Assessment of HY-8 and HEC-RAS Bridge Models for Large-Span Water-Encapsulating Structures

Introduction

Current INDOT policy requires that culvert-like structures with spans greater than 20 feet be treated for purposes of hydraulic analysis as a bridge, and hence mandates the use of software such as HEC-RAS for predicting the headwater, rather than the culvert-specific software, HY-8. In this context, culvert-like structures are assumed to have a standard inlet geometry (e.g., such as those already modeled in HY-8) and a constant barrel geometry. As larger-span culverts with spans greater than 20 feet have become more readily available, they may provide a cost-effective alternative to traditional bridges, and the technical basis of the current INDOT policy needs to be re-examined, and more flexibility in allowing conventional culvert hydraulic analysis to be applied to structures with spans larger than 20 feet may be warranted.

The main aim of the present study was a comparative assessment of conventional culvert hydraulics, specifically as implemented in HY-8, and bridge-hydraulics modeling, as implemented in the HEC-RAS bridge models, in applications where the water-encapsulating structure has a large span relative to its streamwise length. Laboratory experiments were performed with model box culverts of span 1.5 feet and two streamwise lengths, 2.1 feet and 8 feet, and performance curves describing the variation of headwater with discharge were obtained. The effects of bed roughness, the presence or absence of a cover (if present, the rise was 0.5 feet), and a range of tailwater levels were investigated. The laboratory observations were compared with predictions by HY-8 and HEC-RAS models, and the model performance was assessed.

Findings

In general, HY-8 predictions were found to be as good as, and in some cases superior to, the HEC-RAS predictions, for both long and short structures. Example performance-curve results for the case of wholly free-surface flow over a roughened bed (Manning’s $n \approx 0.018$ in the experiment) are given in the figure below. The left and the bottom axes reflect...
actually observed values, while the right and the top axes are those of a scaled prototype corresponding to a scale ratio of 1 in 16 (which would result in a scaled span of 24 ft). The figure on the left (a)) shows results for the longer structure under a single downstream (gate) condition, while the figure on the right (b)) shows results for the shorter structure for two downstream (gate) conditions. For the set downstream gate conditions, the headwater is largely unaffected by the tailwater at low flows, but tailwater effects become significant at high discharges. The predictions of the HY-8 model are seen to be better for the longer structure, and still quite competitive for the shorter structure, compared with the those of the HEC-RAS bridge model (using default or recommended settings and coefficients). Also the HY-8 predictions were more conservative in predicting higher headwater values than the HEC-RAS bridge predictions, which exhibited a pronounced tendency to underestimate the headwater.

The generally good performance of the HY-8 model was attributed to the empirical information in HY-8 being more tailored to the specific standardized geometry of culvert-like structures, and the automatic inclusion of roughness effects, whereas HEC-RAS, at least when used with default coefficients and settings, relied on generic coefficients and under certain conditions neglected roughness effects. Discrepancies between HY-8 predictions and observations (for both longer and shorter structures) are not necessarily due solely to inadequacies of culvert modeling as such, but are in part rather due to the specific HY-8 modeling choices, such as the polynomial approximation for the inlet control (I.C.) model, and to the strategy of choosing the higher of the inlet-control and the outlet-control estimates, which does however lead to the already noted more conservative HY-8 predictions.

Despite the good performance of the HY-8 model in predicting the study cases, its limitations should be recognized. It is restricted to culvert-like structures with standard inlet and constant barrel geometries, and making good predictions requires accurate input data. HY-8 models a structure in isolation, and if other nearby structures or stream features affect markedly the water surface elevations, which may become more likely for larger streams for which larger-span culverts come under consideration, then accurate specification of tailwater may become problematic. The more comprehensive HEC-RAS is capable of modeling a more complex stream system, in which the culvert being examined is only one model element among several, adding to the robustness of predictions. Note that in such a case, the culvert-like structure might still be modeled as a culvert, so that the important distinction is not necessarily between culvert and bridge models, but between modeling a structure in isolation or modeling it as part of a system. Similarly, there may be other issues such as those stemming from debris or stream instability, which might arise more frequently for larger streams, for which neither HY-8 nor HEC-RAS bridge models has distinct advantages, but which may receive greater attention within a bridge-hydraulic design context than in the traditional culvert-hydraulic design context. Thus, a preference for HEC-RAS modeling for larger-span larger-stream situations may be based on concerns that are not narrowly hydraulic in nature, but this should be more explicitly acknowledged rather than, as is often done, making dubious claims regarding the limitations of culvert hydraulics.

Based on the results of the study, it was concluded that the culvert-hydraulic analysis of large-span (>20 feet) culvert-like structures can be technically justified where the structure could be considered in isolation and accurate input and other empirical data, such as inlet control coefficients, are available and appropriate. It was therefore recommended that INDOT hydraulic design policy adopt a more flexible stance, allowing large-span culvert-like structures to be analyzed using conventional culvert hydraulic models, such as HY-8. No limit on span was determined in the study, but it was suggested that prudence dictate an initial phase during which the largest span permitted to be analyzed by HY-8 be limited to, for example, 36 feet. If practical experience in this initial phase did not reveal any serious unintended shortcomings, then the permissible largest span could be increased further if this was deemed desirable.

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