Xanthan Gum Biopolymer for Road Subbase Stabilization

Ryan van der Heijden, Department of Civil and Environmental Engineering, University of Vermont | Advisors: Dr. Ghazanfari and Dr. Dewoolkar
Participating Researchers: Kate Hunter and Dr. Bijay KC

Biopolymers: Advantages and Challenges

Biopolymers may offer an environmentally-friendly alternative to traditional stabilizers for roadway subbase such as cement, asphalt emulsion, and calcium chloride. This study investigated the effects of Xanthan Gum on soil strengthening through the lens of roadway subbase stabilization for two subbase materials. In a reclaimed stabilized base (RSB) project, a portion of the existing roadway and underlying subbase is pulverized and thoroughly mixed with a stabilizing agent before being reused as a new subbase material. A more complete understanding of the engineering properties of biopolymer-treated soil is necessary to advance their use.

Materials and Methods

Xanthan Gum (XG) is a polysaccharide derived from fermenting sugar with Xanthomonas Campestris bacteria. This process consumes CO_2 and results in a fine, off-white powder once processed. The powder is hydrophilic and forms a viscous gel when mixed with water, even at very low proportions. Scanning Electron Microscope (SEM) images of XG mixed with both glass beads and soil (Figure 1, left and right, respectively) show coating of the particles and formation of a lattice structure of connectional bridges between particles.

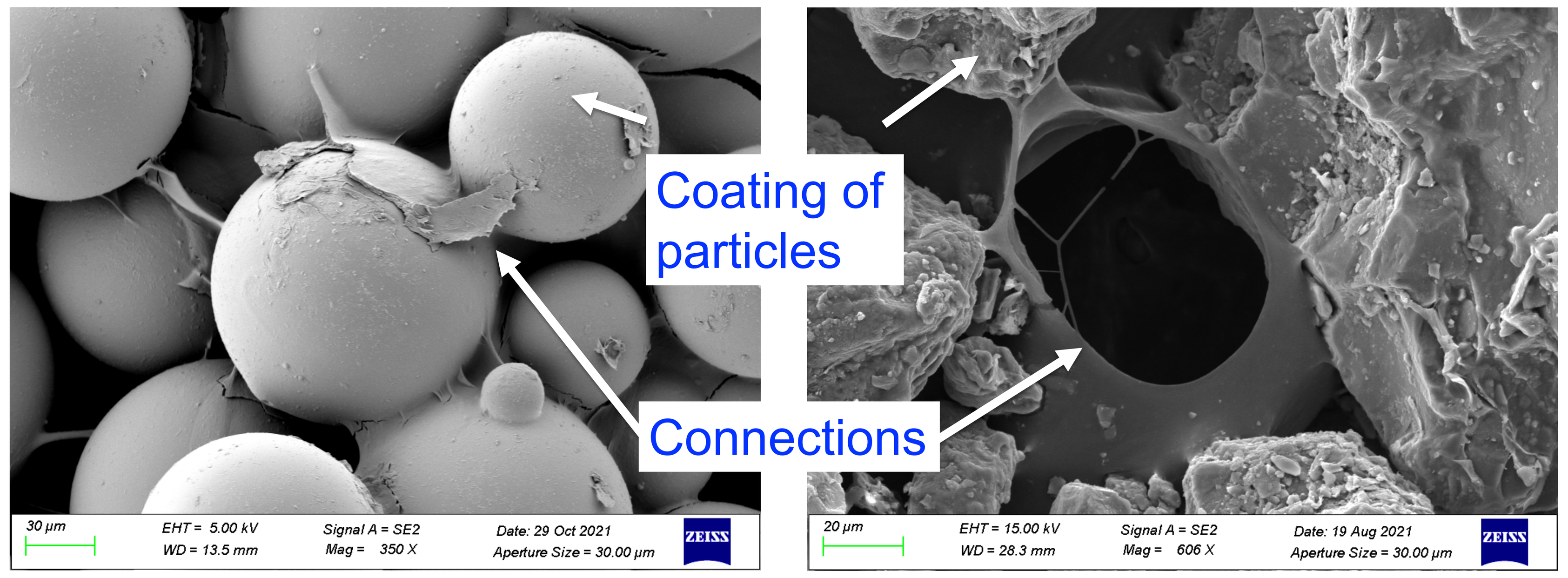

Figure 1: SEM images of XG with glass beads (left) and sand (right)

Materials:

1. Lab-created
   - Composed of sand, gravel, and crushed stone
2. RSB
   - From active VTrans project, containing approx. 5% asphalt

XG Treatment: 0.3%, 0.5%, 1.0%, 2.0%, and 4.0% (plus controls)
Curing Times: 7, 14, and 28 days
Test Method: unconfined compression (UC)
Goal: Assess the effect of XG content and curing time on the unconfined compressive strength and elastic modulus of treated subbase.

