Design of Hydraulic Steel Structures

Course Number: ST-02-585

PDH: 4

Approved for: AK, AL, AR, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater).
If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the specific structure types classified as Hydraulic Steel Structures (HSS) and the environmental factors affecting their design.
- **Evaluate** the primary differences between Load and Resistance Factor Design (LRFD) and Allowable Stress Design (ASD) methodologies.
- **Select** the appropriate design policy and standards for various civil works projects and material types.

Executive Summary: This chapter establishes LRFD as the preferred design methodology for Hydraulic Steel Structures (HSS) to achieve uniform reliability and economy. While ASD remains an approved alternative or a requirement for specific structure types, the manual mandates a transition toward limit state design for civil works, focusing on fracture control and the unique environmental demands of hydraulic environments.

Design Purpose

This manual prescribes guidance for the following:

- **Designing** hydraulic steel structures (HSS) using **Load and Resistance Factor Design (LRFD)**.
- **Implementing** fracture control measures.
- **Utilizing** Allowable Stress Design (ASD) as an alternative procedure or for structure types where LRFD criteria are not yet developed.

Applicability

This manual applies to all **HQUSACE/OCE elements**, major subordinate commands, districts, laboratories, and field operating activities responsible for the **design of civil works projects**.

Design Fundamentals

Types of HSS

Typical HSS include, but are not limited to:

- **Navigation and Flood Control:** Lock gates, tainter gates, tainter valves, bulkheads, stoplogs, and vertical lift gates.
- **Plant Components:** Components of hydroelectric and pumping plants.
- **Miscellaneous:** Lock wall accessories, local flood protection gates, and outlet works gates.

Environmental Stressors: HSS are frequently subjected to:

- Submergence and corrosion.
- Wave action and hydraulic hammer.
- Cavitation and impact.
- Severe climatic conditions.

Material Specifications

Structural grade steels for HSS design should refer to **CW-05502** and **AISC (1986, 1989)**.

- **High-strength structural steels** may be utilized to improve economy, simplify detailing, or enhance safety.
- ⚠️ **Safety Constraint:** You must check for **instability**, **local buckling**, and **deflection** regardless of the steel type used. These limit states are generally more critical when using high-strength steel.

Design Policy

LRFD is the preferred method of design and should be used for all structure types where guidance is provided in Appendices B through I.

Policy Constraints

- **ASD Usage:** May be used as an alternative for LRFD-supported structures only with prior approval from **CECW-ED**.
- **Mandatory ASD:** Required for HSS where LRFD criteria have not yet been developed (see Chapter 4).
- ⚠️ **Safety Constraint:** You **shall not combine** LRFD and ASD methods for the design of a single structure. However, separate structures within a large construction project may use different methods.

Structures Other Than HSS

Design for the following materials and structures must conform to their respective **industry standards** and are excluded from this manual:

- Aluminum, timber, and masonry structures.
- Service bridges and highway structures.
- Building construction and cold-formed steel.
- Railroad bridges and open-web steel joists.

Design Philosophy: ASD vs. LRFD

Historically, the **Allowable Stress Design (ASD)** method has provided safe structures by comparing computed stress to an allowable stress (yield or buckling stress) divided by a single **Factor of Safety (FS)**.

Advantages of Load and Resistance Factor Design (LRFD)

As a **Limit States Design (LSD)** approach, LRFD recognizes that loads and resistances are random quantities. It offers two distinct advantages over ASD:

1. **Non-linearity:** In limit state analysis, you do not have to assume linearity between load and force or force and stress.
2. **Uncertainty Management:** Multiple **load factors** reflect the degree of uncertainty for different loads (dead vs. live), and multiple **resistance factors** reflect uncertainties in specific capacities (bending vs. shear).

💡 **Design Tip:** Use LRFD to attain more **uniform reliability** across the structure. In many cases, this approach results in a more economical design by reducing over-engineering in areas with low uncertainty.

Checkpoint Quiz

---

1. **Which design methodology is currently preferred by USACE for Hydraulic Steel Structures where criteria are available?**
   a) Allowable Stress Design (ASD)
   b) Load and Resistance Factor Design (LRFD)
   c) Plastic Design
   d) Empirical Design

Answer: (b). LRFD is the preferred method to achieve uniform reliability and economy.

2. **Under what condition can LRFD and ASD be used on the same large-scale construction project?**
   a) They can be combined within the design of a single gate leaf.
   b) Only if the project is located in a saline environment.
   c) They may be used for the design of separate structures on the same project.
   d) They can never be used on the same project site.

Answer: (c). While methods cannot be mixed for a single structure, they can be used for separate structures on large projects.

3. What is a primary technical advantage of LRFD over ASD?

a) It uses a single Factor of Safety for all load types.
b) It assumes a linear relationship between load and stress in all cases.
c) It applies multiple factors to account for varying uncertainties in specific loads and resistances.
d) It eliminates the need to check for local buckling in high-strength steel.

Answer: (c). LRFD uses specific load and resistance factors to reflect the degree of uncertainty in different load effects and member capacities.

Module 2: General Considerations

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the four primary failure modes for Hydraulic Steel Structures (HSS) and their corresponding design methodologies.
- **Evaluate** design details and material selections that mitigate various forms of corrosion, including galvanic and concentration cell corrosion.
- **Apply** design strategies to manage unpredictable dynamic loading and cavitation through proper structural detailing.

Executive Summary: Designing HSS requires a comprehensive approach that accounts for limit states ranging from yielding and buckling to fatigue and brittle fracture. Because these structures operate in harsh, often inaccessible environments, designers must prioritize corrosion mitigation through specific detailing (e.g., continuous welds, accessible sandblasting areas) and account for unpredictable dynamic hydraulic forces by adjusting safety or load factors.

Limit States

All possible failure modes must be evaluated during the design process. These are categorized by the principles used to address them:

Yielding and Stability (LRFD/ASD)

- **General Yielding:** Excessive plastic deformation of the member.
- **Buckling:** General instability of the structure or its components.

Fracture Mechanics

- **Fatigue:** Subcritical crack growth that leads to a loss of cross-section or unstable crack growth.
- **Brittle Fracture:** Unstable crack extension resulting in sudden member failure.

Corrosion Mitigation

Painting is the primary defense against corrosion, often supplemented by **cathodic protection** (impressed current or galvanic systems) in severe environments.

Design Guidelines for Reducing Corrosion

- **Thickness:** Severe environments may justify additional thickness for critical members.
- **Connection Type: Welded connections** generally offer superior corrosion resistance compared to bolted connections.
- **Weld Quality: Continuous welds** are required; intermittent welds are highly susceptible to corrosion.

Purchase this course to see the remainder of the technical materials.