"Commonality Test Methodology for Residential Structures in Katrina Canal Breaches Class Action"

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Abstract

The question of commonality of damages was posed in a proposed class of members that was intended to represent the city of New Orleans as a whole. Were patterns of damage common such that they were identifiable by predictive means without individual site assessments? The authors were presented this question in the *Katrina Canal Breaches Consolidated Litigation Levee* with a putative class size of 36 members. Data collection efforts, which involved site specific testing, resulted in detailed class property information such as watermarks; levelness; plumbness; architectural and structural condition; and mechanical, electrical, plumbing (MEP) condition.

Hurricane forces of wind and water and degradation of materials affected structures differently; the extent of subsequent material degradation was related to characteristics unique to each structure (age, design, construction, materials, soil condition, and maintenance). Focusing on flood damages due to canal breaches, predictability was not found due to unknown variables of building height, characteristics, and length of time flood water was present.

The type and degree of damage varied considerably not only in the global putative class but also in the local subclasses, indicating a lack of meaningful subclass boundaries. Damages were not predictive by formula and therefore commonality was not present in the class. The only reliable method of damage assessment due to hurricane related distress is by individual site evaluation. Based on the scientific method, a test methodology is developed for assessing commonality of damages.

Introduction

On August 29, 2005, Hurricane Katrina made landfall between Grand Isle, Louisiana and the mouth of the Mississippi River. At about 8:00 a.m. CDT, Katrina was located 40 miles southeast of New Orleans, and at 10:00 a.m. CDT, Katrina made a second gulf coast landfall near the Mississippi-Louisiana border. The path of this hurricane traveled north to northeast across Louisiana and Mississippi and into Tennessee.

The storm surge associated with Katrina caused the level of Lake Pontchartrain to rise, and the majority of the City of New Orleans was underwater due to rainfall, levee overtopping, and levee breaches. The focus of this paper relates to the damages that occurred due in part to the aforementioned and the influence of wind and other elements during and after the storm event.

The factors that must be present for a class action lawsuit to be certified by the court are numerosity of plaintiffs, commonality of the damages and legal issues of the class, typicality of each class member's claim, adequacy of representation of the class, and viability of the defendant(s) to compensate for the damages (Fed. R. Civ. P. 23(a)). The main purpose of the authors was to establish data for evaluating the validity of the commonality of damages in the class action claim in the *Katrina Canal Breaches Consolidated Litigation*.

Forensic Testing Program

Using the putative class of 36 members (proposed class) located in the City of New Orleans, the cause, origin, and extent of damages from structural, MEP, and architectural standpoints were determined. Following the scientific method, a testing program was developed for the evaluation of the subject structures. Detailed data was collected from each structure using several test methods for the purpose of evaluating damages to the structure. Observed distress, hurricane related or otherwise, and existing conditions were documented and photographed. Data collection and compilation techniques included:

Descriptive Information: The authors developed field-measured floor plans and documented the following information through field observations or review of deposition testimony of proposed class members: structure type: i.e., single-family residential, multi-family residential, commercial, size, number of stories, foundation type, exterior veneer, interior finish, roof type, age, condition of surrounding properties, quality of workmanship, and quality of maintenance prior to/post Katrina.

Elevations: The elevation of each structure relative to the North American Vertical Datum of 1988 (NAVD 88) was determined by a surveying company using a global positioning device. (NAVD 88 is the vertical control datum of orthometric height established for vertical control surveying in the United States.)

Floor levelness: The authors evaluated the levelness of each structure's floor framing by completing a relative elevation survey using an electronic surveying instrument. **Figures 1 and 2** are examples of elevation data.

For comparison purposes within the scope of the forensic testing, the authors classified total floor out-of-levelness less than 3" as minor (**Figure 1**), greater than or equal to 3" and less than 5" as moderate, and greater than or equal to 5" as severe (**Figure 2**). The authors correlated relative elevation data with distress patterns and determined that the majority of damage was due to long-term differential foundation movement, and was not hurricane related.

