Preventing Failure of Earth Dams by Overtopping

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Background

Overtopping is one of the most common and catastrophic failure modes in earth dams. Unlike concrete dams, earthen embankments are highly vulnerable to erosion when water flows over their crest, often resulting in rapid structural degradation and potential dam breach. While significant research has focused on erosion mitigation—such as mixing chemical additives with soil to reduce erodibility—these methods tend to require extensive soil treatment, are labor-intensive, and may raise environmental or durability concerns.

Our Proposed Approach

Rather than mitigating erosion after overtopping begins, we propose a proactive and robust solution: **prevent overtopping altogether** by increasing the effective height of the dam using **SPiRe®+ panel** patented Fiber Reinforced Polymer (FRP) system developed for structural strengthening and protection (Fig. 1). As noted in this recent ACI Paper, SPiRe®+ is a truly unique product developed recently by Prof. Ehsani following 4 decades of innovation and product improvement. This ubiquitous product has many uses in the construction industry including the one being presented here.

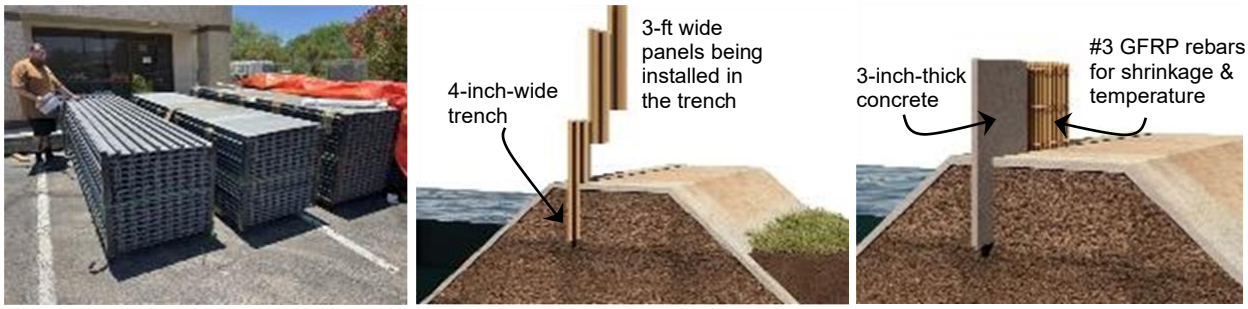

Fig. 1. SPiRe®+ panels at QuakeWrap warehouse in Tucson, AZ and steps of the proposed solution.

These lightweight, non-corroding panels are embedded in a 4-inch-wide trench cut into the dam's crest and are strong enough to extend the height of the dam by up to 10 feet! Unlike conventional earth-raising methods, this approach eliminates the need for soil transport or construction traffic on the dam crest, enabling rapid deployment, even in remote or restricted-access areas. We stock the 3-ft wide panels in 12- and 18-foot lengths; panels of any length can be made for special orders.

Applicability of the Solution

1. Type of Mitigation Technology

The SPiRe®+ system elevates the dam crest by several feet (Fig. 1), effectively eliminating overtopping. The patented panels are composed of Glass FRP and serve three distinct functions: a) stay-in-place form, b) reinforcing bars, and c) waterproofing membrane. Their grit-coated surfaces and integrated T-shaped profiles act as built-in reinforcement, offering a flexural strength equivalent to No. 6 Grade 60 steel bars spaced at 3.5 inches—without the need for any steel rebar. This level of reinforcement is much larger than the required steel rebars in most applications, thus

eliminating the need for additional rebars. The 1.5-inch-tall T profiles require a minimum concrete thickness of 2 inches to be fully encapsulated. We are proposing a 3-inch-thick wall for this application.

In flexural tests, SPiRe®+ panels with a 3-inch concrete backing demonstrated a flexural capacity of **25.5 k-ft/ft of panel width**, sufficient to raise the dam crest by **10 feet** with a factor of safety of **2.4** or raise it by 4 feet with a safety factor of 38!

