Geofoam

Colorado's Innovative Answer to an Emergency Highway Repair

STEPHEN HARELSON

The author is president of Dyer Mountain Ltd. Civil and Mechanical Engineering in Denver, Colorado, and former chief engineer of the Colorado Department of Transportation, also in Denver.

When an emergency strikes, the time is ripe for innovation. Sometimes, however, the best innovations are with techniques and technologies that are unknown or unproven to the decision makers addressing the emergency. In these instances, TRB's published research can help reassure these decision makers and provide justification to allow them to stick their necks out and implement these seemingly cutting-edge techniques.

Problem

On July 12, 2019, the Colorado Department of Transportation (DOT) was faced with an emergency. A mechanically stabilized earth (MSE) bridge abutment failed catastrophically, closing US 36 that connected Denver and Boulder. After two days of troubleshooting, engineers on the scene determined that the abutment had been constructed on an ancient lake bed. The lake bed consisted of fat clay: Clay with a high liquid limit and plasticity index that cause it to lose strength when wet. In this case, the fat clay lost much of its bearing capacity when moist. As the MSE abutment weighed on the moist fat clay, it triggered a rotational failure at the toe of the MSE wall and the entire embankment came tumbling down. Engineers at the scene were faced with a dilemma: how to remove 120,000 cubic yards of failed embankment, address the foundational issues in the lake bed, and return the 120,000 cubic yards of material to the way it was. More than 100,000 drivers who rely on the road every day waited anxiously for the solution.

The Answer

Five days later on July 17, 2019, Colorado DOT selected Kraemer North America to construct the repairs under a construction manager–general contractor (CM–GC) project delivery arrangement. David Evans and Associates was hired to assist Colorado DOT in the repair design. The design consulting team also included RJ Consulting as the geotechnical design subconsultant. Under Colorado's CM–GC contracting protocol, the contractor provides input on the design, while the Colorado DOT engineers and the engineering consultants maintain control over final design decisions.

The first design meeting of the reconstruction team—Colorado DOT, the CM–GC contractor, and design consulting team—took place a day later on July 18. Colorado DOT, the contractor, and the engineering consulting team worked tirelessly to design the repair. Quickly, it became obvious that removing the failed embankment, constructing a foundation through the lake bed to bedrock, and reconstructing the MSE wall would take eight or nine months. Recognizing that much of that construction would occur in the Colorado winter, harsh weather could delay it even further. The geotechnical design subconsultants suggested the use of Geofoam blocks to fast-track the project and get the embankment reconstructed prior to winter.

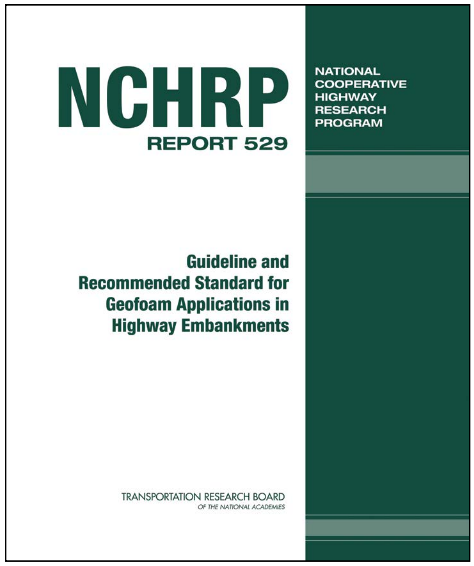
Benefits

Geofoam is an expanded polystyrene product that is specially designed to replace earthen embankments. A lay person would describe it as Styrofoam because it looks and feels very similar to the Styrofoam packing material seen in most every package. It weighs about 1 percent to 2 percent of normal soil fill, so its use would essentially unload the fat clays that had failed (i.e., remove the excess weight that had led to failure). With the use of Geofoam, the structure would weigh less than 10,000 tons instead of 120,000 tons. This was well within the bearing capacity of the lake bed clays, and it would allow reconstruction of the fill quickly and without the need to construct foundation structures through the clay to the more substantial bedrock below.

The contractor had used the product on a 2005–2006 project in Utah and, therefore, was also heavily involved in the design of the emergency project for Colorado DOT. Based on the Utah experience, the contractor was confident that the use of Geofoam would be a solution for the emergency project and that it would accelerate the delivery by at least six months.