Wall plumbness: The authors assessed the plumbness of the exterior or interior walls of the structures. The authors measured the angle of each surface relative to the vertical plane using an electronic plumbness measuring tool.

Using the maximum reading at each structure, for comparison purposes within the scope of the forensic testing, the authors categorized out-of-plumbness readings between 89.5° and 89.1° as minor, between 89.0° and 88.5° as moderate, and severe out-of-plumbness as 88.4° or less.

Based on the plumbness measurements, the authors detected no racking or twist resulting from hurricane winds. Rather, the findings are consistent with long term foundation movement as evidenced by the significant floor out-of-levelness and aged veneer distress.

Watermarks: The authors estimated the maximum flood level within the structures by measuring stains/watermarks left by standing water on interior and exterior finishes including glass window panes, gypsum board, exterior siding, etc. All watermark data were referenced to NAVD 88. The authors found good correlation between watermark data and IPET published data as illustrated in **Figure 3**. (In the Fall of 2005, the U.S. Army Corps of Engineers established the Interagency Performance Evaluation Taskforce (IPET) to provide scientific and engineering answers to questions about the performance of the New Orleans and Southeast Louisiana Hurricane Protection System during Hurricane Katrina. As part of its evaluation, IPET documented flood water elevations throughout New Orleans)

The authors estimated damage to interior finishes using water elevations above finished floor (AFF) based on the IPET high water elevations (IPET, 2006). For comparison purposes within the scope of the forensic testing, damages to interior finishes were categorized as minor for high water levels between 0'-0" and 1'-11" AFF, moderate for high water level between 2'-0" and 5'-11" AFF, and severe for high water level 6'-0" AFF and above.