Results

UCS and elastic modulus (Figures 2 and 3, respectively) were found to increase with both longer curing times and higher XG contents in both the lab-created material and the RSB material. Results from only the lab-created material are shown for clarity. UCS of treated soil at 7 days is similar to the control, but there is substantial strengthening between 7 and 14 days. Between 14 and 28 days, 0.3% and 0.5% show moderate strength increase, with 0.1% not showing and increase and 1.0% showing substantial increase. XG contents greater than 1.0% had, in most cases, negligible additional contributions to strength and stiffness, and in some cases led to reduced strength and stiffness.

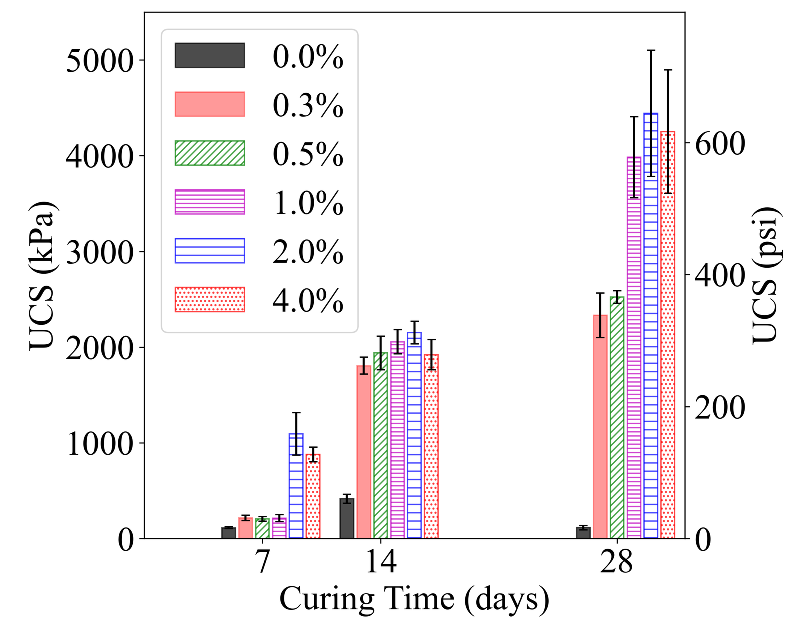

Figure 2: UCS

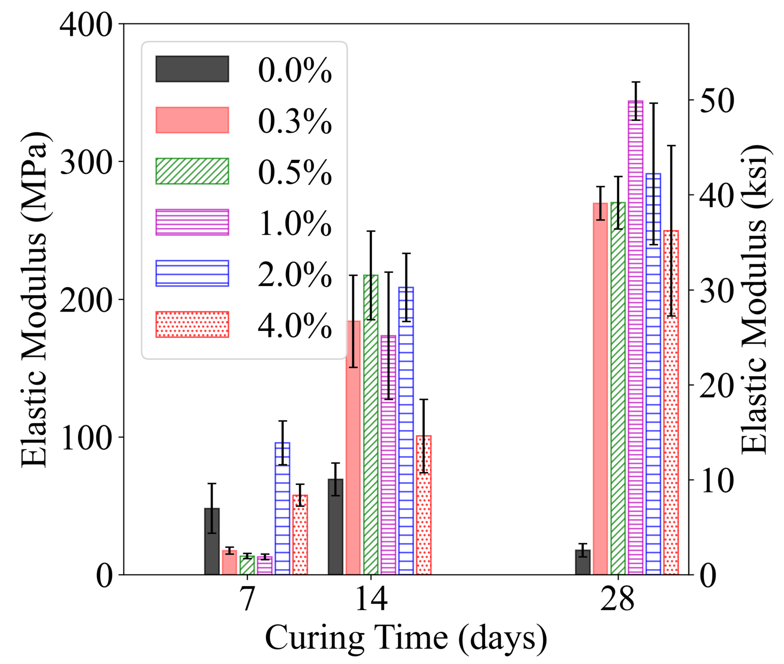

Figure 3: Elastic Modulus

A linear relationship was observed between moisture content at the time of testing and UCS. Drying of the treated soil is primarily responsible for strength gain at a given XG content. Density was found to be dependent of XG content for the lab created gradation (shown here), but not for the RSB material.

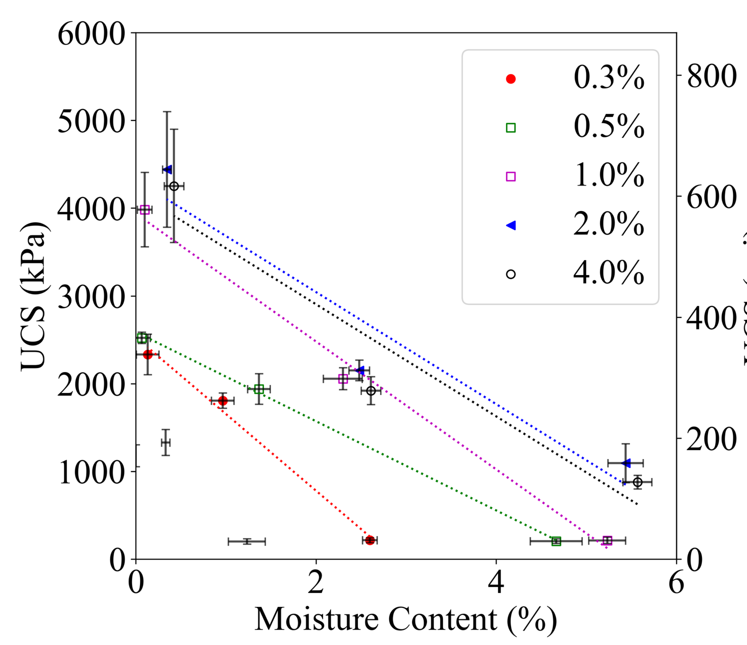

Figure 4: Moisture Content – UCS

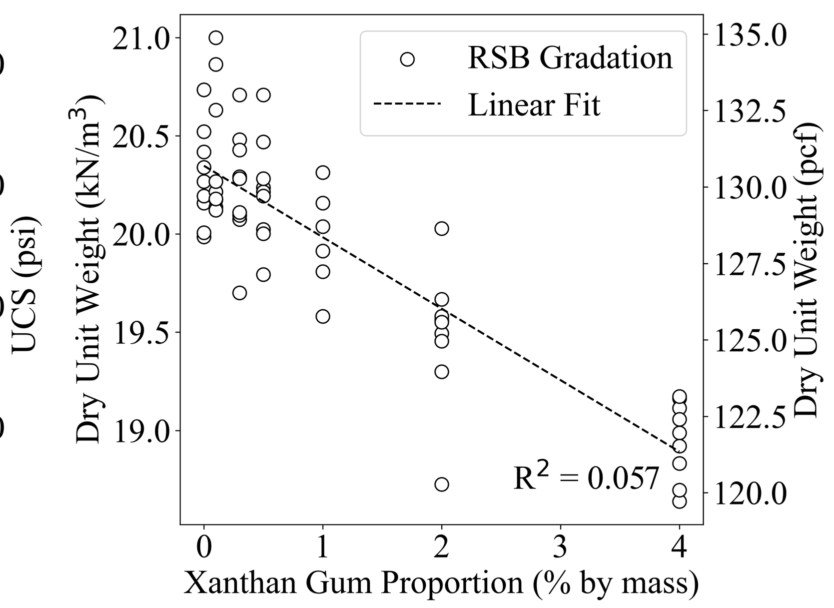

Figure 5: Dry Unit Weight – XG

The strong relationship between moisture content and UCS suggests that curing time is analogous to drying of the specimens.