2. Vendor / Developer Information

The SPiRe®+ system was invented by **Dr. Mo Ehsani**, Professor Emeritus of Civil Engineering at the University of Arizona and President of **QuakeWrap, Inc.** A pioneer in FRP repair technologies, Dr. Ehsani holds over 20 U.S. patents in this field. One of his patented systems, PileMedic®, is the only system approved by the USACE for repair of submerged piles following extensive testing by the U.S. Army ERDC.

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3. Engineering Specifications

Product Data Sheets (PDS) and testing data for SPiRe®+ are available at these links. These tests have validated the flexural strength of walls built with 2-, 3-, and 4-inch-thick concrete over SPiRe®+ panels. Even at 3 inches, the panels exhibit over 25 k-ft/ft of flexural capacity—enough to support a wall height of 10 feet. Thicker concrete walls allow for even taller applications. The panels are made with **UV resistant** vinyl ester resin. With long exposure to sun, the outside surface of the panels may get "chalky". But because that flat plate portion of SPiRe®+ panels is 5mm thick, even if a small fraction of the outer skin were damaged by exposure to the sun, it would have virtually no effect on the structural performance of the system. Note that the T profiles and the interior surface of the flat plate that act as reinforcing elements are fully encased in concrete and will never be exposed to any UV rays. If desired, the wall can be painted every 7-10 years as a part of a maintenance program.

4. Implementation Examples

Though introduced just under two years ago from the experience we gained during a marine pier repair project at the Port of Galveston, SPiRe®+ has already been widely adopted. These videos show its application in repair of:

- Timber seawalls
- Bridge pier walls
- Corroded steel sheet piles
- Deteriorated concrete slabs

A closely related application is for increasing the elevation of seawalls to protect against rising sea levels—currently being implemented on multiple Florida projects. The video of that application is available here.

5. Installation Methods

A 4-inch-wide trench of desired depth (about 2 to 4 feet) is cut along the crest. This trench can be a safe distance away from the edge of the crest to minimize any impact on the water tightness of the dam surface. The 3-ft wide panels are placed inside the trench, extending the desired height above the crest. The panels include 4-inch-wide overlapping edges, sealed with rubber strips to create a continuous, watertight stay-in-place form. If desired, additional self-tapping screws may be added to the overlap region for redundancy. The trench is filled with concrete and allowed to set. This stiff foundation at the base along with the stiffness of the SPiRe®+ panels eliminates the need for bracing the upper portion of the wall, significantly simplifying the completion of the project.

Since the panels resist tensile forces from upstream water pressure, no reinforcement is needed on the downstream face of the wall. A flat, removable & reusable form (plywood or GFRP) is connected to the SPiRe®+ panel to form a wall of desired thickness. This flat form can be quickly connected to the T profiles of the SPiRe®+ using specially designed reusable clips. Concrete for casting the wall and foundation can be delivered in ready-mix trucks or mixed onsite in smaller batches when access is limited. Horizontal #3 GFRP bars can be attached to the T-flanges using special clips at 12–16 inch spacing for temperature and shrinkage control (Fig. 1). The temporary flat forms on the downstream face of the wall will be removed, leaving the concrete surface visible.

Conclusion and Key Benefits

By addressing the root cause—**overtopping**—rather than just its effects, this solution offers a **transformative upgrade** for existing earth dams. Key benefits include:

- Increased storage capacity by raising the dam elevation
- Fast, non-invasive installation
- Use of durable, non-corroding FRP materials
- Elimination of steel reinforcement and corrosion concerns
- Creation of an impervious, watertight barrier

We welcome the opportunity to collaborate with the U.S. Army Corps of Engineers (USACE) on a **pilot demonstration** to validate this innovative solution under real-world conditions. The SPiRe®+ panels are available in our warehouse in Tucson and the technology is **ready for immediate installation**.