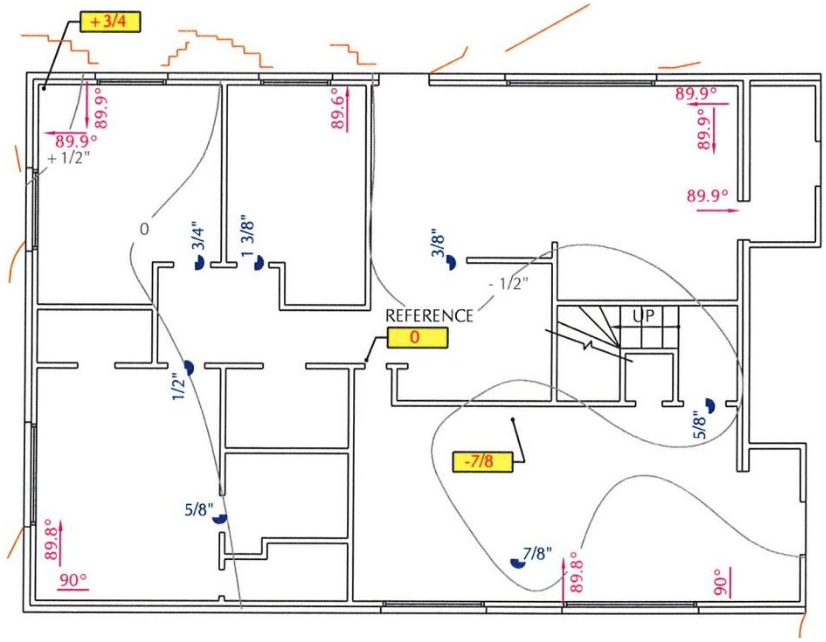

Figure 1: Minor floor total out-of-levelness

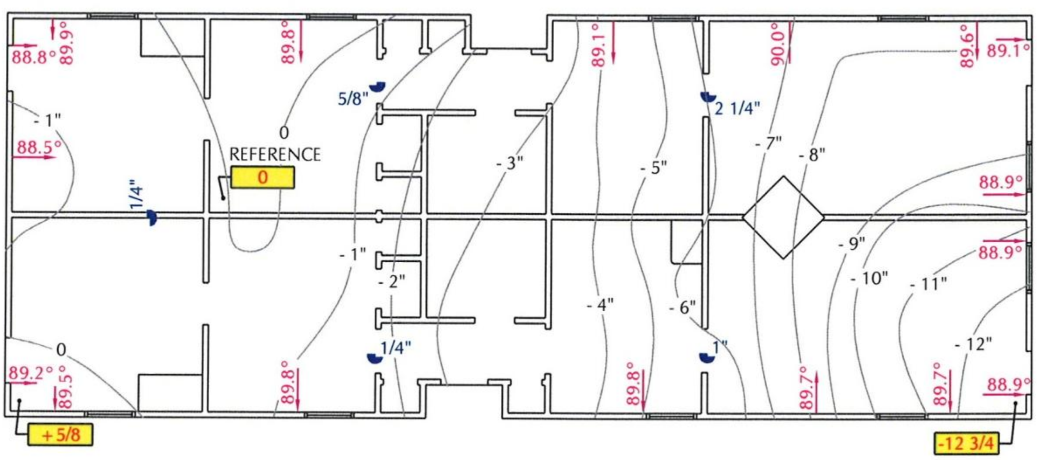

Figure 2: Severe floor total out-of-levelness

Figure 3: Watermark Data

Distress Mapping: The authors visually identified and mapped distress observed in each structure on a field-developed floor plan. The authors investigated crawl spaces, attics, and roofs as safety and accessibility allowed. For comparison purposes within the scope of the forensic testing, with the exception of window distress, distress was categorized as minor, moderate, or severe based on the percentage of the system impacted. The following types of distress were documented when observed in the subject structures:

- Termite damage: Structural members and veneers impacted by termites.
- Wood deterioration: Structural members and veneers.
- Tilted and/or damaged piers (the pier and beam foundations were typically constructed of brick or concrete masonry units (CMU)): Cracks and/or mortar joint separations and out-of-plumbness, generally due to long-term foundation movement.
- Window damage: Broken glass panes, broken frames/sashes, or missing or boarded-up windows, some likely related to post-storm vandalism.

- Veneer damage: Cracks and/or mortar joint separations on brick veneers, detached and/or missing siding, and cracks on stucco.
- Mechanical equipment damage: Corrosion at heating, ventilating, and air-conditioning (HVAC) equipment and plumbing fixtures and vandalism/theft of components.
- Electrical systems damage: Dislocated weatherheads, electrical service boxes, and electrical conduit; corrosion at receptacles, switches, junction boxes, and cabling; and some vandalism/theft of components.
- Scouring of soils: Loss of soil and exposure of foundation elements.
- Roof damage: Missing shingles, deteriorated and/or damaged roof shingles, rotted and/or exposed roof sheathing, missing, detached or broken ridge tiles, missing, detached or damaged flashing, and detached and/or punctured flat roofing membranes.
- Suspected mold/fungal growth at gypsum board walls and ceilings.

Table 1 is a compilation of damages observed by type.

Table 1: Observed Damages by Type

Damage Type	% of Bldgs w/ Damage	# of Buildings with Similar Damage (0 5 10 15 20 25 30 35)	Proximate Cause		
			Non-Hurricane	Wind	Flood
Termite	63%	(22)	X		
Wood Rot	77%	(27)	X		
Windows	54%	(19)	X	X	X
Electrical System	51%	(18)	X		X
Scouring of Soils	17%	(6)			X
Roof Damage	71%	(25)		X	
Exterior Veneer	100%	(35)	X	X	
Suspected Mold	20%	(7)			X
Mech. Equipment	57%	(20)	X		X
Tilted Piers	48%[1]	(11 out of 23 pier-and-beam foundations)	X		
Interior Finishes	91%	(32)			X
Floor Out-of-Level	69%	(24)	X		
Wall Out-of-Plumb	91%	(32)	X		

Legend: : Minor Damage : Moderate Damage : Severe Damage : N/A

1 : Calculation based on twenty-three (23) pier-and-beam foundations

Discussion

Hurricane-related damages can be classified by type and cause. Structural damages can be caused by hurricane-applied forces (wind and flowing water). Degradation of architectural building materials can be caused by exposure to wind driven rain, flood water, and wind.

