CHAPTER ONE HUNDRED FOUR

METHOD FOR ASSESSING STORM DAMAGE TO BEACH HOUSES

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ABSTRACT: Methods and procedures for the assignment of the pro rata share of damages caused by rising water and high winds arising from natural weather phenomena were virtually non-existent following Hurricane Frederic in 1979. Damages to beach front structures were often assumed to be caused by high water. Frederic marked the first natural weather disaster to strike a heavily populated area since the formation of the National Flood Insurance Program in 1970. The damages caused by the winds and rising water from Hurricane Frederic, therefore, created an economic incentive to attempt to distinguish between wind and rising water contributions. This paper presents a method and outlines procedures followed in damage assessments following Hurricane Frederic in an effort to minimize the difficulties insurance carriers and adjustors may have following future similar phenomena. It may, additionally, serve to promote improved design and/or building codes where such phenomena are probable.

INTRODUCTION

Houses located on ocean beaches usually incur considerable damage from storms of hurricane strength. This damage may be caused by wind forces, flood water forces, or a combination of these two forces. Insurance companies and adjustors, both wind and flood insurance carriers, sometimes have a difficult problem in assessing the cause of damage and, therefore, prorating costs to these beach houses.

Such difficulties were encountered by adjustors, insurance carriers, governmental agencies and others following the extensive property damage caused by Hurricane Frederic. Frederic, a force 3 hurricane, whose center passed through Mobile, Alabama on September 12, 1979, caused a reported $2 billion in property damage. Winds were clocked at 140 MPH at Dauphin Island at the entrance to Mobile Bay and rising water was estimated to have been 15 feet above MSL. Hurricane Frederic was the first natural disaster causing both wind and water damage since the birth of the National Flood Insurance Program in 1970. Consequently methodology and procedures to be followed in determining probable cause and in apportioning costs were virtually non-existent. The task of those concerned with the assessment of damages and costs was to develop usable and acceptable criteria and procedures.

This paper outlines a method and provides guidelines which may be used to assess the cause of damage to pile supported beach houses.

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RATIONALE

The rationale used was that careful observation and documentation of damages as evidenced by erosion of foundation soils, water marks, building orientation, elevations, wind surface area and other material factors would yield a logical and equitable basis for assigning dollar values to the respective causal wind and rising water forces.

PROCEDURE

In our approach, we observed and recorded data relative to the way in which wind and water loads affected the pile loads and/or capacities. The two forces, quite obviously directly increased the loads on the piles. Less obvious, however, was the diminished load-bearing capacity of the piles due to the erosion of foundation soils.

Our field observations were directed toward the determination and measurement of the following factors:

1. wind velocity and direction
2. still water depth
3. location of the structure relative to wave protection features such as sand dunes and other structures.
4. size of structure
5. orientation of structure
6. pre-storm elevation of structure
7. soil erosion around structure foundation
8. bracing system used (x-bracing or a concrete floor slab fixed to the piles at ground levels, etc.)
9. type of damage to the structure
10. condition of surrounding structures and the general type of damage sustained.

Using the field data as developed for each given case, we were able to hypothesize the magnitude of loads due to wind and water forces and the change in pile capacities due to erosion of foundation soils.

The rising water could affect the piles both through increased loads and through diminished bearing capacity due to erosion. Consequently the contribution of water toward structure damage was considered to be the sum of the absolute values of load and of pile capacity change. Wind contributed to the damage was assumed to be through increased loading only. The contribution of wind and water forces were totalled and each force then was expressed as a percentage of that total.

Damage proration to wind and water forces (and by extension to wind and flood insurance carriers) was made in accordance with those percentages.

WIND LOADING

Wind loads acting upon the beach houses during storms of hurricane produced a very high lateral force on the structure-especially the foundation piles that are usually used to support beach houses. The force from wind may be computed from the standard formula:

$f = V^2K$

where f = the unit force from the wind in psf
v = the velocity of the wind in mph
k = a constant usually taken as .003

A plot of unit wind load force vs. the wind velocity is shown by Figure 1. The unit wind force for a storm having a given wind velocity can be multiplied by the vertical projected area of the structure which the wind acts upon to estimate the total load acting on the structure.

