PREDICTING COASTAL ROADWAY DAMAGE USING MODIFIED DISPERSION FUNCTIONS

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ROADWAY DAMAGE PREDICTIVE FUNCTIONS

Empirical dispersion functions appear to reasonably predict damage risks for coastal roadways subjected to coastal storm surge and wave hazards. County Road 257 (CR 257) in Brazoria County, Texas had significant damage at various locations during Hurricane Ike in September 2008. Cumulative peak hourly water surface elevation, wave period, and current velocity output from a hindcast ADCIRC+SWAN model was assessed using modified celerity dispersion functions relative to measured distance between road and shoreline. These intensity measures provide a strongly correlated model for predicting likelihood of road damage.

COASTAL MODELING DATA

Coastal model includes Atlantic, Caribbean, and Gulf of Mexico basins and extends into back bays of Galveston and Chambers counties, as well as portions of Brazoria, Harris, and Jefferson counties (see Figure 1). Results for low and high resolution hindcast simulations were output in two different formats: maximum intensities and time series. Data sets included wind fields, currents, storm surge elevations, flooding depths, and wave characteristics. Storm surge water levels and waves were well predicted as verified with model-data comparisons. Model output data were extracted along CR 257 between Galveston and Surfside, Texas. Data were evaluated for multiple variables assessing significance and correlation.

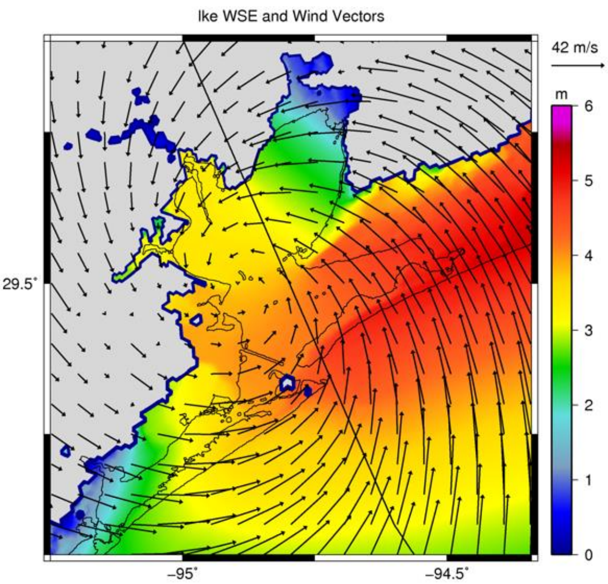

Figure 1 - Coastal Hindcast Model

CORRELATED RANDOM VARIABLES

Initial correlation analyses compared various intensity measure (IM) data from coastal model to other measured and modeled attributes of the storm event, road, and beach transects. Analyses focused on damage and no-damage points along CR 257 as confirmed by reviewing post-event field inspections and road damage repair drawings. Horizontal setback distance from road to shoreline is strongly correlated to damage potential. Significant damage potentially occurs with road alignments sited within 150 m of the shoreline.

MODIFIED CELERITY DISPERSION FUNCTIONS

Gravity wave celerity dispersion functions using cumulative water surface elevation and cumulative wave period hourly peak IM for overtopping flows are strongly correlated as shown in Figure 1. Linear wave theory applied to cumulative shallow water celerity functions for event duration show a strong coefficient of determination, but damage points are not separate from no-damage. Identifying strong correlation between cumulative celerity functions using peak IM variables is unique research.

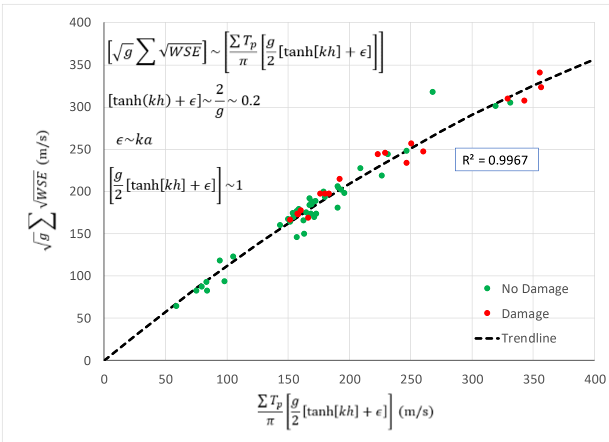

Figure 2 - Cumulative Celerity Dispersion Functions

Cumulative functions were recognized to vary based on approximate distance from CR 257 to shoreline measured at mean sea level from pre-event aerials. Figure 3 shows the revised distribution of modified celerity function as a gradient value relative to setback distance of the roadway.

