Selecting Flocculants for Transportation Sites

Prepared for
Bureau of Equity and Environmental Services

Prepared by
CTC & Associates LLC
WisDOT Research & Library Unit
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Request for Report

The Wisconsin Department of Transportation's Bureau of Equity and Environmental Services requested a report for use with the AASHTO Product Evaluation Group on methodologies for effectively selecting flocculants for transportation uses with soil and runoff. BEES staff were particularly interested in identifying state testing requirements, on-site testing of polymer and natural flocculants, state specifications and product approval lists, and practices and research with regard to natural flocculants such as aluminum sulfate (alum).

Summary

Our Web search indicated that only in recent years has the research and development of flocculants for transportation applications blossomed. A smattering of work since the late 1970s has evaluated clay flocculants, but for the most part only this decade has the topic gathered concerted attention from researchers and transportation agencies. As a result, there does not appear to be a great deal of information on selection of flocculants for specific uses, or on products and transportation specifications for their use.

This Transportation Synthesis Report includes four sections:

- **Testing Requirements and Field Testing Methods** highlights a just-published FHWA guide on best management practices in chemical treatment systems for construction stormwater. This section also includes two WisDOT reports that evaluate polymer flocculants for use as soil tackifiers, including one of the most commonly used and widely studied flocculants—polyacrylamide.
- **Specifications, Approved Products, and Selection** practices for flocculants in a handful of states, including California, Minnesota and New York.
- **Natural Flocculants:** A variety of reports and studies of chitosan flocculants derived from seashells, of alum, and of smectite clays.
- **Research** on various flocculants for use in controlling turbidity or in tacking down soil.

Testing Requirements and Field Testing Methods

The key resource in our search of state and national testing requirements and procedures is a 2009 FHWA guide on best management practices in flocculant use, which includes an emphasis on site analysis before deployment. For reference, this section also includes reports of two Wisconsin product evaluations in which field-testing of flocculants was conducted. We were unable to determine what testing methods or requirements other state agencies employ.

Best Management Practices for Chemical Treatment Systems for Construction Stormwater and Dewatering, FHWA, January 2009.
http://www.wfl.fhwa.dot.gov/td/publications/documents/CTS-booklet.pdf (Also see FHWA's Web page on the project at http://www.wfl.fhwa.dot.gov/td/publications/cts.htm.)

This study, which originated from a 2003 FHWA solicitation for a guide on the use of gel flocculants, pursued two primary objectives:

- Provide a technical basis for best management practices in the use of chemical treatment systems to reduce turbidity on road construction projects.
- Identify the most important variables to address when selecting a CTS for a site.

The report discusses chemicals that can be used, costs, selection, methods of application, design and location, maintenance, decommissioning of systems, and more. Key findings include:

- Chemicals typically used for reducing suspended sediment in water include chitosan and polyacrylamide polymers, diallyldimethyl ammonium chloride (DADMAC), gypsum, alum, and aluminum and iron chlorides.
- Flow control through a chemical treatment system is the critical factor in effective use of flocculants in stormwater applications.
- Conventional hydrologic analysis is the most important tool for selecting and devising a proper flocculant application.

Contact: Amit Armstrong, Western Federal Lands Highway Division, (360) 619-7668, amit.armstrong@fhwa.dot.gov.

WisDOT Product Evaluations

"Evaluation of Polymer for Soil Stabilization: Natural Earth Poly Stable Plus," WI-06-03, Gilbert Layton, August 2003.
http://on.dot.wi.gov/wisdotresearch/database/reports/wi-06-03polymer.pdf
WisDOT field-tested the Type B soil stabilizer Natural Earth Poly Stable Plus and found that it performed within established guidelines, and noted that soil stabilizers are "extremely cost-effective." The product was adopted by the WisDOT Product Acceptability List (PAL) Committee on May 1, 2003.

"Polyacrylamide as a Soil Stabilizer for Erosion Control," WI-06-98, Kenneth Nwankwo, January 2001.
http://on.dot.wi.gov/wisdotresearch/database/reports/wi-06-98polyacryl.pdf
WisDOT evaluated a polyacrylamide soil stabilizer (CFM 2000, PAM) and found that the product worked effectively and at less cost than erosion mats, and was easy to apply and environmentally safe.

Specifications, Approved Products, and Selection

National and state databases offer state standard specifications, special specifications, updates and more online, as well as sites devoted to approved or acceptable product lists. In a targeted search of these databases we found limited information on flocculants for various state transportation and environment departments; we highlight key findings below. This section also includes a *CE News* article on selecting erosion control materials, including flocculants.