FIGURE 1

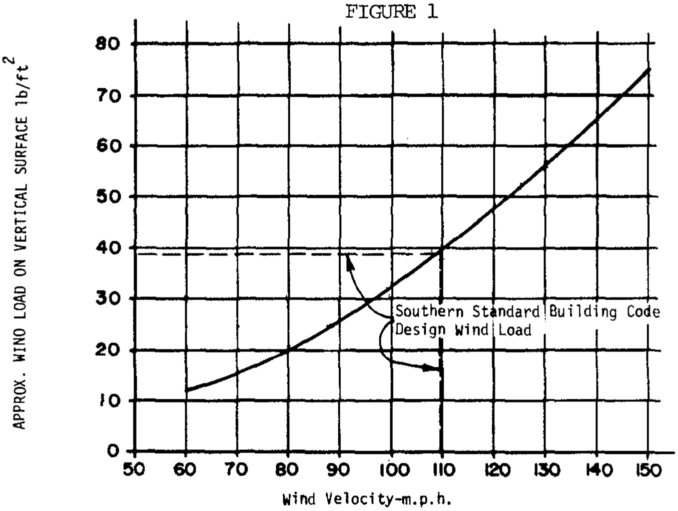
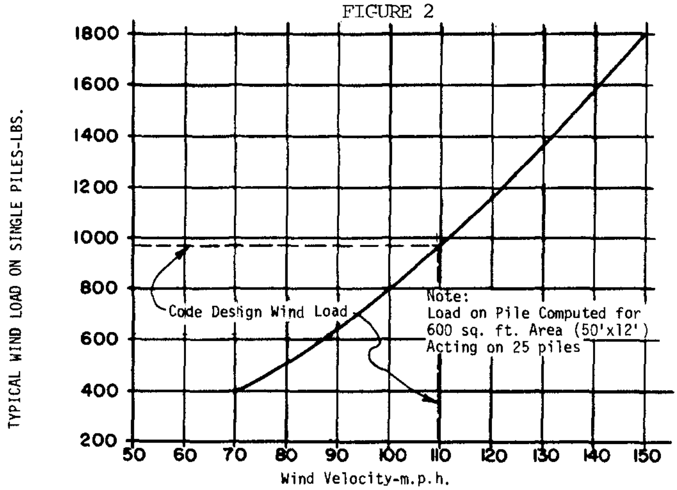


FIGURE 2



The formula to be used for this load determinations is:

$P = f\,A$

where P= Total load on structure

f= Unit Force from wind

A= Structure surface area perpendicular to the wind.

For a pile supported structure where all the piles are securely fixed to it, the total wind load will be distributed nearly evenly to each pile and this load is computed as:

$f_p = P/\text{No. of Piles}$ = horizontal force on top of pile

A plot showing the load on single piles (for a given size structure and number of piles) vs. the wind velocity is shown on Figure 2.

