COMPARING RESPONSE-BASED AND EVENT-BASED OVERTOPPING DESIGN

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INTRODUCTION

Coastal structure crest elevations are routinely designed to a specific hazard level. In the U.S., for example, levee crest elevations often correspond to the 1% annual exceedance probability (AEP) overtopping rate at 90% confidence level (CL). Statistical methods to compute coastal structure response range from simply inputting wave and water level forcing conditions at a certain AEP into a response equation (i.e. event-based or frequency-based approach) to a fully stochastic Monte Carlo numerical simulation where thousands of storm responses are sampled and epistemic uncertainties incorporated (i.e. response-based approach). Event-based approaches oversimplify both statistics and physics; however, time, cost, and complexity can limit application of the response-based simulation. Response-based stochastic simulation approaches tend to more realistically characterize structure responses. Herein we compare common frequency-based and response-based stochastic approaches for levee and floodwall overtopping design. For frequency-based approaches, structure responses are computed using wave and water level forcings at a given AEP, and for response-based approaches, a large number of storms are sampled in a Monte Carlo simulation.

EXAMPLE COMPARISON

As an example, coastal structure overtopping response was computed using multiple levee and floodwall geometries using the following stochastic approaches:

- EB2: frequency-based simulation with Monte Carlo sampling of epistemic uncertainty
- RB1: response-based simulation with Monte Carlo sampling of peak storm parameters and epistemic uncertainty
- RB3: response-based simulation with Monte Carlo sampling of full storm time-series and epistemic uncertainty

Structure elevations considered were 4.6, 6.1, and 7.6 m and, for each structure elevation, a levee with 1:3 seaside slope, levee with 1:6 seaside slope, and a floodwall were considered. Forcing condition results were selected at locations from the Sabine-to-Galveston (S2G) study (Melby et al. 2021), located in north-east Texas, US, with non-storm toe depths between -0.8 and 12.2 m. S2G considered only synthetic tropical cyclones within the Joint Probability Method with Optimal Sampling workflow (JPM-OS) that represent the practical forcing probability space for this region. Storm response parameter ranges at the 1% AEP are shown in Table 1.

Performance metrics were computed over the entire frequency range, as well as individually for low-, mid-, and high-frequency ranges. Correlation between parameters and errors were evaluated. Performance metrics computed for EB2 and RB1 were compared against the most accurate RB3.

	50% CL	90% CL
SWL (ft, NAVD88)	3.2 to 4.5	3.7 to 5.2
*Hm*0 (ft)	0.9 to 8.7	1.0 to 10.1
Tp (s)	3.4 to 13.8	3.7 to 17.8

Table 1 - Storm parameter ranges at 1% AEP

RESULTS

Figure 1 shows a comparison of overtopping rates.

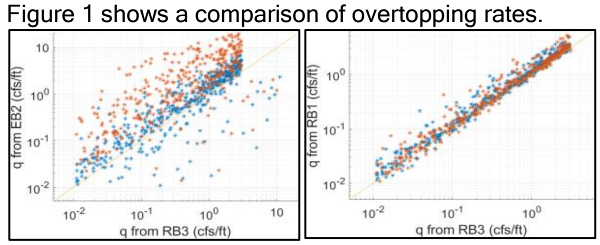

Figure 1 - Overtopping rate comparison. Blue dots are at the 50% CL and orange dots are at the 90% CL.

There is large scatter in EB2 and the results at the 90% CL are biased high. This suggests that EB2 generally over-predicts, but may also under predict overtopping rate responses. No correlation was found between errors and storm and structure parameters. Performance metrics showed that RB1 is most accurate in mid-frequency range of responses, where US structures are typically designed. EB2 method performed poorly in all frequency ranges and confidence levels. RB1 and EB2 require similar computational times; however, RB3 is relatively computationally expensive. Overall, RB1 is more accurate than EB2 because the frequency of the response is not assumed to equal the frequency of the forcing parameters.

Design crest elevations were compared using the three methods for an existing system. The overtopping limit states were at the 1% AEP as: 0.01 cfs/ft at 50% CL for levees, 0.03 cfs/ft at 50% CL for floodwalls, and 0.1 cfs/ft at 90% for levees and floodwalls. Crest elevations were incrementally increased until limit states were satisfied. EB2 yielded a weighted average crest elevation high bias throughout the system of 0.5 m and maximum difference of 1.5 m. RB1 was unbiased but generally within 0.15 m.

Melby, Massey, Stehno, Nadal-Caraballo, Misra, Gonzalez. (2021): Sabine Pass to Galveston Bay, TX Pre-Construction, Engineering and Design (PED): Hurricane Coastal Storm Surge and Wave Hazard Assessment - Report 1, Background and Approach, ERDC/CHL TR-21-15, Vicksburg, MS: U.S. Army Engineer Research and Development Center. https://hdl.handle.net/11681/41820.

Stehno (2021): Coastal Structure Overtopping and Overflow Stochastic Simulation Method Comparison. Mississippi College, M. of Sci.