US Army Corps of Engineers

ENGINEERING AND CONSTRUCTION BULLETIN

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SUBJECT: Design of Fiber Reinforced Polymer Hydraulic Composite Structures

CATEGORY: Policy and Guidance

1. **References:**

a. ER 1165-2-217 Civil Works Review Policy
https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/ER 1165-2-217s.pdf

b. ER1110-2-1156 Safety of Dams – Policy and Procedures
https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/ER_1110-2-1156.pdf?ver=2020-01-29-103920-173

c. ER 1110-2-8159, Life Cycle Design and Performance
https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-8159.pdf

d. ER 1110-2-8157, Responsibility for Hydraulic Steel Structures
https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-8157.pdf

e. ER 1110-1-8168 Roles and Responsibilities of the Inland Navigation Design Center Mandatory Center of Expertise https://www.publications.usace.army.mil/Portals/76/Users/182/86/2486/ER_1110-1-8168.pdf

f. ER 1110-2-1150 Engineering and Design for Civil Works Projects
https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1150.pdf

g. UFGS 35 20 15, FRP Composites for Low-Head Water Control Structures
https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-35-20-15

2. **Purpose.**

This Engineering and Construction Bulletin (ECB) establishes interim policy and guidance for the design of fiber reinforced polymer hydraulic composite structures (HCS). The purpose of this ECB is to ensure quality, consistency, and standardization while USACE personnel gain knowledge and experience with HCS and more explicit guidance is developed.

3. **Applicability.**

This ECB applies to HQUSACE elements, major subordinate commands, districts, centers, laboratories, and field operating activities. It applies to the design and construction of new or replacement structures that control or regulate water, that would traditionally be defined as Hydraulic Steel Structures (HSS), in accordance with ER 1110-2-8157, regardless of business line funding source. In ER 1110-2-8157, typical examples of HSS are lock gates, roller gates, tainter gates, dam spillway gates, tainter valves, bulkheads and stop logs, and vertical lift gates. Exempted structures are those already permitted in guidance or specification such as low-head water control structures (see head, size, and use restrictions in UFGS 35 20 15) and those that have an unacceptable life safety risk. In accordance with ER1110-2-1156, dam safety issues that result in unacceptable life safety risks must be referred to the Dam Safety program.

4. **Background.**

There are over 10,000 hydraulic steel structures operated and maintained by USACE and 70% of them have exceeded their design life. Due to the current and foreseeable surge in infrastructure funding and requirements, capabilities for hydraulic steel structure fabrication are stretched. With steel cost growth based on recent price escalation and supply challenges, the timelines, and costs to replace these critical structures are growing. In addition, many of these steel structures operate in corrosive/saltwater environments requiring expensive and time-consuming periodic maintenance efforts over the life cycle of these structures.

Fiber-Reinforced Polymers (FRP) materials offer a potential low-maintenance solution for the future. Initial estimates show similar initial costs to steel but significantly reduced life-cycle cost savings (100-year life). In addition, the fabrication timeframes appear to be shorter than steel and with increased demand, the expectation is that the FRP industry will continue to expand.

In many cases, FRP is stronger than steel (per weight basis) and may provide a higher design factor of safety. HCS structural designs are usually governed by deflection limitations instead of strength limitations due to the modulus of elasticity of the glass fiber being about 5 times less than steel. Thus, design parameters are defined related to deflection, stiffness, weight, and buoyancy. Converting a structure from steel to composites will require a complete redesign effort, rather than simply refabricating from as-built drawings. Also, due to highly customizable fiber architectures and manufacturing processes, and lack of industry design standards for large custom fabrications, it is typical to use a performance-based contract to delegate detailed design to manufacturer's representative engineer (similar to A-E design of HSS). Any design and procurement method must meet the requirements of ER 1165-2-217 Civil Works Review Policy. Currently, USACE lacks comprehensive guidance, or criteria for the design of large composite structures intended for immersed service. USACE will need to rely on the in-house and industry expertise available as outlined in the Policy section below to ensure quality, incorporation of lessons learned, and standardization.