The addition of XG was shown to have diminishing returns on both strength and stiffness. For the lab-created material, XG additions greater than between 0.5% and 1.0% (depending on curing time) did not contribute additional strength or stiffness. For the RSB material, XG additions beyond this range had a detrimental effect on strength.

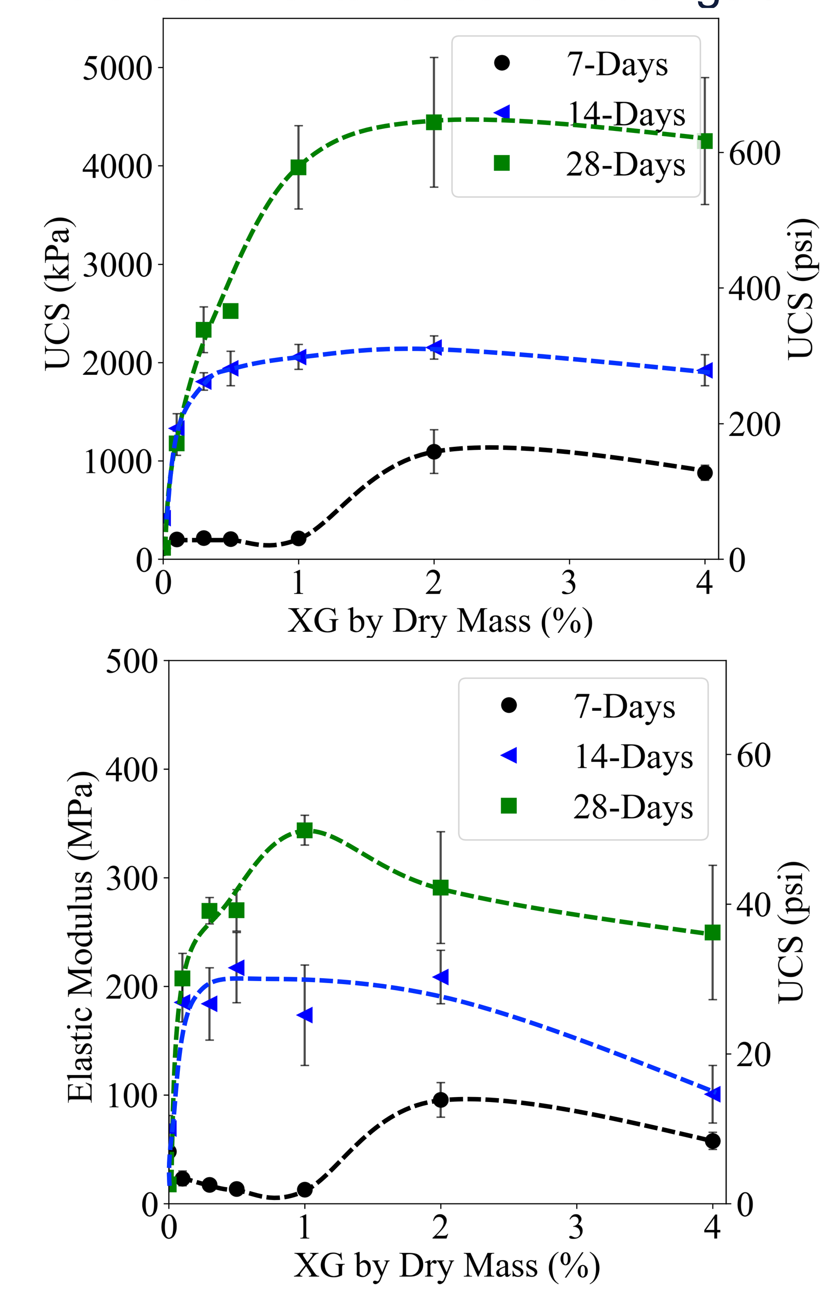

Figure 5: Lab-Created Material
Top—UCS
Bottom—Elastic Modulus

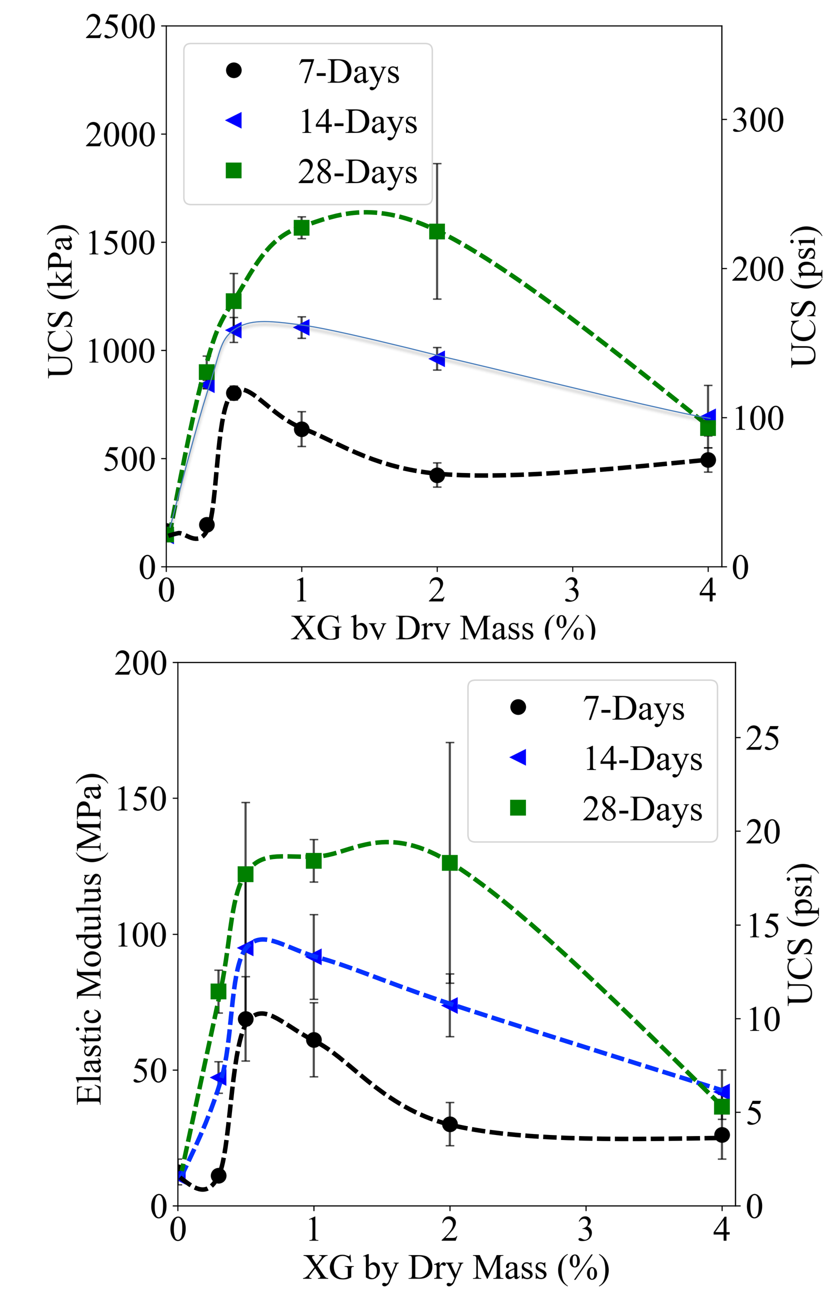

Figure 6: RSB Material
Top—UCS
Bottom—Elastic Modulus

Conclusions

Subbase treatment with XG has shown:

- Reduction in bulk unit weight
- Increase in UCS and stiffness with increasing XG content up to a certain limit
- Strength and stiffness are sensitive to moisture content

The moisture sensitivity of XG that could impact all aspects of it's use in the field; from initial mixing with subbase material, to curing times, to long-term stability. Regions that experience frequent heavy rains and/or have high groundwater may not be appropriate for XG application. The effect of environmental conditions such as moisture intrusion, high sodium chloride levels, and freeze-thaw cycling needs to be investigated.

Acknowledgements

Funding for this research is provided by the Transportation Infrastructure Durability Center at the University of Maine under grant 69A3551847101 from the U.S. Department of Transportation's University Transportation Centers Program. Additional support from the Vermont Agency of Transportation is gratefully acknowledged. The contributions of Dr. Ian Anderson from the Vermont Agency of Transportation is greatly appreciated. The contributions of undergraduate student Greer Scambos is also appreciated.