FIGURE 3

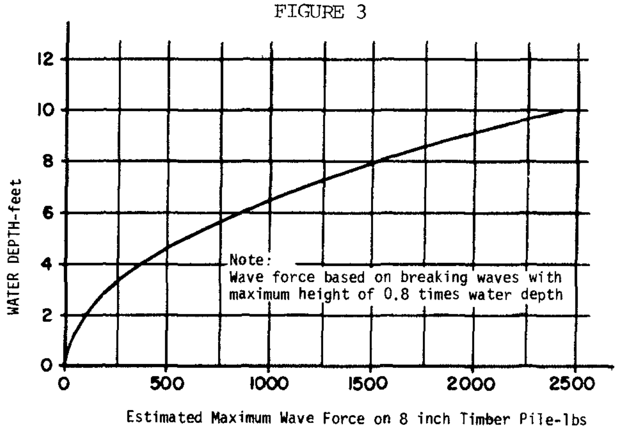
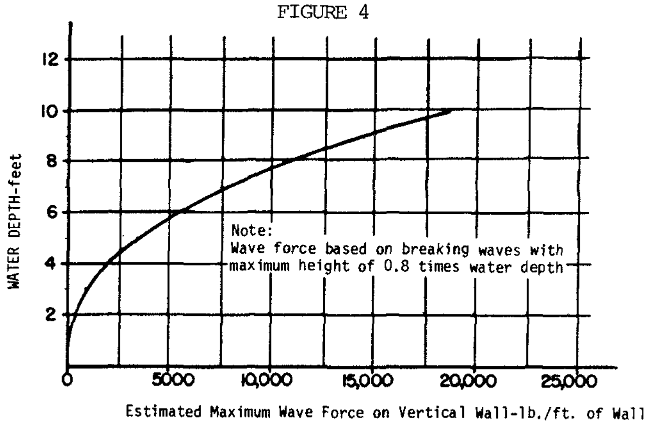


FIGURE 4



WAVE LOADING

Forces from waves acting upon structures are considerably more variable than are the wind loads during a storm of hurricane intensity. Many factors are to be considered for determining wave heights and thus forces from the storm. Some of the significant factors are:

1. Wind Velocity
2. Duration of wind
3. Distance wind travels over water (fetch)
4. Changing direction of wind
5. Water Depth
6. Sea bottom characteristics
7. Wave protection features-jetties, sand dunes etc.
8. Particular theory used for estimating wave heights and forces

For the evaluations made, generally a worst case condition was assumed where load forces for breaking waves were estimated to act on the structure. It was assumed in computations that the waves would have a maximum height of Ø.8 times the still water depth. Therefore, if the still water depth could be determined, an estimate of wave height and wave forces could be made. Using methods published in the U. S. Army Coastal Engineering Research Center Shore Protection Manual, estimates were made of maximum wave loads on typical 8 inch timber piles. This water depth load relationship is shown by Figure 3.

The load would act on the pile at about the still water depth. For other size piles the loads would be directly proportional to the pile width. It is our opinion that a breaking wave would only act on a few piles at a single instant when it breaks with the most number of piles being one row of piles that support the structure. A portion of this horizontal load would be transferred to the structure and distributed to the other piles - the amount depending on the location of load application at about the still water depth.

Estimates were also made of the maximum wave force that would act on a vertical solid stationary wall for various water depths. This relationship is shown on Figure 4.

It can be seen from Figure 4 that very high wave loads are placed on the vertical solid wall of a structure and this load may act on all or a portion of the wall at an instant. It is our opinion that most beach house structures located at elevations where waves break upon the vertical walls could not stand up to the very high forces. This is verified by the very heavy seawall structures or jetties that are often constructed where waves break against the wall.

EROSION OF SOILS AROUND PILES

During flooding of the coastal areas from the storm the water with wave and tidal actions usually move back and forth around the fixed structure. This water movement around fixed objects causes an increase in the water velocity and while this increased velocity does not exert a significant force on the structure, it does erode or scour the soil (usually sand along the beach) away from the foundation or pile. For footing foundations supporting the structure on the soil, erosion below the foundations will cause it to settle and thus the structure would settle and may collapse if the erosion if deep enough. For pile supported structures the erosion around the pile tends to decrease the load supporting ability of the piles- both axial load and lateral load capacity. Our surveys after Frederic indicated that a loos of axial pile capacity was not a significant cause of damage to beach houses. Table 1 shows typical axial pile capacities for a range of pile tip penetrations that may be evaluated if necessary to assess damage to a structure.

The lateral load capacity of piles may be significantly affected by the erosion of supporting soil from around the piles. Not only is the soil resistance on the pile decreased by the loss of soil but the moment or level arm at which the horizontal loads are applied to the soils are increased.

