Preventing Overtopping of Earth Dams by Increasing Crest Elevation

A Rapid Crest-Raising Concept Using SPiRe®+ FRP Panels

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Background

Overtopping is one of the most common and catastrophic failure modes in earth dams. Earthen embankments are vulnerable to rapid erosion when water flows over the crest; once erosion begins, it can progress quickly to headcutting and breach.

FEMA P-1015, Technical Manual: Overtopping Protection for Dams, was prepared to help dam owners and engineers evaluate, design, construct, inspect, maintain, renovate, and repair overtopping protection systems. Most systems discussed in that manual, such as roller-compacted concrete, conventional concrete, articulating concrete blocks (ACB), gabions, turf reinforcement, riprap, and geosynthetics, focus on protecting the embankment so rare overtopping flows can pass safely.

The concept presented here is different: rather than armoring the downstream slope after overtopping begins, it seeks to prevent overtopping by increasing the effective nonoverflow crest elevation. In that sense, it is a rapid crest-raising system that addresses the root cause of the failure mode.

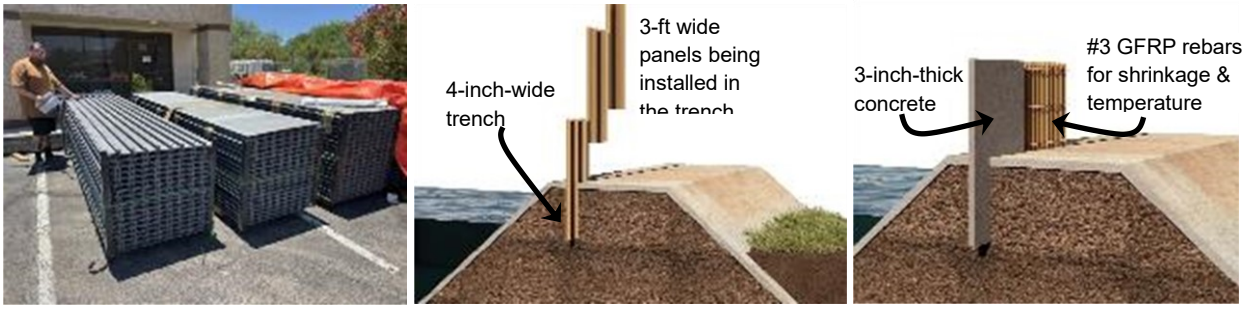


Fig. 1. SPiRe®+ panels at QuakeWrap warehouse in Tucson, AZ and steps of the proposed solution.

Proposed System

The proposed system uses patented SPiRe®+ glass fiber-reinforced polymer panels embedded vertically in a narrow trench along the dam crest and encased in concrete. The panels are lightweight, corrosion-resistant, and serve as a stay-in-place form, built-in reinforcement, and water-resistant face for the new crest wall.

SPiRe®+ panels are 3 feet wide and commonly stocked in 12- and 18-foot lengths. The ribbed side includes integral 1.5-inch T-shaped profiles that become fully embedded in concrete. The smooth side provides a durable finished surface. A typical dam application would use a 3- to 4-inch-thick wall, with horizontal #3 GFRP bars added as needed for shrinkage and temperature control.

Flexural testing of SPiRe®+ panels with a 3-inch concrete backing demonstrated a capacity of approximately 25.5 kip-ft per foot of panel width. Based on preliminary calculations, that capacity is sufficient for a crest raise of up to 10 feet with a factor of safety of about 2.4, or a 4-foot raise with a much larger reserve capacity. Final wall height, embedment, and details would be established by project-specific engineering calculations.

How the Concept Fits FEMA P-1015 and State Review

FEMA P-1015 recognizes several ways to address hydrologic deficiencies, including improving spillway capacity, adding overtopping protection, or raising the dam crest. Because this concept is intended to increase the effective crest elevation, it should be presented as a crest-raising and overtopping-prevention alteration, not simply as downstream-slope armoring.

