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The Galveston Seawall

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Abstract

Galveston, Texas is a coastal city in the Southeast United States, situated on the Gulf of Mexico. In 1900, a major hurricane struck the city, resulting in significant property damage and loss of life, destroying much of the city. Following this disaster, a seawall was constructed to minimize damage caused by future hurricanes. A seawall is a large reinforced concrete structure designed to absorb the impact of waves as they strike the shore. Expansions have increased the length of the seawall from its initial length of 3.3 miles to its current length of approximately 10 miles. The Galveston Seawall has repeatedly proved its worth in the century since it has been built. The city has experienced many severe hurricanes in that time and the presence of the seawall has reduced devastation significantly. The following paper examines the events leading to the construction of the seawall, subsequent hurricanes in which the seawall effectively protected Galveston, and improvements and extensions to the seawall.

1 Introduction – Galveston, Texas

1.1 City of Galveston

Galveston is a coastal city in Texas, situated between Galveston Bay to the northwest, and the Gulf of Mexico to the southeast. The city is on Galveston Island, a barrier island which is approximately 28 miles long, ranging from one-half to three miles wide. The city was founded in 1816, and the port was founded in 1825 by the Congress of Mexico, prior to the Texas Revolution.

Figure 1 – Map of Texas, Location of Galveston (Image source: www.texasmapstore.com)

Figure 2 – Satellite image of Galveston Island (Image Source: maps.google.ca)

1.2 Galveston, Pre-1900

Prior to the development of the city of Galveston, 12-15 foot high sand dunes protected the island from the effects of severe Atlantic hurricanes. These dunes were removed during development, leaving city vulnerable to storms. In 1900, the highest point in Galveston was less than nine feet above sea level.

In 1900, the city of Galveston had a population of approximately 38,000. At that time, the Port of Galveston was the third largest American port and the second most frequented point of entry for European immigrants entering the United States.

2 Hurricane of 1900

On September 8, 1900, a Category 3 (Saffir-Simpson Scale) hurricane struck Galveston, featuring estimated wind speeds of 120 miles per hour (mph) and a storm surge of 15 feet. This storm caused widespread destruction in Galveston. Estimates of losses of life vary, however it has been determined that at least 6,000 people died as a result of this storm, making it the deadliest natural disaster in American history. All of Galveston's municipal infrastructure was heavily damaged or destroyed in the storm. Bridges to Galveston Island were destroyed, leaving the island cut off from mainland Texas for 13 days following the storm. Approximately 3,600 homes were destroyed by the storm, half of the total houses in Galveston at the time. Property loss was estimated to be in excess of $30,000,000, or $500,000,000 when adjusted to 2007 dollars. Even after the city had been reconstructed, the Port of Galveston did not reach the status it held prior to 1900, and Houston became the leading port in Texas. Galveston transformed into a beach resort community, as opposed to its previous role as a commercial hub.

3 Response to Hurricane of 1900

3.1 Robert Commission

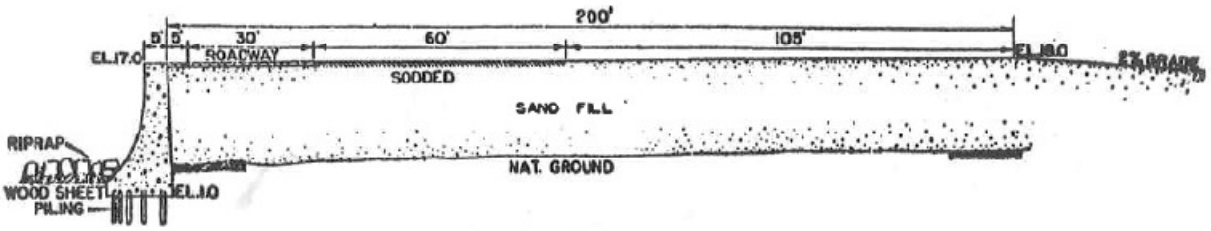
Following the Hurricane of 1900 and the devastation it brought to Galveston, the City of Galveston appointed a board of engineers, known as the Robert Commission, to ascertain the best way to protect the city from the effects of hurricanes and avoid a reoccurrence of the losses of life and property caused by the 1900 storm. The board consisted of three engineers: Brigadier General H. M. Robert, A. Noble, and H. C. Ripley. General Robert was retired from the U.S. Army Corps of Engineers and had been instrumental in the dredging of Galveston Harbor. Ripley was also a member of the Corps of Engineers, having designed one of the bridges linking Galveston Island to mainland Texas. Noble was from Chicago and had been involved with major coastal engineering projects in that city, such as grade raising. The board was issued three directives: protecting the city against storm surges, raising the grade of the city, and design of a breakwater or seawall. In 1902, the board submitted its report, recommending the construction of

a concrete seawall, an embankment behind the seawall, and raising the grade of the city using fill dredged from Galveston Bay.