Application

Colorado DOT, however, had very limited experience with Geofoam—with only two examples of its use and on a much smaller scale than was envisioned on this project. However, the contractor had used the material on several previous projects, and the geotechnical experts at RJ Consulting were also convinced of its advantages. A quick literature review showed that two National Cooperative Highway Research Program (NCHRP) publications discussed its use in highway embankments: *NCHRP Report 529: Guideline and Recommended Standard for Geofoam Applications in Highway Embankments* and *NCHRP Web Document 65: Geofoam Applications in the Design and Construction of Highway Embankments* (*1*, *2*). Both documents were prepared under NCHRP Project 24-11, "Guidelines for Geofoam Applications in Embankment Projects". *NCHRP Report 529* provided detailed and well-thought-out design suggestions for the use of the material, while *NCHRP Web Document 65* provided several case examples that convinced Colorado DOT staff that they were traveling down a feasible path.


NCHRP
REPORT 529
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Guideline and Recommended Standard for Geofoam Applications in Highway Embankments
TRANSPORTATION RESEARCH BOARD
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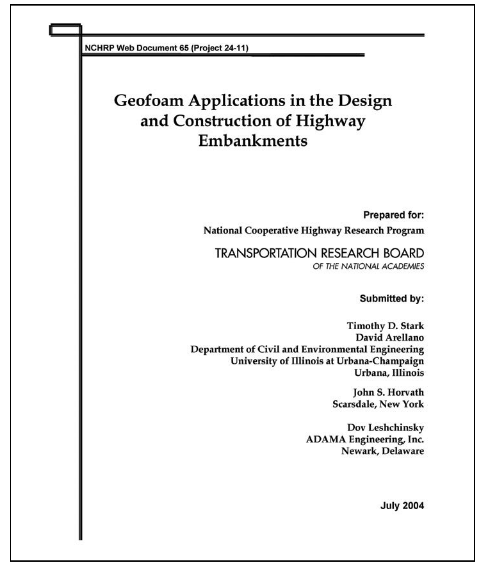

NCHRP Web Document 65 (Project 24-11)
Geofoam Applications in the Design and Construction of Highway Embankments
Prepared for:
National Cooperative Highway Research Program
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES
Submitted by:
Timothy D. Stark
David Arellano
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois
John S. Horvath
Scarsdale, New York
Dov Leshchinsky
ADAMA Engineering, Inc.
Newark, Delaware
July 2004

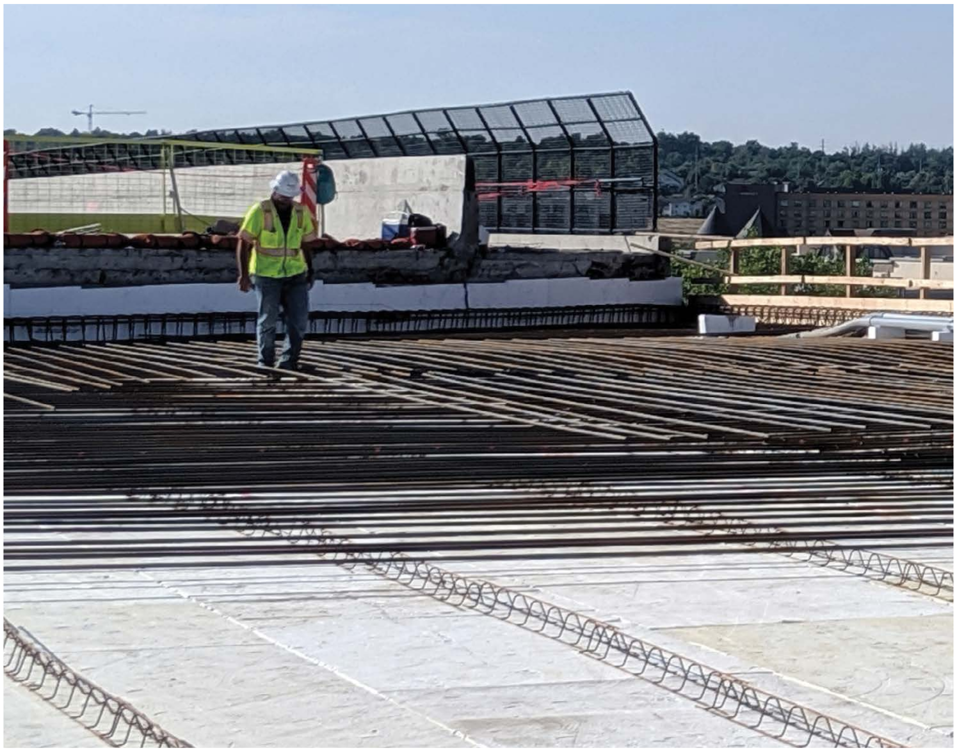
The project team followed best practices outlined in *NCHRP Report 529* and *NCHRP Web Document 65* to design a novel use of Geofoam expanded polystyrene blocks to repair a section of US 36 in Colorado.