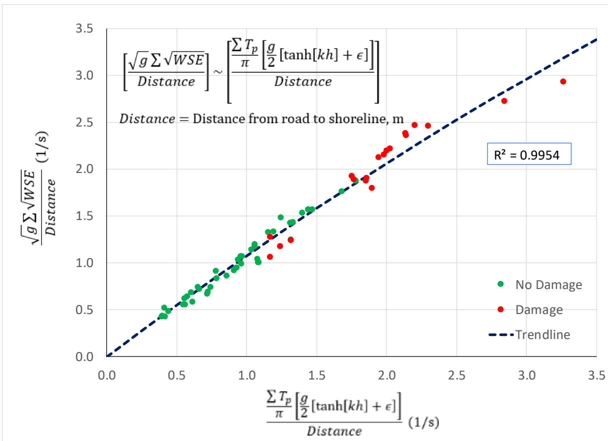

Figure 3 - Dispersion Function relative to Distance

Cumulative current velocity accounts for velocity head at overtopping flow. Cumulative velocity head inclusion in the modified celerity function is shown in Figure 4. Resultant value is reported as cumulative dispersion per meter of distance measured between road and shoreline.

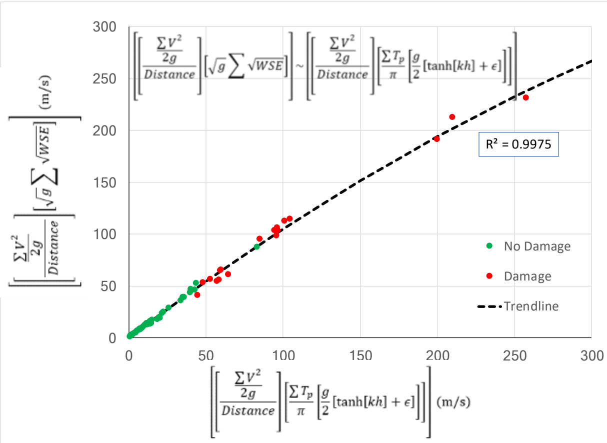

Figure 4 - Modified Celerity Dispersion Function

Cumulative rates for modified dispersion functions converge to approximately the same value over storm's duration as shown in Figure 4. Cumulative dispersion function progression for event duration assists with assessing likely damage failure mode. The critical threshold value for predicting likely damage along CR 257 suggests a cumulative dispersion value greater than 42 m s^{-1}. Threshold is determined by evaluating probability distribution function for damage and no-damage points as shown in Figure 5 with a (right) long-tailed distribution.

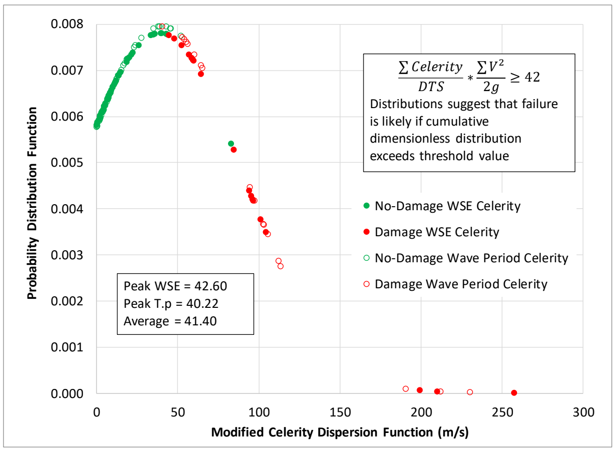

Figure 5 - PDF for Celerity Dispersion Function

Cumulative dispersion values were compared to current velocity flow vectors to assess whether damage likely occurred with initial storm surge overwash, or receding storm surge backflow into the Gulf of Mexico. Data show that critical cumulative damage values are realized soon after current velocity vectors reverse direction as storm surge recedes. This suggests that significant damage occurs with backflow over roads with saturated subsoils, effectively creating broad-crested weir scour conditions. Data also show that damage occurs at overtopping depths where critical wave breaking depths are reached. Since wave steepness changes with strong ebb currents, data suggest that significant forcings occur with plunging wave breakers likely damaging pavement surfacing.

Theories have been proposed regarding failure mechanisms required to satisfy dispersion functions that show strong correlation in predicting likelihood of failure. Research is progressing to assess these forcings in a wave flume to validate resultant pressures and forces on pavement slab and in verifying likely failure mechanisms. Research is also progressing to further develop and validate these highly correlated modified dispersion functions by evaluating similar events at different locations. Research intends to incorporate these functions as fragility curves into a spatiotemporal all-hazards model to be integrated in assessing risk and resiliency of coastal highway transportation systems.