3.2 Galveston Seawall

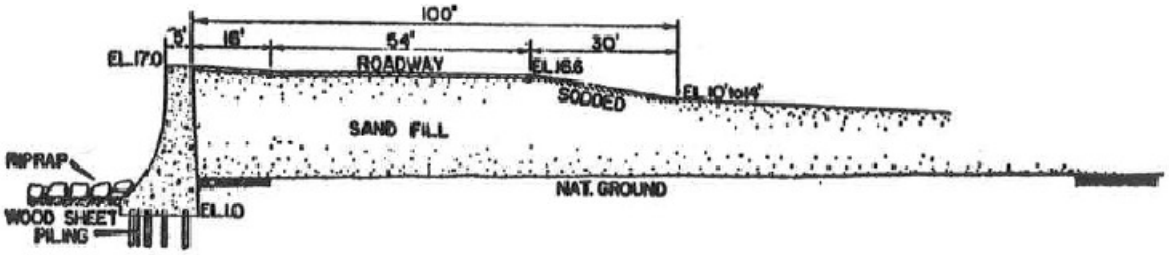
The seawall was designed to be three miles long, with the following dimensions: 16 feet wide on bottom, five feet wide on top, 17 feet high, and a curved face to direct waves upward. A 200 foot embankment behind the seawall with a 1:200 downward slope was recommended. The seawall was to be founded on wooden piles and protected by sheet piling and layer of riprap (27 feet wide, three feet thick).

Figure 3 – Initial Seawall Design



Construction of the seawall took place from 1902-1904. Construction was consistent with the initial design, with the sole exception being that the embankment was only 100 feet wide.

Figure 4 – Seawall as constructed



3.3 Galveston Grade Raising

Using approximately 16.3 million cubic yards of sandy fill dredged from Galveston Bay, the grade of the city was raised by approximately one foot per 1,500 feet from Galveston Bay to the Gulf of Mexico. The buildings in Galveston which had not been destroyed by the hurricane, including massive structures such as churches, mansions and commercial buildings, were lifted using jacks to enable fill to be placed underneath.

4 Notable Storms

Due to the presence of the seawall, Galveston is far better protected from the effects of pounding waves and storm surges experienced during Atlantic hurricanes. While not a comprehensive list of hurricanes which have struck Galveston, the following storms evidence the effectiveness of the seawall by causing considerable damage to nearby municipalities, compared to minor damage in Galveston. Many of these storms featured storm surges similar to the devastating Hurricane of 1900

4.1 Hurricane of 1909 (Storm 4)

In 1909, a Category 2 storm struck Galveston, featuring a ten foot storm surge. The town of Valesco, only 25 miles from Galveston, experienced major destruction. In its first test, the seawall protected Galveston from experiencing significant damage, although the embankment behind the seawall was scoured considerably. Following this storm, the embankment was extended to 200 feet behind the seawall, consistent with the initial recommendation made by the Robert Commission.

4.2 Hurricane of 1915 (Storm 2)

In 1915, Galveston experienced a Category 3 storm, bringing a 16 foot storm surge. While the seawall was damaged and the beach in front of the seawall eroded considerably, the seawall prevented further coastal erosion. Within the city of Galveston, only 11 lives were lost; however, on the unprotected western region of Galveston Island, losses of life were five to ten times higher.

4.3 Hurricane of 1932 (Storm 2)

In 1932, a Category 4 hurricane made landfall near Freeport, Texas, 25 miles southwest of Galveston. The section of Texas' Gulf Coast between Freeport and Galveston saw major destruction, with 40 lives lost. The city of Galveston, protected by the seawall, experienced only minimal damage.