Estimates have been made of the lateral load capacity of typical 8 inch diameter piles having various embedment depths in typical sands we have found along the coast. These lateral load estimates based on one inch of deflection at the ground line are for two conditions. One is for piles having all the lateral load acting at the top of the piles such as a pile without any bracing and this capacity- embedment depth relationship is shown on Figure 5. The other condition analyzed is for a pile with the horizontal load acting on the pile at about eight ft from the top such as a well braced pile and this capacity relationship is shown on Figure 6.

It is noted that the braced pile should have two to three times the lateral load capacity of the unbraced piles regardless of the pile embedment depth.

FIGURE 5

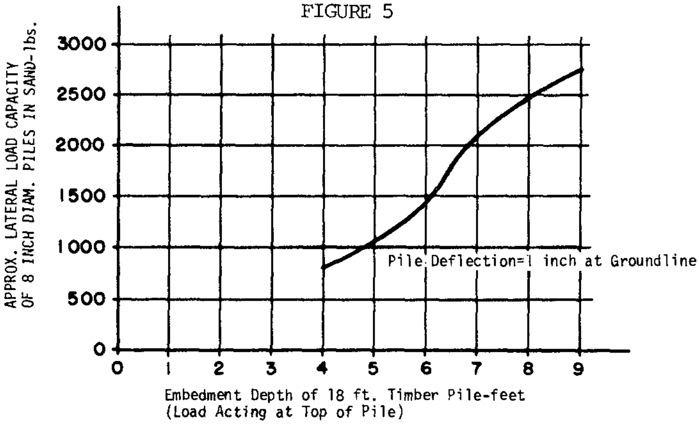


FIGURE 6

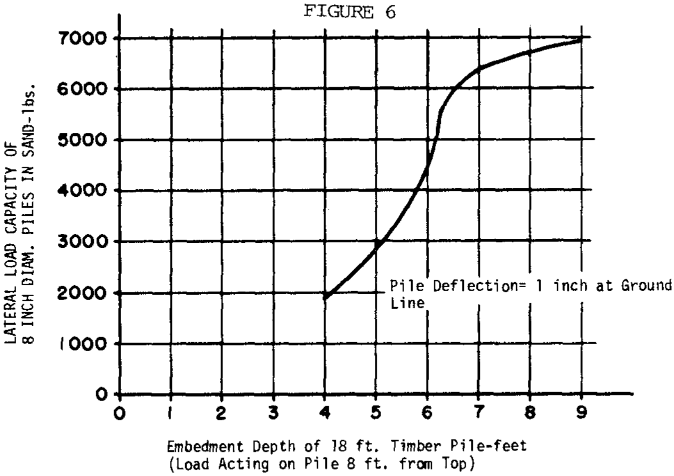


TABLE NO. 1

TABLE OF ESTIMATED ULTIMATE STATIC PILE CAPACITIES
FOR 8 INCH TIMBER PILES

BEACH HOUSE STRUCTURES
LOCATED IN COASTAL AREAS

APPROXIMATE GROUND ELEVATION: 0

SUBSURFACE SOIL PROPERTIES

LAYER NO.	LAYER TOP DEPTH	UNIT WT,PCF	FRICT ANG,DEG	CONST K	ADHESION PSF	POINT BRG FACTOR,NQ
1	0	60	33	1	0	30

ESTIMATED ULTIMATE CAPACITIES-TONS

TIP DEPTH	TIP ELEV.	SKIN FRICT.	POINT CAPACITY	SHORT-TERM CAPACITY	LONG-TERM CAPACITY	TENSION CAPACITY	POTENTIAL DRAG LOAD
2	-2	.1	.6	.7	.7	.1	0
4	-4	.3	1.3	1.6	1.6	.2	0
6	-6	.7	1.9	2.6	2.6	.5	0
8	-8	1.3	2.5	3.8	3.8	.9	0
10	-10	2	3.1	5.2	5.2	1.4	0
12	-12	2.9	3.8	6.7	6.7	2.1	0
14	-14	4	4.4	8.4	8.4	2.8	0
16	-16	5.2	5	10.2	10.2	3.7	0
18	-18	6.6	5.7	12.3	12.3	4.6	0
20	-20	8.2	6.3	14.4	14.4	5.7	0