For a pilot project or regulatory submittal, the design package should focus on the same issues FEMA and state dam-safety offices would expect for any dam modification:

- Flood routing before and after installation to show the maximum water surface elevation and remaining freeboard;
- Potential failure modes for both existing and modified conditions, including seepage, piping, sliding, overturning, flexure, settlement, and end-around erosion;
- Geotechnical and seepage review of the trench, embedment depth, filter compatibility, phreatic surface, and tie-ins at abutments or spillways;
- Construction sequencing, temporary freeboard, reservoir restrictions, and inspection/quality-control procedures; and
- Long-term inspection and maintenance of the wall, exposed FRP surface, joints, concrete, crest settlement, and seepage observations.



Fig. 2. SPiRe®+ panel showing the integral T-shaped profiles that become embedded in concrete.

Cutting the Narrow Trench

A key advantage of the system is that installation requires only a narrow trench along the crest instead of large-scale embankment widening or heavy earthwork. The concept can begin with a nominal 4-inch trench, but a 4- to 6-inch width should be allowed in practice to account for soil conditions, trench stability, concrete placement, and dam-safety review.

The trench can typically be cut with commercially available equipment. Candidate tools include a ride-on chain trencher with a 4-inch chain and 48- to 60-inch depth capacity; a tracked trencher for improved stability and lower ground pressure; an excavator-mounted trencher attachment where alignment or access is difficult; or a rockwheel/rock saw where the crest contains hard, cemented, or rocky materials.

Before construction, the contractor and engineer should confirm trench stability, equipment access, vibration effects, spoil handling, weather restrictions, and the ability to place concrete without voids. For dam safety, the trench should normally be offset from the upstream edge of the crest and excavated in a sequence that maintains adequate temporary freeboard.

Installation Sequence

- Survey and mark the wall alignment on the dam crest.
- Cut the narrow trench to the required depth and clean loose material from the bottom.
- Place SPiRe®+ panels in the trench, align them vertically, and overlap/seal panel edges.
- Place concrete in the trench to form the embedded foundation for the wall.
- Attach reusable flat forms on the downstream face using clips or temporary connectors.

- Install horizontal GFRP shrinkage/temperature bars as required, place concrete, and remove the reusable forms after curing.

Preliminary Cost Considerations

The SPiRe®+ panel material cost can be budgeted at approximately $45 per square foot of panel area. This figure is for the panels only and does not include engineering, permitting, trenching, concrete, forms, labor, mobilization, inspection, or site-specific access requirements.

Installed cost can be reduced by using the SPiRe®+ panel as the upstream stay-in-place form and reusable plywood or fiberglass sheets as the downstream form. The thin wall reduces concrete volume and avoids much of the hauling, compaction, and rebar placement associated with conventional earth crest raising. Assuming $90/SF for installation, an 8-ft tall wall (4 ft. below grade and 4 ft. above grade) would cost $1,080 per linear foot; a 500-ft long wall will cost around $550,000.

Key Benefits

Benefit	Practical Meaning
Addresses the root cause	Raises effective crest elevation to reduce or eliminate overtopping.
Low-impact construction	Narrow trench; limited earthwork; reduced traffic on the dam crest.
Corrosion resistance	GFRP reinforcement avoids steel corrosion concerns.
Rapid deployment	Lightweight panels can be installed with smaller equipment, including remote sites.
Cost control	Panel acts as stay-in-place form; downstream form can be reusable plywood or fiberglass.
Pilot-ready	Panels are available and the concept can be demonstrated on a small dam or test section.

Conclusion

The proposed SPiRe®+ crest-raising system offers a practical alternative for selected existing earth dams where additional freeboard is needed but conventional earth raising or spillway enlargement may be difficult, costly, or disruptive. The concept is compatible with the intent of FEMA P-1015 when presented as a dam alteration that prevents overtopping rather than a system that allows the embankment to overtop. The next recommended step is a pilot demonstration supported by project-specific hydrologic, geotechnical, seepage, structural, and construction-risk evaluations.

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