damage after the first floors were elevated to or above the BFE.

The reported damage to the oceanfront structures does not appear to follow this trend. It must be noted, however, that all of these structures lie within 20 feet of the dune line, in an A-Zone with a BFE of 10 feet. Even with the consideration of the lower area enclosures, only five of the 54 structures have actual first floor elevations below the BFE. Therefore, it appears that the damage sustained was a result of erosion and inundation of the lower area enclosures, decks, and stairways.

## References

U.S. Army Corps of Engineers

1963 *Report On Operation Five High: Disaster Recovery Operations From 6-8 March 1962 Storm.* U.S. Army Corps of Engineers, North Atlantic Division, Construction-Operations Division, Civil Works Branch.

# EROSION HAZARDS AND COASTAL CONSTRUCTION DEFICIENCIES OBSERVED ON KAUAI AFTER HURRICANE INIKI

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## Introduction

Since the inception of the National Flood Insurance Program (NFIP) 25 years ago, the contribution of both storm-induced and long-term erosion to coastal property damage has been increasingly recognized (Davison, 1993). An accurate estimate of both the vertical and horizontal components of erosion is a fundamental design consideration for providing adequate foundation embedment for coastal buildings. Based on observations made on the south shore of the Island of Kauai after Hurricane Iniki, this paper describes the general geotechnical setting, hurricane-induced erosion processes, and building failure due to this erosion and offers general design guidance for foundation embedment applicable to Hawaii's coastal zone.

Shortly after Hurricane Iniki struck Kauai County, Hawaii, the Federal Emergency Management Agency (FEMA) Technical Standards Division assembled an interdisciplinary team of building scientists, planners, and professionals versed in mitigation. The team assessed the performance of buildings (both success and failure) subjected to wind, flood, and erosion forces (FEMA, 1993). An area of special interest was the south shore of Kauai. In particular, the resort area known as Poipu Beach suffered considerable damage. In addition, modes of building failure along Poipu Beach due to hydrodynamic loading and debris impact have been well documented (FEMA, 1993).

## Geologic Setting and Erosion Processes

Under 44 CFR §60.3(e)(4), NFIP building standards for new and substantially improved construction in coastal high hazard areas require that:

> the pile or column foundation and structure attached thereto is anchored [in the underlying substrate] to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base [100-year] flood. Wind loading values shall be those required by applicable State or local building standards.

To meet this NFIP performance standard for embedment of building foundations along the coast of Hawaii, two geotechnical factors are critical: 1) the thickness of unconsolidated sediments, and 2) a basic knowledge of hurricane-induced erosion processes.

In general terms, the surficial geology along Poipu Beach is characterized by a thin layer of unconsolidated sediments and weathered basalt overlying basaltic bedrock ("lava rock"). The thickness of the unconsolidated sediments is highly variable, ranging from less than 1 meter to 4 meters. The thickness of this layer is important because it governs the type and severity of erosion at a particular building site. Two contrasting examples demonstrate the range of potential erosion and the type and depth of foundations necessary to withstand undermining.

Type 1: Where the layer of unconsolidated sediment is relatively thin (i.e., less than 1 meter), it can be completely removed during hurricanes. The process is termed scarping or "bench retreat" and occurs progressively in a landward direction as the storm proceeds. Adjacent to the coast (i.e., in the first row of buildings), removal of unconsolidated material can be complete down to the bedrock. Thus, shallow building foundations penetrating through this layer and bearing on hard rock can be undermined and buildings completely destroyed during hurricanes.

Type 2: Where the layer of unconsolidated sediment is relatively thick (i.e., 1 to 4 meters), the layer is not completely removed, but the pre-storm grade can be significantly lowered. If the foundation base is above this scour zone, it will obviously be undermined and the building destroyed. If the foundation base is below this scour zone but not deep enough to provide bearing strength to withstand the simultaneous vertical and horizontal loading from both wind and water, the foundation will be compromised and the building will suffer considerable damage or be completely destroyed.

Numerous examples of the building failure modes described above were observed along Poipu Beach after Hurricane Iniki. Considering the number of undermined or compromised foundations observed, most buildings in this area were constructed without an understanding or consideration of storm-induced erosion forces.