The geotechnical design subconsultant relied heavily on the NCHRP design guidelines. Early in the deliberations with the contractor, the geotechnical designers knew conceptually that the Geofoam product would work as a solution and found that *NCHRP Report 529* was invaluable in getting the design right and modeling the expected compression of the material under final load.

While the CM–GC contractor removed the failed embankment from July 19 to August 13, the design team worked on the design of the Geofoam embankment—using the suggestions outlined in *NCHRP Report 529*. One of the greater challenges was procuring the necessary 6,000 Geofoam blocks in the narrow construction window available to avoid winter weather conditions. The contractor worked with the Geofoam manufacturer to deliver the material from multiple plants throughout the country to keep the project on track.

Foam material compresses under load, so settlement of the material as it was loaded with the roadway slab was another important consideration. This compression occurs over several days, but then it stabilizes. The amount of the compression must be considered in the design of the embankment so that the roadway is at the proper grade once the compression stabilizes. Other issues addressed included protecting the Geofoam from rodent infestation, as well as any solvents that might be spilled from highway traffic and attack the expanded polystyrene.

Embankment construction during September 2019 went smoothly. The refrigerator-size Geofoam blocks replaced the earthen embankment by being stacked in an interlocking pattern. It was critical that the blocks be fitted tightly together to minimize the compression of the structure. When stacking was complete, the Geofoam was protected with a membrane and a concrete panel wall. The roadway deck was placed on the Geofoam, while the Colorado DOT engineers carefully measured the compression



Courtesy of Colorado DOT

Crews assemble the rebar mat that will reinforce the concrete slab that rests on top of the Geofoam structure.

of the structure as it was loaded. The compressed Geofoam stabilized exactly as the NCHRP report indicated. The roadway was reopened to traffic on October 4, 2019, less than three months after the failure and less than half the time of a more traditional fix, saving Denver–Boulder commuters an entire winter's worth of construction detours.

The availability of the NCHRP research provided design guidelines and material and construction suggestions, as well as the engineering properties of the geofoam material and a summary of successful case histories (*3*). This research provided design tools, established methods of design, reassured Colorado DOT staff that the approach would work, and confirmed that the product was proven and reliable. It also documented use in other regions of the country and, although it was cutting edge and innovative to the project team, the research demonstrated that Geofoam had been used successfully elsewhere and provided an engineering basis for its use in Colorado.

Courtesy of Colorado DOT

Precisely stacked Geofoam blocks form the face of the new structure. A steel-reinforced concrete caisson is one in a series that will support the precast concrete panels that protect the Geofoam wall.

REFERENCES

1. Stark, T. D., D. Arellano, J. S. Horvath, and D. Leshchinsky. *NCHRP Report 529: Guideline and Recommended Standard for Geofoam Applications in Highway Embankments*. Transportation Research Board, Washington, DC, 2004. https://doi.org/10.17226/13759.
2. Stark, T. D., D. Arellano, J. S. Horvath, and D. Leshchinsky. *NCHRP Web Document 65: Geofoam Applications in the Design and Construction of Highway Embankments*. Transportation Research Board, Washington, DC, 2004. https://doi.org/10.17226/21944.
3. Arellano, D., T. D. Stark, J. S. Horvath, and D. Leshchinsky. *NCHRP Research Results Digest 380: Guidelines for Geofoam Applications in Slope Stability Projects*. Transportation Research Board, Washington, DC, 2013. https://doi.org/10.17226/22630.