5. **Policy.**

For all Civil Works projects, when a new or replacement hydraulic structure (traditional HSS) is being planned, a design charrette lead by INDC and appropriate CX/RMO will develop a 100-year life cycle cost analysis comparing steel to composite. The level of effort, as well as cost, for the design charrette

depends on the scope, complexity, and risks of the project and/or structure. For non-navigation projects, INDC will lead the HCS portion of the design charrette. The design charrette will be completed prior to the start of the design phase. The scope of the design charrette and the recommendation will be sensitive to cost, complexity, and risk and comply with ER 1110-2-8159. The decision to recommend FRP for life-safety applications on dam and levee projects should be based on the ability to achieve the desired structural performance with respect to flood and seismic hazards, ability to construct (including maintaining quality control during construction), ability to operate, inspect and maintain, and cost effectiveness. The design charrette report will be recommended by the district engineering functional chief, endorsed by the INDC and appropriate CX/RMO, and approved by the MSC. When a District recommends a steel or other metal structure, and INDC and appropriate CX/RMO does not concur, the MSC will coordinate with HQ CECW-CO and CECW-EC for approval.

In accordance ER 1110-2-1150, for first-of-a-kind navigation HCS, the Inland Navigation Design Center (INDC) will be the designer of record and technical lead to ensure enterprise commonality and development of an enterprise navigation standard design. First-of-a-kind navigation HCS will be defined as "Category 1" work per ER 1110-1-8168. Where an enterprise design exists, the project will be defined as "Category 2" work per ER 1110-1-8168. The District will be the Designer of Record and technical lead for the project delivery team (PDT) and the INDC will approve the technical lead and key engineering staff. If the District prefers, it can choose to have the INDC lead and be the designer of record for the project. In this case, the District and INDC will work to staff the project with district staff and other resources. INDC will be the review management organization (RMO) for HCS projects. In addition, INDC will provide HCS knowledge & expertise for non-navigation projects to the RMO assigned in ER 1165-2-217.

In general, the requirements of ER 1110-2-8157 and EM 1110-2-2107 will apply to the life cycle responsibilities (from planning, design, construction, operation, and maintenance) of HCS. For policy clarifications and interpretations, PDTs will coordinate with INDC and HQ-EC.

A list of enterprise navigation standard designs will be developed and maintained by the INDC. The INDC will determine if a structure is an application of an enterprise navigation standard or a first-of-a-kind design. A design repository will be created by INDC for the enterprise designs, past design charrette reports, best practices, lessons learned, submittal requirements, and a list of excluded components and structure types.

To develop and increase USACE expertise and knowledge of FRP, INDC will lead enterprise training efforts to include design, maintenance, inspection, testing, and repair. More information on training opportunities is available at: https://usace.dps.mil/sites/KMP-IND/SitePages/Composites-Work-Group.aspx.

6. Resources.

These resources which provide additional design and material specification are available at: https://usace.dps.mil/sites/KMP-IND/SitePages/Composites-Work-Group.aspx.

a. Specification Template for VARTM Custom Hydraulic FRP Structures (SAJ Lift Gate Specification)

b. ASCE 74-23 Load & Resistance Factor Design (LRFD) for Pultruded Fiber Reinforced Polymer (FRP) Structures

c. ANSI Code of Standard Practice Industry Guidelines for Fabrication and Installation of Pultruded FRP Structures

d. PIANC InCom WG Report No. 191 – Composites for Hydraulic Structures

e. CROW-CUR Recommendation 96:2019 "Fiber-reinforced polymers in load-bearing structures in buildings and civil engineering works" (Dutch Guidance w/ English Translation)

f. ASCE Design Guide for FRP Composite Connections (Manuals and Reports on Engineering Practice No. 102)

g. Composite Wicket Gates, Illinois River Basin, Peoria and LaGrange Dams, Design Documentation Report.

h. UFC 3-301-01, Structural Engineering, Appendix F

i. Rescinded ETL 1110-2-548 (1997), Composites Materials for Civil Engineering Structures. The rescinded ETL provides a comprehensive introduction to composites. It is planned that this document will be updated to reflect current standards and performance expectations.

Resources under development include:

a. Guidance and procedures for HCS design, inspection, evaluation, and repair. This will augment existing industry guidance. This resource will require additional research and development. Therefore, we anticipate an expanded timeframe to publication.

b. A-E services IDIQ contract administered by INDC to allow districts to access additional resources for design, review, fabrication QA and inspection.

7. **Point of Contact.**

HQUSACE technical point of contact for this ECB is Ms. Vanessa Bateman, CECW-EC, (202) 761-7423 or Vanessa.C.Bateman@usace.army.mil and the INDC point of contact is Eric Johnson, CEMVR-DC, 309-229-6049 or Eric.O.Johnson@usace.army.mil. The HQUSACE Operations point of contact for this ECB is Michael Tarpey, CECW-CO, (202) 761-4449 or Michael.J.Tarpey@usace.army.mil.

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