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**RESEARCH PROJECT TITLE**

Low-Cost Rural Surface Alternatives

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# Low-Cost Rural Surface Alternatives

tech transfer summary

This project presents a literature survey of the state of practice for granular surface road construction with respect to freeze/thaw damage and provides recommendations for a phase 2 study.

## Problem Statement

Freezing-thawing action induces physical changes to granular surface roads that can negatively impact public users, reduce emergency responder access/time, and result in maintenance costs for secondary road departments. Stabilization can help reduce frost-susceptible conditions for unbound granular roads, but requires careful engineering design and controlled construction techniques. The comprehensive literature review conducted for this project categorized technical and some economic aspects of freeze-thaw mitigation for granular surfaced roadways.

## Project Overview

A detailed literature survey was conducted on the topic of unbound granular road performance and construction with respect to freeze-thaw damage and resistance. Figure 1 shows typical Iowa gravel roadway conditions during the spring thaw period. Improvements to reduce rutting due to thaw weakening and preventing frost heave are desired. In this document and the accompanying report, engineering recommendations are provided for (1) collecting local information to better characterize the extent of the problem and (2) constructing test sections to evaluate freeze-thaw mitigation technologies at full-scale.

A worldwide literature review was conducted using many sources, and the results were assessed in a systematic approach using a rating system



*Figure 1. Examples of spring thaw conditions on unpaved roads in Iowa (pictures from Boone County on March 20, 2013)*

developed as part of this project. The results of the literature review are organized by engineering categories. Approximately 300 technical articles were reviewed and then down-selected to about 150 sources for full assessment and inclusion in the bibliography.

## Literature Assessment

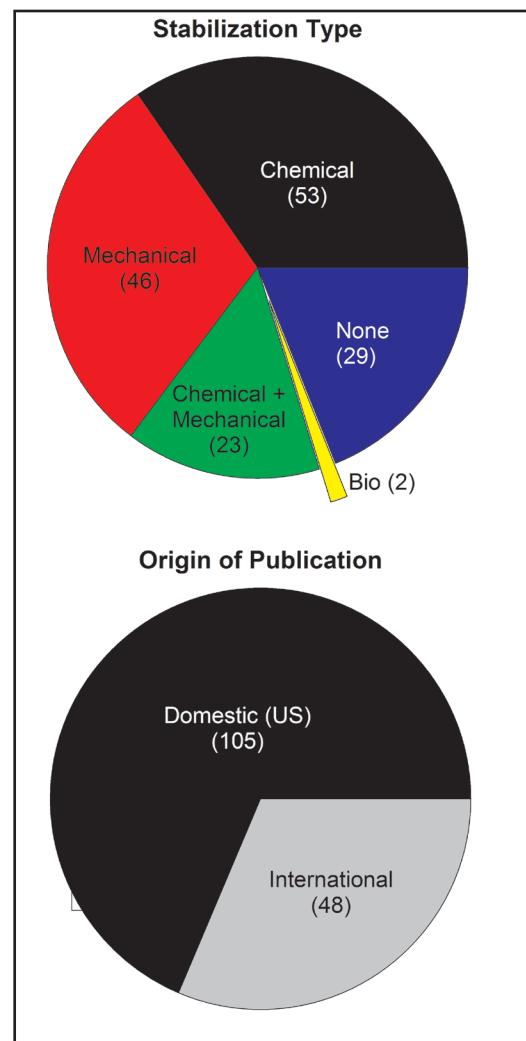
The literature database was organized in an electronic database (EndNote®), which can be shared with other researchers and practitioners. The database will be used as a future resource to search for information regarding the various repair and mitigation solutions, measurement technologies, and experiences that have been documented by selected domestic and international researchers and practitioners.

