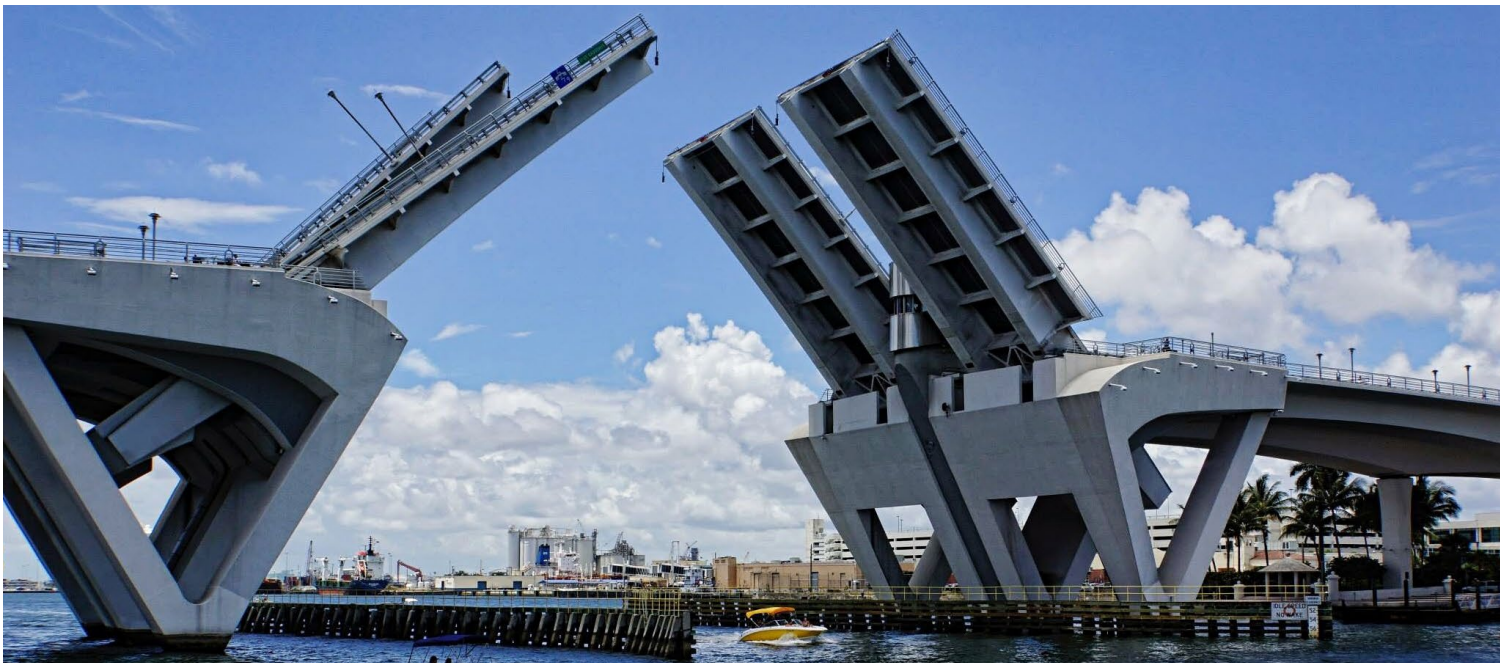


# Applying technology and maintenance practices to maximize movable structure uptime



## Methods of moving heavy structures

The types of movable structures considered for this paper include bridges, (as shown in Figure 1) and other civil engineering applications. Two primary methods have been used to move these structures—electro-mechanical and hydraulic.

## Introduction

As operational costs continue to increase for public works systems, the importance of reducing unplanned downtime is growing. Unexpected failures can knock systems out of commission for weeks and cost millions in repairs and user costs. An inoperative movable structure can result in delayed shipments, expensive re-routing, and various other negative impacts.

Movable structures—such as bridges, sector gates, and locks—face unique challenges over the course of their operational lifetimes. Exposure to harsh environments such as marine elements and weather can wreak havoc on equipment if it is not maintained properly. Equipment size requirements, fluid leakage, and emergency-stop (e-stop) conditions also have presented challenges. New technologies, along with improved maintenance, can help address these challenges and prevent downtime in hydraulically actuated bridges.