## Design Guidance

The number of failures observed along Poipu Beach underscores the importance of having a sound understanding of not only pre-storm geotechnical conditions but also how this environment behaves under storm conditions. The geotechnical environment along the coast is a dynamic variable of great uncertainty, not a static parameter. The highly variable bedrock coastline of Hawaii presents design challenges even greater than those experienced along the more homogeneous sandy barrier islands of the Atlantic and Gulf coasts of the mainland United States, where NFIP coastal construction standards originated.

In Hawaii, the design professional must consider the following fundamental criteria for foundation embedment along the coast:

- Depth of the unconsolidated sediment lying above bedrock.
- The maximum potential zone of vertical erosion that may occur during a hurricane.
- The maximum potential zone of horizontal erosion relative to the distance of the building from the coast. This horizontal erosion must be considered over both the short term (the expected penetration of erosion during the next hurricane) and long term (shoreline recession due to the net effect of all storms over the physical life of the building). For the short term, the depth of vertical scour normally tapers in a landward direction.

In the case of Type 1, if the unconsolidated sediment is of insufficient thickness to support a building during severe wind and water loading conditions, the foundation must be keyed or drilled into the lava bedrock and grouted. Figure 1 shows one example of a bedrock-anchored foundation, although alternative designs have been suggested (FEMA, 1993). While anchoring into bedrock is a more expensive proposition, in this case it is the only design that can withstand storm-induced erosion and meet NFIP performance standards for coastal high hazard areas.

In the case of Type 2, if the unconsolidated sediments are of sufficient thickness that a foundation can be driven or excavated below the maximum vertical scour zone, then the embedment design shown in Figure 2 is applicable.