4.4 Hurricane of 1945 (Storm 5)

In 1945, a Category 2 hurricane struck Galveston. Storm surges up to 15 feet were measured in Gulf Coast communities such as Port Lavaca. While much of Texas' Gulf Coast experienced major destruction, Galveston again received only minor damage.

4.5 Hurricane Carla (1961)

Hurricane Carla struck Galveston in 1961. By the time it reached Galveston, it had diminished to tropical storm status, although it first made landfall as a Category 4 storm 115 miles southwest of Galveston. Minor flooding was experienced in Galveston from the unprotected shore of Galveston Bay, and subsequent tornadoes caused damage to the city; however, there were no fatalities or destroyed homes in the area protected by the seawall.

4.6 Hurricane Alicia

Hurricane Alicia struck Galveston as a Category 3 hurricane in 1983. Galveston experienced a 12 foot storm surge on Galveston Bay, and eight feet on the Gulf Coast. Similar to the Hurricane of 1915, the western side of Galveston Island, unprotected by the seawall, experienced significantly greater damage than the area protected by the seawall.

4.7 Hurricane Jerry

In 1989, Hurricane Jerry made landfall at Galveston as a Category 1 hurricane. Storm surges of over seven feet were experienced; however, damage to the city was minimal.

4.8 Hurricane Ike

On September 13, 2008, Hurricane Ike made landfall at Galveston. Ike was one of the most devastating storms in the history of Texas, largely due to the sustained storm surge. While Galveston experienced considerable flooding and destruction, the elevated area near the seawall experienced the least damage. As seen in previous storms, nearby communities unprotected by the seawall or natural sand dunes were destroyed or heavily damaged, far more so than Galveston. Considerable beach erosion took place due to Hurricane Ike; however, areas protected by the seawall experienced considerably less erosion, as indicated in Figure 4.

Figure 4 – Coastal erosion due to Hurricane Ike (Image source: http://coastal.er.usgs.gov)

5 Seawall Extensions and Improvements

5.1 Fort Crockett Extension

During construction of the initial section of the Galveston Seawall, the United States Congress authorized the construction of an identical seawall to protect the nearby Fort Crockett Military Reservation. This section had length of 4,395 ft, and was constructed following the completion of the initial section of the Galveston Seawall. Construction took place from 1904-1905.

5.2 Aftermath of 1909 Storm – Grade Improvement

Following the 1909 hurricane and the ensuing damage to the embankment behind the seawall, the embankment was extended to a width of 200 feet as initially recommended in 1902.

5.3 1913 Proposed Extension

In 1913, an board of engineers, appointed by the United States Congress, recommended that an eastern extension be added to the seawall. The recommended length of this extension was 10,300

feet, to be funded by the federal government and local business interests. Despite the recommendation, the extension was not immediately built.

5.4 1915 Improvement

In 1915, following the hurricane of that year, General Robert recommended that pavement on top of the seawall be extended to a width of 200 feet and a reinforced concrete sheet pile bulkhead be installed to protect the embankment. The upward grade of the embankment was also improved.

5.5 1918 Extension

Due to damage caused by the 1915 hurricane, Congress authorized an eastward extension of the seawall in 1916, as per the recommendation of the board of engineers in 1913. Construction began in 1918; however, delays were caused by a hurricane in 1919 which damaged the partially constructed seawall. Completed in 1921, the extension extended to the Fort San Jacinto military installation with a length of 10,300 feet. This section used concrete sheet piling to protect against undermining.

5.6 1923 Extension

A further eastward extension was authorized by Congress in 1922 and constructed from 1923-1926. This extension extended across the Fort San Jacinto Reservation. This extension was 2,860 feet in length, and of the same design as the 1918 extension.