In bridges actuated by hydraulic cylinders, the cylinders have been improved to address common challenges faced by owner/operators. Unique sealing systems in the cylinders help prevent leakage and advances in coating technology, such as laser-cladded weld overlays that help protect the cylinder's piston rods from corrosion. In addition, advanced cushioning systems have helped minimize e-stop impacts of movable structural components.



Figure 1: Bascule bridge

## Electro-mechanical movement challenges

Electro-mechanical movement of heavy structures has been accomplished through various techniques, primarily gear- and electric motor-driven systems. Electro-mechanical methods can be accompanied by various challenges such as:

- Size of equipment (weight and space/length)
- Alignment
- Couplings
- Torque density
- Corrosion of the drive line
- Complicated means for declaration of the structure (e.g., programming, PLCs, and limit switches)
- Significant amount of lubrication points and environmental challenges of removing old grease

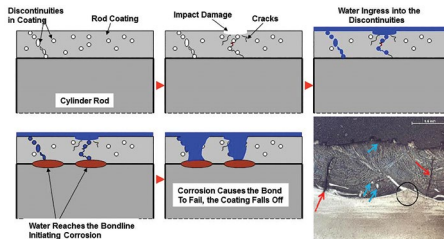


Figure 2: Illustration of how coatings fail on cylinder rods. Cross-sectional view of rod coating indicates large cracks (red arrows), porosity (blue arrows), and corrosion in deeply penetrated bond line (black circle).

## Hydraulic movement challenges

Hydraulic movement of heavy structures can be achieved using hydraulic cylinders (linear actuators). Challenges associated with hydraulic movement include leakage of hydraulic fluid, corrosion of components, and e-stops of prime movers.

### Fluid leakage

Fluid leakage can occur at fittings, hoses, pumps, valves, cylinders, and various combinations of components. Failures can often be attributed to internal and external contamination of the system including the ingress of debris in the system. Besides fluid consumption, the negative effects of hydraulic system leakage include inefficient machinery operation, environmental damage, safety and accident liability, premature machine component failure, poor manufacturing quality, and increased capital costs.

### Corrosion

Corrosion can transpire when steel hydraulic components are exposed to water and other environmental elements (as shown in Figure 2). In cold regions, salt and other de-icing chemicals can bring additional corrosive conditions. Structures in saltwater environments also face accelerated corrosion, while land-based structures may encounter dust, dirt, and other elements.

### E-stop failure

E-stop problems occur when a movable structural component fails to decelerate and slams into another component. For example, a bridge span being lowered into position strikes a bridge abutment with excessive force, rather than being lowered gently. In the past, air buffers had to be used, but these systems presented maintenance issues. In hydraulic cylinder operated bridges, various cylinder cushioning systems have been employed. However, many cushioning options have proven inadequate to properly stop a runaway moving structure and have resulted in significant structural damage.

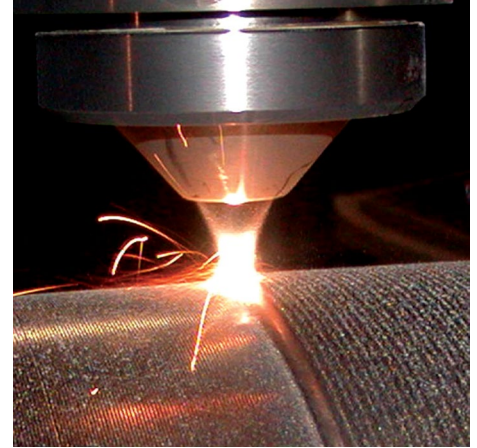
## New technologies offer solutions

### Hydroclad Laser Cladding

Hydroclad™ Laser Cladding reduces the corrosion damage on cylinder rods. This technique provides a metallic coating with a strong metallurgical bond between the coating layer and a substrate material, such as carbon steel in the case of cylinder rods. Using precise, state-of-the-art lasers such as the high-power diode laser (HPDL) as a controllable heat source, metallic powder is injected into the system by nozzles. Energy from the laser beam produces a shallow, molten cladding pool. Filler material powder is injected into the beam and the pool. As the laser beam passes through the area, the cladding pool solidifies rapidly, leaving the desired build-up of cladding material with minimal dilution of the base material.