Structural damage is a function of the magnitude of the forces (wind and flowing water) exerted on a structure and a structure's resistance to those forces, also commonly referred to as demand to capacity ratio. Structural damage (**D_s**) occurs via deformation or failure when the demand to capacity ratio exceeds 1.0. Increasing the applied forces or decreasing the structural resistance increases damages.

Wind damages buildings through velocity-generated pressures (positive and negative) and via debris impact. Flowing water damages structures through dynamic action of storm surge (waves, high velocity flow, scouring, flood-borne debris impact). Riverine (rising water) flooding typically has minimal or no velocity and generally does not lead to structural damage, except in the case of buoyancy.

A particular structure's resistance (**R**) to applied forces (**P**) is determined by its individual and unique characteristics, which include its property topography (its elevation relative to flood levels), age, building design, construction, type and quality of materials, underlying soil properties, pre-existing damage (including termites and wood rot), and maintenance thereof.

The relationship is as follows:

$$D_s \text{ (structural damages)} = f\begin{bmatrix} P \text{ (wind, water)} \\ R \text{ (topography, age, design, construction, materials,} \\ \text{soil, pre-existing damage, maintenance)} \end{bmatrix}$$

The authors found a wide range of variability in the subject structures' resistances, which resulted in a wide range of variability in damages observed. For example, the structures with pre-existing damage (pre-Hurricane Katrina) such as wood rot and/or termite damage were significantly weaker than structures that were not impacted. No two structures featured identical type, degree, and extent of structural damages.

Degradation of a structure's architectural finishes is a function of exposure to flood water, wind driven rain, and wind forces. A structure's finishes' resistance to water and wind is determined by its unique characteristics, including its property topography, age, height, design, and its material water resistive properties. For example, an increase in the flood water exposure height (**E**) or immersion time (**T**), or a decrease in the building material's water resistance increases the flood damage (**D_f**) to an individual structure. The relationship for material degradation damages is as follows:

$$D_f \text{ (finish degradation)} = f\begin{bmatrix} E \text{ (water exposure height)} \\ T \text{ (immersion time)} \\ R \text{ (topography, age, height, design, and material water resistance)} \end{bmatrix}$$

As the height of the flood water rises within a structure, more surface area of building materials and electrical and mechanical systems are exposed to water and the damage increases. The flood water height above the structure foundation was a distinct and variable parameter in the flooded structures in New Orleans. The water level varied due to four conditions: subclass basin, topography, type of foundation system and the structures' height, or generally, the number of stories. Flood damages varied from structure to structure and ranged from no flood damage to complete damage to finishes.

Comparative Case Study Examples

Case study comparison examples of several structures by structure type, damage type and cause of damage are presented in this section. The comparisons indicate that individual site assessments are required to evaluate the type and extent of damage, which vary as a function of the hurricane forces and the resistive characteristics of the building.

Example 1 – Variability of Structural Damage: This example illustrates different causes of structural damages at different structures. Structural damage varied at each structure and individual site assessments were necessary to ascertain structural damage and the cause thereof at a specific structure.

Tilted Piers | Termite Damage | Scour Damage

Figure 4: Structural Damage

At Structure #29, the authors observed several tilted piers, including what appeared to be remedial piers under the floor structure. As the piers tilted, the floor system deflected, causing the superstructure to move. This movement caused distress to architectural finishes as evidenced by plaster cracks and out of square door frames. The tilting of the piers was most likely caused by long-term movement of the subgrade. The maximum riverine type flood water level recorded by IPET was approximately 2'-1" *below* the finished floor elevation (placing the water level near grade), and unlikely to have caused the tilting of the piers.

Structure #12 featured significant pre-existing (non-hurricane) structural damage caused by termite and wood rot. The extent of the damage was such that large sections of framing members had disintegrated. For example, two ceiling joists had collapsed and several wall top plate sections were near failure. The extent of termite damage at this structure rendered the dwelling structurally compromised and unsafe for habitation.

Structure #6 featured damage in the form of scouring and/or undermining of the wooden piles and concrete grade beams. The IPET observed watermark at this structure was 5'-1" A.F.F. The observed scouring was attributed to flood and/or surge.

