LESSONS LEARNED FROM FAILURES DUE TO HURRICANES KATRINA AND RITA

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Abstract
Hurricanes Katrina and Rita, passing through in August and September of year 2006, caused devastating damage to the Gulf coast region in general and the City of New Orleans in particular. Hurricane Katrina passed through the eastern part of the city while hurricane Rita passed through the western part of the city within a two week period compounding the damage in New Orleans area. The notable failures include the levee system, residential building, erosion around bridge foundations and bridge deck failure.

Introduction
Much of the City of New Orleans sits below sea level and is surrounded by the Mississippi River to the southern part of the city, Lake Pontchartrain to the north, and the Lake Borgne to the east. The city, some parts being as much as about 10 feet below water surface, is defended by a complex flood protection system and these units are dewatered by pumps during storm events. The protection system has several components including levees and flood walls (I walls, and inverted T walls), floodgates and pump stations all of which are equally important for the defense of the city against flooding.

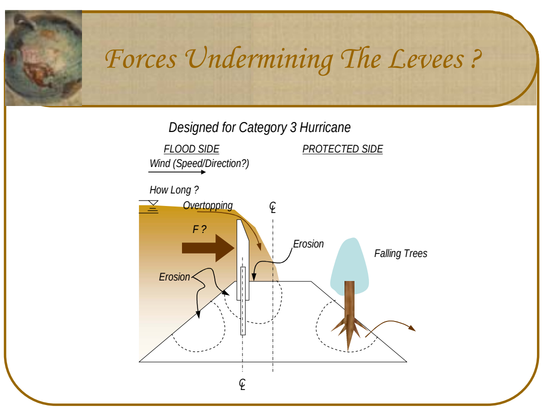

Figure 1. The Forces Undermining the Levee System

The total length of the levees in the New Orleans is 780 miles, which is equivalent to the driving distance from Houston to El Paso in Texas, drive across the State of Texas. Some of the major protected units of New Orleans flood protection system are Orleans East Bank, New Orleans East, and St. Bernard Parish. These units are designed to provide protection against category 3 hurricanes and constructed under the supervision of the U.S. Army Corps of Engineers. Local public agencies (e.g.: the New Orleans Levee Board, and the New Orleans Sewage and Water Board and the levee board) and private property owners (e.g.: Department of Transportation roadways and highways, railways, private shipping companies, etc.) are responsible for the maintenance of the system.

Hurricane Katrina crossed the Florida peninsula on August 25, 2005 as a Category 1 hurricane. It gathered energy and eventually made its landfall at east of New Orleans as Category 4 hurricane on Monday, August 29. It has become the most destructive and costliest natural disaster in the history of the United States so far. Its high winds and storm surges brought widespread destruction to the states of Louisiana, Mississippi, and Alabama. The official death toll stands at 1,302 and the damage from $70 to $130 billion in all three states [3]. Hurricane Rita affected Beaumont to Port Arthur in Texas and some parts of Louisiana.

Lessons Learned

(a) Levee Failures

Approximately 75% of the metropolitan areas of New Orleans got flooded due to failures in the flood protection system and consequent flooding. Most of the levee and floodwall failures were caused by overtopping, as the storm surge, as high as approximately 25 ft, rose over the tops of the levees and/or their floodwalls and produced erosion that subsequently led to failures and breaches.

In a levee system where many elements came together, the weakest portion controlled the overall performance of flood protection system. The reported failures in the levee systems occurred mainly at earthen levees and I-wall sections where a concrete capped sheet pile (Fig. 2) was used both as a structural element and seepage cutoff purpose. Also, considerable erosional distress, and a number of failures, was noted at transitions between different earthen levee and concrete structural segments.

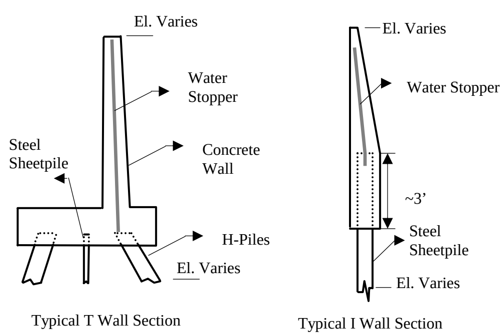

Figure 2. Typical Cross Sections of I-Wall And T-Wall

There are several on going studies on the performance of the New Orleans levee system during Hurricane Katrina and investigations for the reasons of failures by ASCE and NSF-sponsored levee assessment team(s) [1], USACE [2], and private investigators. The evidence suggest that a common mode of failure was the erosion of soils at the land side toes of floodwalls as water overtopped the concrete floodwalls atop the earthen levees where eroded levees reduced the lateral soil support at the protected side of the walls, and reduced the walls' ability to withstand the lateral forces produced by high waters on the flood side (Fig. 1). This was not a problem with T-walls as the concrete base of the inverted T-wall sections acted to deflect the overtopping waters and prevented erosion. T-walls also were constructed with more substantial supporting foundations.

Another issue noted at a number of both failed and distressed levee sites was an inconsistency in crest heights when multiple flood protection system elements came together. The inconsistencies in the crest heights caused overtopping flows to concentrate at vulnerable transition locations. Also failures were seen due to fallen trees on the protected side of the levees and relatively poor maintenance.

The 17th Street and London Avenue Canal floodwall failures caused some of the major damage to the residential areas in the city. The still storm water surge reached about 2 to 3 feet below the top of the floodwalls but no overtopping occurred. These failures were likely the result of stability failures within the embankment or foundation soils at or below the bases of the earthen levees. The failures in these locations might have resulted from a combination of severe under seepage at high water stages resulted in piping or internal erosion, possibly exacerbated by the uprooting of trees near the levee, and the presence of a weak stratum (peat) with low shear strength.

It was learned that T walls should be the preferred floodwall types due to their successful performance during the hurricane and transitions between earthen levees, sheet piles, and concrete wall sections should be robustly designed so that such transitions do not represent locations of potential weakness. Also, improvement of the levee system could be implemented with the addition of overtopping erosion protection at the protected sides of the floodwalls through the placement of rip-raps, concrete splash slabs, or paving of the ground surface effective in reducing erosion.

(b) Residential Building Failures

Residential buildings failed due to the high wind and flooding in the New Orelans area. The wind totally separated the houses from the foundations indicating the importance of anchoring to the slab foundations [4]. There were numerous cases where the houses were missing but the toilet seats were well anchored to the floor. Falling trees also damaged the foundations in some locations. In the Beaumont and Port Arthur areas falling trees and roof damage due to high winds were the common modes of failures during hurricane Rita

(c) Highway Failures

A bridge failed possibly due to poor anchoring of the decks to the cross beams. The design must be revised for improving the anchoring system. In number of locations soil erosion around bridge support systems were observed. Steps must be taken to prevent erosion around the support systems such as pile caps and slabs.

Conclusions

As an engineer and educator, the author is satisfied with how the engineered structures performed during the two hurricanes for which the levees were not even designed in the first place. Politics must not be mixed with reality and the risk and uncertainty involved with any engineered system must be clearly explained to the public. Regular maintenance and redesigning the levees and related system for hurricane category 3 with higher factor of safety to endure no failure at category 5 may be the way to address the problem in the New Orleans area. Similar approach must be taken to develop anchor systems for the residential structures. Steps should be taken to avoid planting large trees next to residential houses, especially in the regions where high winds are expected during an hurricane.

References

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