EROSION + WAVELOAD SUM VS WIND LOAD

The method suggested to proportion this damage is to add the average wave load on a pile (estimate number of piles in one row that wave might act on in a given instant and multiply by the individual pile load for the given water depth and divide by the total number of piles supporting the structure to determine the average wave load on each pile) to that lateral load capacity which might be lost by the decrease in embedment depth from erosion for the given pile condition. This load change could be attributed to the water while the wind loading placed on each pile would be attributed to the wind. These loads would be used to obtain a causal percent.

CONCLUSION

The estimates of storm load forces that might be applied to a beach house structure during a hurricane may provide a basis for assessing the cause of damage for a particular structure. A survey of the structure after the storm, some basic design data for the structure, and factual data about the storm will be needed. Generally the data needed will be:

1. The wind velocity and direction.
2. The still water depth.
3. The location of the structure relative to wave protection features such as sand dunes and other structures.
4. The size of structure and its orientation.
5. The elevation of the structure before the storm.
6. The amount of soil erosion around the structure foundation.
7. The bracing system used for piles-(X bracing or a concrete floor slab fixed to the piles at ground level etc.)
8. The type of damage that the structure sustained.
9. The condition of surrounding structures and the general type of damage which they sustained.

Using these data and the utilization methods that we have discussed, one should be able to make good judgments as to the cause of the damage-whether it be water or wind.

This method for assessing storm damage to beach houses may be used by insurance companies or adjustors to make realistic judgements of the relative cause of damage to structures which are subjected to both high winds and rising waters during natural weather phenomena. The factors presented and their potential for causing damage to beach house structures may be used to improve the initial design or to strengthen existing structures where such weather conditions are probable.

EXAMPLES OF DAMAGE ASSESSMENT

1. For waves breaking against the main beach house structure the very high loads would probably demolish the structure-flood water would be the primary cause of damage.

2. For erosion below foundations of a structure, the beach

Photographs of structure torn from its foundation. Wave and wind loads probably caused the damage.

Photograph of "X" braced structure that has received very little damage at ground level. Erosion of soils was approximately three feet.

Photographs of structure that was originally enclosed at ground level. Wave forces obliterated the ground level enclosure and the water eroded approximately four feet of sands from below the concrete slab. The wind loads, wave loads, and sand erosion probably caused the horizontal deflection of the supporting piles.

Photograph of piles that supported a structure that are broken. Excess wind loading probably caused these piles to break.

Photograph of leaning piles that supported a structure. Excess wind loading and loss of soil resistance from erosion probably caused this failure of the foundation.

Photograph of structure that is essentially undamaged except for leaning piles and obliterated stairs. The leaning piles was probably caused by a combination of excess wind loading and loss of soil resistance due to erosion of about two feet of sands. The obliteration of the stairs was probably caused by wave forces.

Photograph of structure foundation that is essentially undamaged. The wind forces probably tore the structure from the foundation leaving the floor attached to the piles. Most of this damage was caused by the wind forces.

house would probably collapse-flood water would be the primary cause of damage.

3. For a beach house elevated or located where waves did not reach the main structure and the foundations remain undamaged or where piles may be broken but that portion in soil remains plumb and undamaged-wind would be the primary cause of damage.

4. For a beach house where soil erosion occurred and/or waves broke against the piles plus wind loading on the piles- add the loss of pile capacity from erosion for decrease in embedment depth to the wave loading and compare that sum to the total wind load per pile to proportion the cause of damage to wind and water.

5. For some beach house locations where little to no evidence or data remains about the structure to make judgments about the cause-we suggest splitting the cause 50-50 between wind and water.

6. In all cases, use common sense along with as much analytical judgment as possible to assess damages.