Example 2 – Structure #1 (slab-on-grade vs. pier and beam): This second example is a comparative case analysis illustrating different causes of distress based on foundation type. Structures with pier and beam foundations behave differently than structures with slab-on-grade foundations during hurricane and flooding events.

The piers in a pier and beam foundation system transfer the weight of the structure to the load bearing soils. The open pier and beam system allows for fairly unobstructed flow of water during floods (FEMA 2005), but a dangerous condition is created once the flood level reaches the finished floor. In pier and beam construction, the floor system typically consists of lightweight, buoyant wood framing. The combination of buoyancy uplift forces, and possibly wind forces, tends to overstress the piers and the pier to floor connections, potentially resulting in the displacement of piers and/or the entire structure.

In contrast, most of a slab-on-grade foundation lies below grade, so the structure will sustain architectural damage due to flood water at lesser flood elevations than a pier and beam structure. However, slab-on-grade foundations are constructed of concrete and are not as buoyant as lighter structures with pier and beam systems.

A satellite image obtained from Google Earth (Google Earth, 2005) (**Figure 6**) shows the condition of Structure #1, a slab-on-grade structure, and the adjacent structures post Hurricane Katrina (Spring 2006). The image shows that the structure located east of Structure #1 was detached from its foundation and displaced from its original plan position approximately 50' south and 8' east. In addition, the structure had been rotated around its original north-south axis by approximately 45 degrees counter-clockwise. Displacement of the structure and associated damage was the result of flood.

The impact of flood and storm surge was very different for the subject 40th Street structure and the adjacent structure on the east side. While the structure east of Structure #1 was detached from its foundation, displaced, and rotated well beyond its original as-built condition, Structure #1 remained at its original position without any significant displacement, tilting and/or rotation.

The different behavior of these structures during the storm is most likely the result of the structures' different foundation systems. Structure #1 has a slab-on-grade foundation while the adjacent east structure had a pier and beam foundation. Most likely, upward buoyancy (and possibly lateral water forces due to the proximity to the 17th street canal breach) contributed to the displacement and rotation of the structure east of Structure #1. In addition, improper, failed and/or missing hold-downs at the pier and beam foundation might have contributed to the detachment of the structure from its foundation.

Although the above comparison of substantially different structure responses to flood water forces was not evident at any of the other subject (proposed class) properties, this condition was not isolated and occurred at many other structures as evident by at least nine properties in a three-block area noted to be displaced and/or rotated in plan.

Figure 6: Structure #1 & Adjacent Properties

Example 3 – Structure #5 (two-story) vs. Structure #21 (one-story): The third example is a comparative case illustrating the observed variation and degree of distress between two structures based on the number of floors. On all of the two-story structures, the water level did not reach the second floor (**Figure 3**). Damage consistent with flood was not observed (on the second story of these structures.) Therefore, on a per-living-area basis for a given structure, two-story structures sustained less flood damage than one-story structures.

Conclusions

The study of the 36 class member structures illustrates the varying degrees of damage and uncommon effects related to the wind and water forces from Hurricane Katrina. The causes, types, and extent of damages to one particular structure were not indicative or predictive of causes, types, and extent of damages to another structure.

The cause and effect of damage at each structure depended on the applied hurricane forces and the structure's resistance thereto. Hurricane forces of wind and water and degradation of materials affected structures differently; the extent of subsequent material degradation was related to characteristics unique to each structure.

Based on this analysis, estimates of damages cannot be properly or fairly determined without individual site assessments. A mass assessment of damages without specific site evaluations would be inaccurate because it would not take into account the variability of the applied hurricane forces and the structure-specific resistance characteristics. In this study, each of these variables required site-specific evaluation.

In summary, the authors did not find commonality of type, degree, or extent of damages for the residential structures in the city of New Orleans. Damages were not predictive by formula and therefore, commonality was not present in the class. The cause, type, and degree of damage varied considerably not only in the global putative class, but also within the local subclasses, indicating that the proposed subclass boundaries presented no meaningful divisions.

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