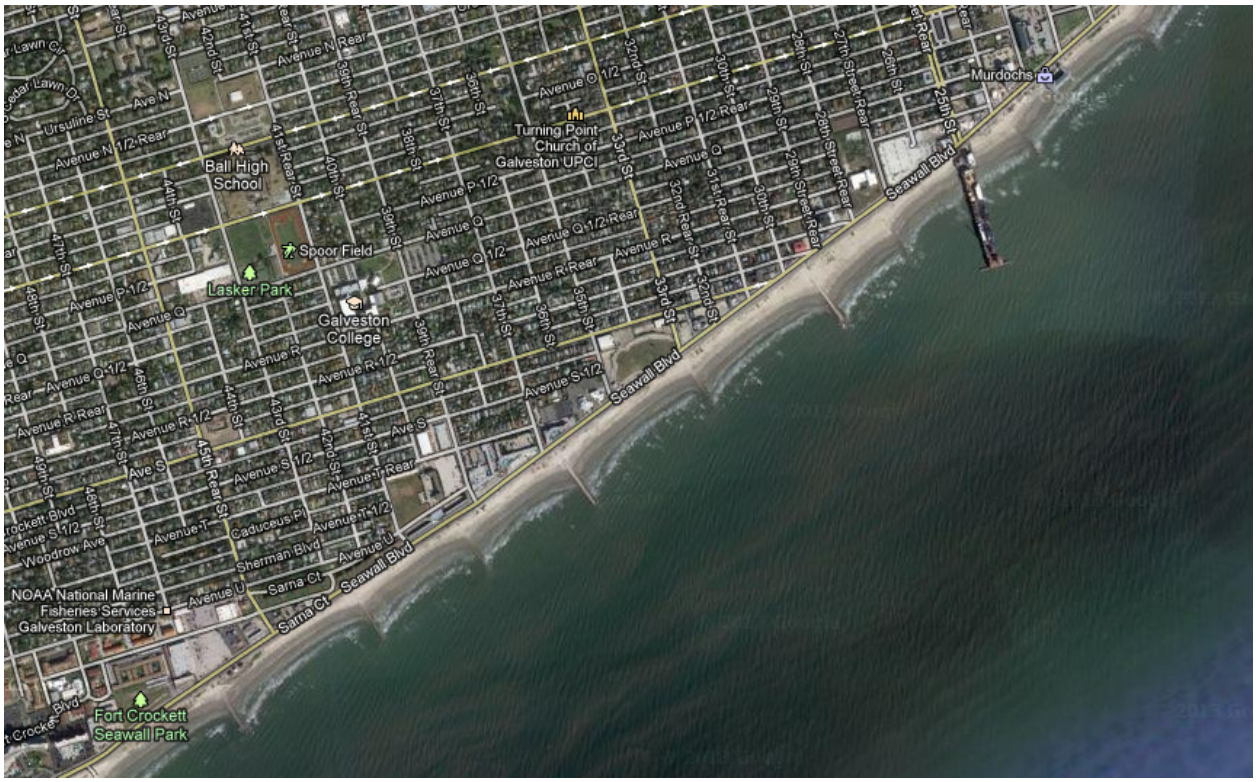
5.7 1926 Extension

A westward extension of 2,800 feet was constructed from 1926-1927 by Galveston County. This extension was of the same design as the original seawall.

5.8 Groin System

The Beach Erosion Board, Army Corps of Engineers determined that a system of groins would effectively protect the seawall from the effects of beach erosion, as well as providing a beach for recreation. Construction was authorized by Congress in 1936. 14 groins, each 500 feet long, were constructed at 1,500 foot intervals from 1936-1939. Steel sheet piles, timber piles, and support piles were used in construction. These groins protect the toe of seawall. The intended recreational beach not provided due to loss of beach materials during hurricanes. These groins were rehabilitated from 1968-1970 due to deterioration of the existing piles. The existing groins were replaced with rubble mound groins.

Figure 5 – Groins along the seawall (Image source: maps.google.ca)



5.9 1953 Extension

Another westward extension was authorized by Congress in 1950 due to expansion of the city of Galveston. This extension was initially planned to extend three miles, however the outbreak of the Korean War caused a delay, therefore only one mile was built in 1953 by Galveston County.

5.10 1958 Extension

This extension was a continuation of planned 1953 Extension. Two miles of seawall were constructed by the Army Corps of Engineers from 1958-1963, using a combination of federal and county funding. This extension brought the seawall to its present length of approximately 10 miles.

6.0 Conclusion

The Galveston Seawall has proven to effectively protect the city of Galveston against the effects of powerful Atlantic hurricanes which are common to the Gulf of Mexico. Extensions added to the seawall have furthered its ability to protect against storm surges associated with these hurricanes, as well as allowing the city to expand.

7.0 References

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