The literature documents have been assessed as shown in Table 1, according to the assessment criteria and eighteen different engineering categories (highlighted in gray in Table 1). Each article was rated on a scale of 1 to 4 as it relates to the potential to contribute to solutions to this problem in Iowa (1 – not applicable, 2 – marginally applicable and not considered, 3 – marginally applicable but technically strong, 4 – applicable and technically strong). Engineering judgment was used in rating each article.

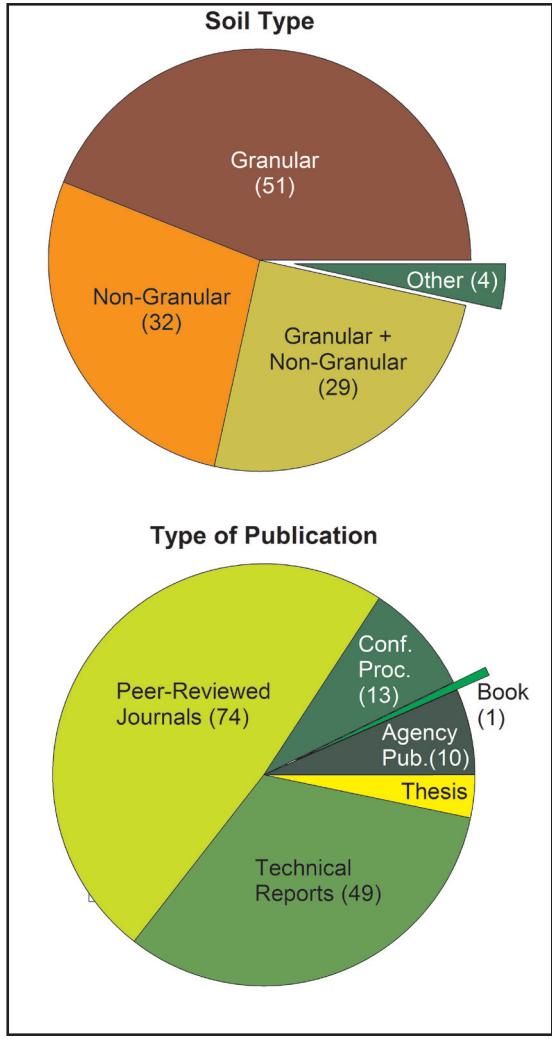
Out of the 153 assessed, 105 were from domestic research (within US) and were from international research (including Canada, South America, Europe, South Asia). The number of references collected based on the stabilization type, soil type, origin of publication, and type of publication are summarized as pie-charts Figures 2 and 3. A pie chart with number of references for each engineering category is shown in Figure 4. Out of the 153 references, 10 received a rating of 1, 70 received a rating of 2, 65 received a rating of 3, and 6 received a rating of 4. The literature that received ratings of 3 and 4 were considered in developing recommendations for field testing.