#### Advantages of a protective coating:

- Optimized corrosion, wear, scratch, and impact resistance
- Optimized ductility and strength
- Resistance to bending
- Consistent coating depth
- Strong adhesion due to the metallurgical bond
- Hardness throughout depth and length without cracking
- Optimized surface characteristics designed for longer seal life
- Certified production welds tested both destructively and non-destructively before and after the weld to verify superior quality
- Field reparability



## Emergency stop cushioning

E-stop cushioning problems in hydraulic-cylinder-actuated bridges can be addressed through more advanced cushioning systems [1]. As mentioned previously, air buffers have been the norm, but have undesirable maintenance issues. Standard hydraulic cylinder cushions have proven unreliable as well. A multi-stage cushioning design that provides progressively adjustable deceleration can help avoid high-impact collisions of structural components. The design also meets AASHTO requirements, providing a fail-safe means for slowing the inertia of the structure in a runaway situation. The progressive design expands on standard cushioning options using longer cushion spears and multiple needle valves. They are arranged in a manner that gradually reduces the number of available needle valves in the return fluid flow path, allowing adjustable deceleration to fit a particular application.

#### Key factors to be considered when designing progressive cushioning systems include:

- Length of the cushion spear
- Calculating the load to be decelerated
- Sizing needle valves for optimum flow control

## The importance of proper maintenance

Hydraulic systems require proper maintenance and operating conditions for optimal performance. Maintaining a clean environment and providing contamination control can improve system performance, increase component life, increase uptime, and reduce repair requirements.

A systemic approach to contamination control can help establish objectives and best practices to avoid contamination-related failures. This approach strives to clean the fluid sufficiently to eliminate contamination as a factor in the failure of system components.

Systemic contamination control can be broken down into three main steps:

### 1) Set a target cleanliness level that accounts for the specific needs of the system

To set a target cleanliness level, the cleanliness recommended for the most sensitive component in system should be determined. An appropriate standard, such as ISO 4406, may be useful in determining these levels. Adjustments may be necessary for fluid type and external factors that increase stress on system components.

### 2) Select and position filters in the system so the target can be achieved

Filter selection should be conducted to achieve the desired performance level, ideally employing a filter with the following characteristics: high initial filter element efficiency, high strength under system stress, and a long service life. Filters should be positioned to encounter sufficient system flow to capture the contaminants.

### 3) Monitor performance and confirm that the target cleanliness level is being maintained

Performance monitoring can be accomplished by sending a fluid sample to a particle-counting laboratory that provides cleanliness code data to established standards. Proper selection and placement of contamination control devices in a system can eliminate most hydraulic system failures.

### Proactive maintenance approach

In addition to contamination control, a proactive maintenance approach can help maximize component and system life. A proactive approach uses a combination of careful design, fluid analysis, and condition monitoring to track system health. This considers factors such as fluid degradation and declining system performance to detect potential failures at an early stage, allowing maintenance planners to schedule repairs and replacements before a failure occurs. The proactive approach differs from a reactive approach, which consists mainly of crisis management and emergency repairs. A third approach, preventive maintenance, can be effective, but often relies on fixed scheduled maintenance and repairs, whether needed or not [2].

## Conclusion

The various challenges encountered in moving heavy structures can be addressed by modern technology and proper maintenance practices. Improvements in reliability and serviceability of hydraulic systems can address concerns of infrastructure designers and make hydraulic systems a viable alternative in movement of heavy structures.

## References

- [1] "Progressive Cushioning for Hydraulic Cylinders," Michael Hanley, Electro Hydraulic Machinery Co., Heavy Movable Structures, Inc. Power & Motion, October 2019.
- [2] "Birds Bones and Sludge: A Complete Guide to Hydraulic System Contamination Control," Vickers, Inc., 1996.



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