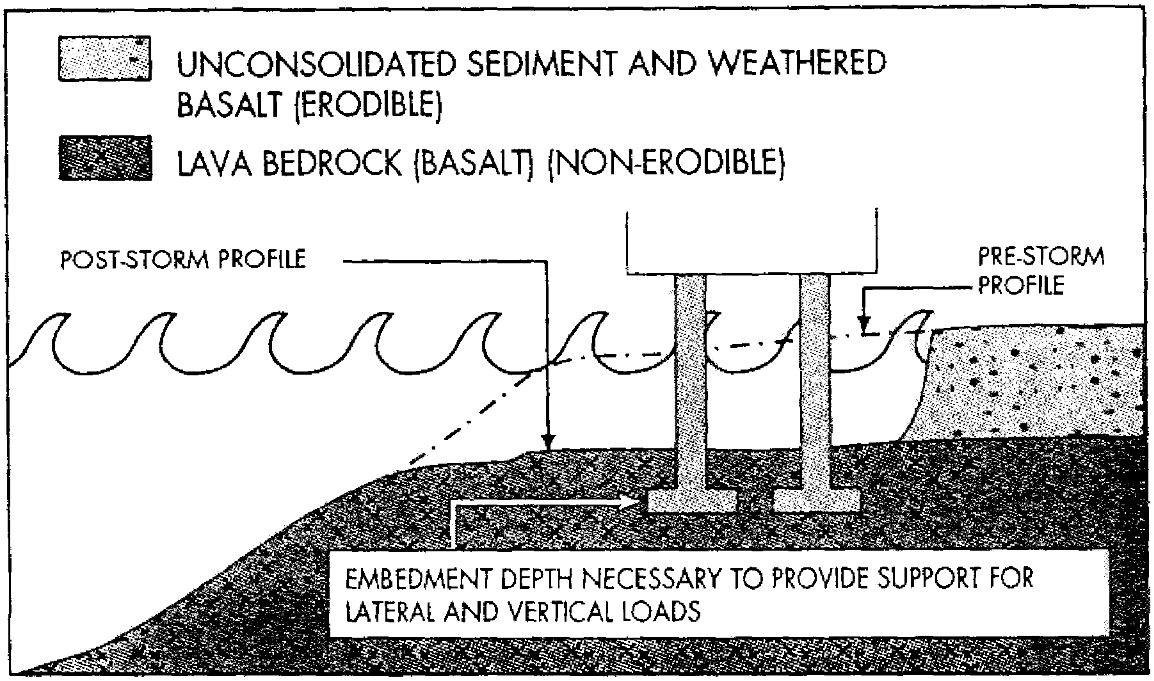


*Figure 1. Recommended foundation embedment, Type 1.*

This design should allow for supporting a building under simultaneous wind and water loading during a 100-year flood. The fundamental factor is an accurate estimate of the potential storm-induced vertical scour. Given that our current understanding of geomorphic processes is lacking and geologic conditions are highly variable at different sites, an accurate and confident measurement of storm-induced erosion is tenuous. Thus, a foundation embedment depth that is conservative or includes a safety factor is imperative.

## Conclusions

To construct a coastal building to withstand wave forces produced during hurricanes such as Iniki, three primary considerations must be met.

1) The building must be elevated to or above the predicted 100-year flood elevation on piles and columns so that waves can propagate unobstructed underneath the lowest floor without transferring the loads to the structure.

2) The building must be constructed with adequate connecting devices to provide a continuous load transfer path such that all wind and water loads are transferred to the foundation.

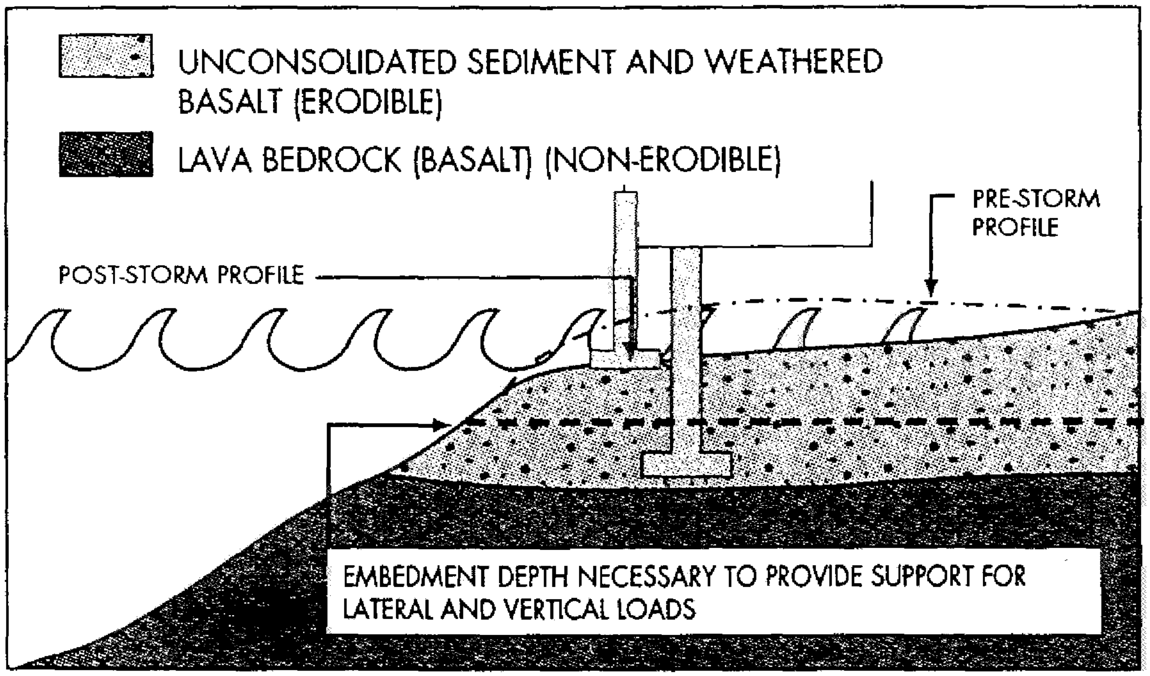


***Figure 2.** Recommended foundation embedment, Type 2.*

3) The foundation must be embedded deep enough so that it is not undermined due to the severe vertical and horizontal erosion processes that occur during hurricanes.

While considerable guidance is available concerning design for the first two criteria, a sound understanding of storm-induced erosion for the design of foundations is lacking.

## References

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