**Table 1. Literature assessment matrix**

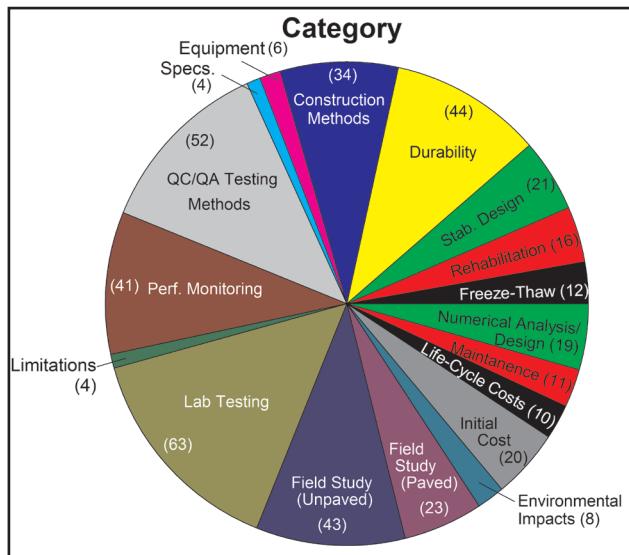
KEY:	Stabilization Type	Soil Type	Freeze/Thaw or Frost Boil Issues	Rehabilitation/Repair Options	Stabilization Design Procedure/Typical Values	Durability (Freeze/Thaw Cycles)	Construction Methods/Considerations and Time	Equipment and Contractors	Specifications	QA/QC Testing Procedures	Performance Monitoring Results	Limitations	Lab Testing Results	Field Study – Unpaved Road	Field Study – Paved Road	Environmental Impacts	Initial Cost	Life Cycle Costs	Maintenance Issues	Numerical Analysis / Thickness Design Aspects	Origin of Reference	Publication Type	Number of Instances Cited <sup>a</sup>	Rating (1 to 4) <sup>b</sup>
✓ = item addressed																								
C – Chemical stabilization (cement, fly ash, bitumen/asphalt emulsion, hydrated fly ash, lime, chlorides, sodium montmorillonite/bentonite, combinations, biofuel byproducts)																								
M – Mechanical stabilization (blending, geosynthetics, macadam base, fibers, use of recycled products)																								
B – Bio-stabilization (microbial)																								
G – Granular Soil																								
NG – Non-Granular Soil																								
O – Other (e.g., hydrated fly ash)																								
D – Domestic																								
I – International																								
AP – Agency Publication																								
B – Book																								
CP – Conference Proceedings																								
IP – Industry Publication																								
NJ – Non Peer-Reviewed Journal																								
P – Patent																								
PJ – Peer-Reviewed Journal																								
T – Thesis (Masters)																								
D – Dissertation (Doctorate)																								
TR – Technical Report																								
Addison and Polma (2007)	C	NG								✓	✓													



**Figure 2. Number of references obtained (# shown in parentheses) for stabilization type and origin of publication**



**Figure 3.** Number of references obtained (# shown in parentheses) for soil type and type of publication



**Figure 4.** Number of references obtained (# shown in parentheses) for each engineering category

One of the important findings of this study is that field performance measurements are lacking on unpaved rural surface roads that have been stabilized and subjected to freeze-thaw cycles over a long period of time. Out of the 150+ literature documents reviewed, only 5 relevant references were found on unpaved granular surface roads with a very limited amount of long-term performance measurements. Detailed field studies are needed with a variety of stabilization alternatives where long-term performance measurements before, during, and after spring thaw cycles can be monitored.

## Damage Mitigation and Evaluation Techniques

Based on the review of the literature, stabilization methods and drainage were identified as feasible mitigation solutions to the problems of frost heave and thaw weakening. Stabilization works by increasing the shear strength of the surface and/or subgrade layers to resist the actions of freeze-thaw and drainage works by eliminating or reducing water from the freeze-thaw process. Following is a list of different stabilization technologies identified in the literature:

1. Chemical stabilization using active chemical agents such as lime, fly ash, and portland cement, or passive chemical agents such as bitumen, foamed asphalt, bio-fuel byproducts, and polymer emulsions.
2. Mechanical stabilization by blending coarse-grained and fine-grained materials, using non-biodegradable reinforcements (such as fibers, geotextiles, geogrids, geocells, and geocomposites), using recycled materials (recycled concrete or asphalt and industrial by-products), and use of macadam base with large particle size to facilitate drainage and stability.
3. Bio-stabilization involving biological processes. This process is relatively new with very little field data.

Various damage evaluation techniques involving field and laboratory test methods to evaluate frost-heave and freeze-thaw damage have been documented in the literature.

Laboratory evaluations include characterizing soils' frost susceptibility ratings based on soil gradation parameters (percent finer than 2 microns) or conducting ASTM D5918 tests to determine frost-susceptibility and thaw-weakening susceptibility rating, heave rates and thawed California bearing ratio (CBR) values. Preliminary test results for a few Iowa soils are provided in the full report.