California

We located a number of documents pertaining to Caltrans and its use or permitting of use of flocculants. These include the following:

> *Caltrans Erosion Control New Technology Report*, CTSW-RT-03-049, June 2003.
> http://i80.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-03-049.pdf
> This report recommends approving erosion control products that include a fiber matrix containing flocculants: Conwed 2500 Bonded Fiber Matrix (page 156 of the PDF); Earthbound, a PAM hydraulic soil stabilizer (page 224); MULCHTACK41, a PAM-based tackifier (page 234); and an organic soil amendment called Kiwi Power (pages 420-421).
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> "Polymer Stabilized Fiber Matrix Specification: EarthGuard Fiber Matrix," 2006.
> http://www.earthguard.com/pdf/Caltrans_Construction.pdf
> A company called EarthGuard developed a white paper for Caltrans on its temporary hydraulic mulch, a polymer-stabilized fiber matrix used in soil stabilization.
>
> "EarthGuard Fiber Matrix: Pre-approved Product Evaluation Request & Summary," Colorado DOT, undated.
> http://www.dot.state.co.us/App_APL/PDF/2544.pdf
> According to this Colorado product evaluation request, EarthGuard's fiber matrix was field- and lab-tested for Caltrans at San Diego State University, and is used in California, Idaho, Nevada, Texas and Washington.
>
> *Best Management Practices Construction Handbook,* California Stormwater Quality Association, updated 2006.
> http://www.cabmphandbooks.com/Construction.asp
> The CSQA recommends use of PAM flocculants to control erosion. See also Fact Sheet EC-13, Polyacrylamide, at http://www.cabmphandbooks.com/Documents/Construction/EC-13.pdf.
>
> Caltrans Lake Tahoe Storm Water Treatment Pilot Project: Jar Test Results and Summary Report, Vol. 1 of 3, June 2003.
> http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/tahoe/CTSW-RT-03-063/CTSW-RT-03-063.pdf An extensive examination of various coagulants, including alum and PAM flocculants, this study found that Superfloc A1840 performed poorly.

"Spray Solutions: Performance-based classification system simplifies selection of hydraulically applied erosion control materials," Frank J. Lauro, Marc S. Theisen, *CE News*, August 2006.
http://www.cenews.com/article.asp?id=891
This article focuses on flocculation and functional longevity—how long hydraulically applied flocculants will protect seed and soil from overland flow erosion from rainfall. This piece describes a performance-based selection system for such materials.

Minnesota

Minnesota DOT Standard Specifications for Construction, Section 3898, Flocculants
http://www.erosion.umn.edu/resources/mndot/specs/3886to3898_final.pdf (page 18 of the PDF)
This pre-letting specification about flocculants focuses on storing and use, but does not address testing.

See also limited detail on the use of flocculants as a temporary erosion control method on pages 2 and 3 of a 2007 memo from the Office of Environmental Services on Turf Establishment and Erosion Recommendations at http://www.dot.state.mn.us/environment/pdf_files/districtseed/d6seed.pdf.

New York
New York State DOT Standards and Specifications, Section 5A, Temporary Structural Measures for Erosion and Sediment Control
http://www.cicacenter.org/pdf/NYESC5a.pdf (see "Chemical Treatment" on page 54 of the PDF)
A very brief mention of flocculants as a method of chemical erosion control includes PAM, aluminum sulfate (alum), and polyaluminum chloride, but notes that flocculants cannot be used as substitutes for standard erosion and sediment control methods.

Natural Flocculants

The principal naturally occurring flocculants are aluminum sulfate—alum—and chitosan, a material derived from seashells. Another naturally occurring flocculant mentioned in a 2002 conference paper is smectite clay.

Oregon
A number of documents address Oregon DOT and DEQ studies of flocculants, particularly natural chitosan materials. These include:

> *Assessing the Effectiveness and Environmental Impacts of Using Natural Flocculants to Manage Turbidity*, Oregon DOT, SPR 615, October 2005.
> http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/AssessingTheEffectAndEnvir.pdf
> This research evaluated the feasibility of using chitosan as a natural flocculant to control turbidity during in-stream construction work. Field testing proved inconclusive, so research turned to bench scale tests to evaluate chitosan's effectiveness in test conditions of various pH, initial turbidity, chitosan dose, and sediment type. Findings include that effectiveness of chitosan flocculants varies with the type of sediment, but that an unidentified water quality parameter—likely related to organic matter—is the most critical factor in chitosan's usefulness.
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> Also see a two-page summary of this project:
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> > "Clearing Up the Benefits of Chitosan Flocculant," Oregon DOT Research Notes, March 2006.
> > http://www.ch2ocsi.com/rsn06-07%5B1%5D.pdf
>
> *Flocculation of Construction Site Runoff in Oregon*, Oregon Department of Environmental Quality Northwest Region, undated.
> http://www.deq.state.or.us/wq/stormwater/docs/nwr/flocculation.pdf
> This report details the use and effectiveness of flocculation in managing runoff from construction sites. It addresses turbidity, discharge testing and impact on salmonid.

Australia
The Use of Flocculants and Coagulants to Aid the Settlement of Suspended Sediment in Earthworks Runoff: Trials, Methodology and Design [draft], Aukland Regional Council, Technical Publication 227, June 2004.
http://www.arc.govt.nz/albany/fms/main/Documents/Plans/Technical%20publications/201-250/TP227%20The%20use%20of%20flocculants%20and%20coagulants%20to%20aid%20the%20settlement%20of%20suspended%20sediment%20in%20earthworks%20runoff%20trials%20methodology%20and%20design.pdf
This report focuses on a number of treatments for runoff water, and aluminum-based coagulants and flocculants, as well as alum, are studied and discussed throughout. Aluminum concentrations, alum use and impact on acidity, the effects of alum overdose, and the use of alum with limestone soils are evaluated and described. Polyaluminum chloride is found to be a most effective treatment.