Field testing to evaluate damage during the spring thaw includes (a) visual inspection, (b) rut measurement, (c) dynamic cone penetrometer to determine frost depth and CBR profile (during thawing) down to about 3 ft., (d) falling weight deflectometer (FWD) to determine support capacities/stiffness of the gravel and foundation layers, (e) ground penetrating radar (GPR) survey to determine frost depth and evaluate road conditions, and (f) in-ground moisture content and temperature monitoring to determine thawing periods.

## Summary of Key Findings

Freeze-thaw cycles combined with frost-susceptible soils and inadequate drainage lead to damage in unbound roads, and in severe cases, make them impassable. Intersections and bridge approaches are common trouble locations, but damage due to frost heave and boils can occur throughout a given roadway depending on variations in drainage, construction quality, and traffic loading.

Some approaches currently used by County Engineers to deal with frost boils include temporarily spreading rock on the affected areas, lowering or improving drainage ditches, tiling, bridging the area with stone and geosynthetic covered by a top course of aggregate or gravel, coring bore holes and filling them with calcium chloride to melt lenses and provide drainage, and regrading the crown to a slope of 4 to 6% to maximize spring drainage. However, most of these maintenance solutions are aimed at dealing with conditions after they occur.

The primary task of this project was to perform a detailed literature review and then conduct a systematic assessment of the documents to identify technologies suitable for future evaluation and implementation in Iowa. An important outcome of this effort is an organized database of literature with 150+ technical articles on this research topic. The literature documents have been organized in to an electronic database, which can be shared with other researchers and practitioners.

## Recommendations

It is recommended that demonstration research projects be conducted to examine a range of construction methods for building and treating granular surfaced roadways. The primary methods identified in this study include chemical and mechanical stabilization; scarification, blending, and recompaction; removal and replacement; separation, and reinforcement; geogrids and cellular confinement; drainage control and capillary barriers, and use of alternative/ recycled materials. To be effective, stabilization practices must address multiple issues simultaneously, including water migration, durability, cost, performance under loaded vehicles and snow plows/blades, etc. A range of potential stabilization technologies to address these issues are proposed for field evaluation:

- Macadam base + 2 to 4 inches of unbound aggregate
- Surface treatment with bio-stabilization w/ calcium chloride
- Subsurface treatment w/ bio-stabilization + 4 inch wearing surface

- 12 inches of 10% cement stabilization + 2 to 4 inches for wearing surface
- Geo-composite drain at different depths
- 6 to 8 inch diameter aggregate column drains with and without geocomposite wrap
- High-energy impact compaction + surface compaction
- Geogrid (biaxial and triaxial)
- Heavy non-woven geotextile at 12 inches – stabilization and drainage
- Heavy woven at 12 inches - stabilization
- 2 inch drainage layer clean aggregate with non-woven above and below at 12 inches
- Base reinforcement with chip seal surfaces

Demonstration projects could be established to monitor a selected set of these technologies. The test sections of roadway should be monitored year round in terms of performance and maintenance requirements. The objectives of the demonstration projects could be to:

1. Perform field testing of a range of granular surface stabilization technologies.
2. Measure and document the performance of the demonstration roadway sections before, during, and after a seasonal freeze-thaw cycle.
3. Assess the initial cost, relative performance, maintenance requirements, and long-term life-cycle costs of the different stabilization techniques.
4. Identify the most effective and most economical alternatives for minimizing or eliminating frost heave/boil issues before they occur.

Evaluation of the field performance can be determined from laboratory and field testing. Laboratory testing should involve ASTM D5918 frost susceptibility rating tests. Field testing should capture FWD, DCP, and moisture and temperature data periodically throughout the year capturing freezing, thawing, and summer conditions over several years to obtain performance measurements. Further, visual observations and rutting measurements must be obtained to keep track of performance. For current monitoring, it is recommended that engineers use GPS enabled cameras and send images of problem areas for compilation on a common ftp site and the results studied to find geographic trends