Washington
"Contractor's Corner: Chitosan: A New Tool for Water Quality," Western Chapter IECA Newsletter, Winter 2003.
http://www.wcieca.org/newsletter/022003/index.htm#3
This article describes the use and effectiveness of chitosan as a flocculant for controlling water quality at construction sites in Washington. Reported by the International Erosion Control Association's Western Chapter (which does not include Washington state).

"Clay-Based Flocculant for the Removal of Suspended Matter and Heavy Metals," A.K. SenGupta and J. Darlington, presented at 2002 SME Annual Meeting, Feb. 25-27, Phoenix; 4 pages.
Abstract: http://www.onemine.org/search/summary.cfm/ClayBased-Flocculant-For-The-Removal-Of-Suspended-Matter-And-Heavy-Metals?d=532037177C24211B0D3B2AE6FE9C2436F1E8F09BBAC79148AA8C2D2B8E938E0238135
This study identifies smectite clays as effective flocculants of suspended debris and metal ions in water, and recommends using the clays in conjunction with anionic polymers for enhanced performance.

Research

A number of studies and papers address the effectiveness of various flocculants in reducing turbidity or as soil tackifiers. This section includes a selection of academic studies and articles, state white papers, and technical reports.

"Soil Factors Influencing Suspended Sediment Flocculation by Polyacrylamide," Richard A. McLaughlin and Nathanael Bartholomew, *Soil Science Society of America Journal*, March 2007.
http://soil.scijournals.org/cgi/content/full/71/2/537
In a study of the use of PAM flocculants to settle suspended sediment in construction site runoff in North Carolina, scientists from North Carolina and Minnesota found that PAM reduced turbidity in sample subsoils by over 90 percent, and that turbidity reduction correlated with sand content; the higher the sand content, the higher the turbidity reduction.

"Targeting Fine Particle and Phosphorus Removal with Chemical Treatment Technologies," Phil Bachand, Alan Heyvaert, John Reuter, *Journal of the Nevada Water Resources Association,* Winter 2007.
Abstract: http://www.tahoescience.org/EventImage.aspx?sa=1&id=108 (page 16 of the PDF)
From the abstract: Tests with flocculants have demonstrated that settling times can be an order of magnitude faster than for fine particles without flocculants. This study looks at several key design issues that will be important for the implementation of chemically enhanced best management practices and discusses how chemical technologies could be integrated with current stormwater management practices to more effectively target fine particle and phosphorus removal. It also describes the authors' work on logistical, environmental (e.g., ecotoxicological) and performance issues that must be addressed before these technologies can achieve broad-scale implementation in the Tahoe Basin.

"Agglomeration of Struvite Crystals," Kristell S. Le Corre, Eugenia Valsami-Jones, Phil Hobbs, Bruce Jefferson and Simon A. Parsons, *Water Research*, Vol. 41, Issue 2: 419-425, January 2007.
http://dx.doi.org/10.1016/j.watres.2006.10.025
From the abstract: Struvite crystallization is widely studied as a way to remove phosphorus from wastewater effluents and simultaneously generates a valuable product for the fertilizer industry. However, to date, some crystallization processes experimented at either pilot/or full scale face problems linked to the formation of fines. This paper presents results of the investigation of struvite agglomerative properties and the possible application of coagulants and/or flocculants to remove fines. Coagulants investigated were hydrolyzing metals salts ($Al3+$ and $Fe3+$), calcium compounds and a cationic polymer, polydiallyldimethylammoniumchloride (polyDADMAC). The effects of a natural flocculant (alginate) have also been tested. Results demonstrated that destabilization of struvite particles by chemical addition was feasible and identified polyDADMAC as a good option for the agglomeration of struvite particles. However, optimization of its dosage under typical pH conditions for struvite formation showed floc formation to be very pH sensitive.

"Polymer Coagulants and Flocculants for Stormwater Applications," ProTech General Contracting Services, Inc., Technical Report TR01.1, July 2004.
http://www.protech-services-inc.com/Library/TR01.1-electronic.pdf
This consultant white paper finds polymer flocculation "very effective" in stormwater management and provides data on testing of four flocculants, including chitosan and mimosa bark, but not alum.

"Effects of Exchangeable Ca:Mg Ratio on Soil Clay Flocculation, Infiltration and Erosion," Katerina Dontsova and L. Darrell Norton, *Sustaining the Global Farm: Selected Papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999,* pages 580-585; published 2001.
http://www.tucson.ars.ag.gov/isco/isco10/SustainingTheGlobalFarm/P057-Dontsova.pdf
In a study of rainfall, soil sealing, Midwest clay soils, and calcium and magnesium content, researchers from Purdue University found that a high Ca:Mg ratio can reduce aggregate destruction and clay movement.