DIFFICULT SUBGRADE CONDITIONS AND A COLD FALL LEADS THE ILLINOIS DEPARTMENT OF TRANSPORTATION TO SOIL STABILIZATION TO GET THIS PROJECT BACK ON TRACK

Technical Case Study

Transportation - Pavement Construction

Mt. Carmel Stabilization Group is the leading soil stabilization company in North America with over 60 years of experience in providing expert soil stabilization services to our customers across the country. Our technical reports and case studies are an effort to educate our contractor partners, consultants and agencies on the merits of design, construction, and the environmental benefits of soil stabilization.

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Project Location: Sugar Grove, IL

Introduction

This two part case study examines the use of Lime Modification to solve the problems that were encountered during the construction of a new road in Sugar Grove, Illinois in November, 2008. Mt. Carmel Stabilization Group, North America's leading soil stabilization company since 1949, was hired by Geneva Construction, North Aurora, IL, to improve subgrade soils that were extremely unstable and to build a solid working platform for pavement construction to resume in order to meet the deadline on this Illinois Department of Transportation (IDOT) project in District 1.

Poor subgrade soil conditions in road construction are commonly encountered in northern Illinois and in much of the United States. These conditions cause problems for everyone involved on a project from the pavement designer and project owner, all the way to the contractor trying to build the road. The term, poor soil conditions, is a commonly used term to describe a variety of soil types and situations. These include: weak soils, pumpy soils, highly plastic soils, expansive soils, soils with high silt content and of course, wet soils. All of these conditions contribute to the poor engineering properties of a pavement's subgrade and subsequently, the pavement is difficult to construct and may require additional thickness to account for the underlying poor soil. There are many remediation techniques that have been used over the years to deal with the multitude of problems that a poor subgrade presents during pavement design and construction. A very common, economical and effective treatment method is Lime Modification.

Inside:

The Problem

Engineering Enterprises, Inc. (EEI), Sugar Grove, IL was the consulting firm acting in cooperation with IDOT, village officials and Geneva Construction on this project. This particular contract is the second phase of the construction of two new roads - Municipal Dr. and Galena Blvd. in Sugar Grove that are intended to serve as a spur for new commercial and retail development. Much like in the first phase, EEI knew that when the area in contract B was excavated, poor soil conditions would be encountered and they would have to be addressed. Todd Wells, EEI's Senior Project Engineer explained that they were forced to undercut about 70% of contract A because of the soil conditions. The soils encountered on contract B were similar. Some areas were primarily

Standing water and deep ruts were causing major delays for Geneva Construction on this project.

fat clay (high plasticity, high swell potential) and wet lean clay (more silt and sand) was common in other areas. The entire area was extremely unstable. Based on the DCP (Dynamic Cone Penetrometer) results, they were anticipating undercutting the entire area to a depth of 12" – 18" and replacing it with coarse aggregate.

Soil samples from the project were taken to a geotechnical testing laboratory for analysis. The characteristics of the "in-situ" soils are shown in Table 1, exemplifying exactly what was seen in the field.

In Situ Soil Properties

The most representative soil from this site is described in Table 1. This soil is high in clay content (35%) as well as silt content (57%). The result is a very weak and unstable base when at or above optimum moisture content. This helps explain why the field conditions were so poor.

Soil Classification	A-7-6, CL
Optimum Moisture %	20%
In-Situ Moisture %	25% - 30%
Plasticity Index	29
In-Situ Immediate Bearing Value (IBV)	0 - 3
Illinois Bearing Ratio (IBR)	3.5

Table 1 - Soil properties in situ, prior to lime treatment.

Proposed Solutions

Everyone involved on the project gathered for a meeting on site in early November to discuss solutions to the problem. IDOT Geotechnical Field Investigator Chad Goddard was at that meeting and explained that undercutting was certainly an option and it is a common solution to poor subgrade soils in District 1. Geneva Construction mentioned Mt. Carmel Stabilization Group, and hiring them to perform lime modification as an alternative. Mr. Goddard advised the group that lime modification is certainly a viable alternative and that the decision on which method to choose should be based on the construction costs.

One Problem, Two Solutions

Option 1 - Undercut & Backfill

This is a common approach to dealing with poor subgrade soils, particularly in northern Illinois. The area is excavated to a depth that exposes drier, more desirable soil conditions. The excavated soil is then transported off site for disposal. Select granular fill, in this case coarse aggregate, is brought in to replace the undercut area. The aggregate is delivered to the site and placed, shaped and compacted back to the original elevation. The cost associated with this process is often quite significant and the truck traffic and material involved can be a burden to the surrounding community. On this project, the total undercut area was fairly large - 18,975 square yards. Based on a 12" undercut, the total volume of material estimated to be removed from the site and replaced with aggregate fill totalled 6,325 cubic yards. The cost for

this process on this project is summarized in Table 2.

Option 2 – Lime Modification

Based on over 15 years of prior experience with Mt. Carmel Stabilization, Geneva Construction was confident that they could fix the problem on this project at a much lower cost than undercutting and bacfill. However, with the exception of Geneva, no one else on the project had much experience with Mt. Carmel and lime modification. Consequently, the suggestion for lime modification was met with some skepticism and uncertainty. Concerns about the effectiveness of this method and the perception of the process being too dusty were raised.

Mt. Carmel Stabilization Group has been providing expert soil stabilization services across the country since 1949. "The soil stabilization industry has grown exponentially in the last sixty years and a lot of the growth has occurred in the last ten years. We have been fortunate enough to lead the growth in our industry and today we are the largest soil stabilization company in North America. We are dedicated to stabilization, because stabilization is all that we do and our personnel approach every project with the same attention to detail and dedication to quality because if we don't, the entire industry gets a black eye." Says Neil Ryan, Marketing Manager for Mt. Carmel.

The soil stabilization industry encompasses three major processes: 1) Soil Drying, 2) Soil Modification and 3) Soil Stabilization. Various chemicals are used to achieve all three processes based on soil conditions and soil types. Lime modification is a process that essentially engineers the existing poor soil in place, alleviating the need for undercutting and replacing the subgrade soil. Mt. Carmel's own custom built spreader trucks apply Lime Kiln Dust (LKD) to the subgrade at a rate that is determined by the project superintendant. A 5% application rate is a very common treatment rate. Water is added to the area to ensure the LKD is properly hydrated and the soil is at its optimum moisture content for compaction. The LKD and subgrade soil is then mixed to a depth of 16" using high powered, self-propelled rotary mixers. This mixing equipment is specially built for soil stabilization applications and is capable of thoroughly pulverizing and mixing even the most difficult soils with any chemical in one or two passes. Following mixing, the area is shaped with a motor grader, compacted with a pad foot roller and then sealed with a smooth drum roller.

Lime Modification improves a number of engineering properties of poor soils including reduction in plasticity index, reduction or elimination of swell potential, as well as significat increases in unconfined compressive strength, Immediate Bearing Value (IBV) and Illinois Bearing Ratio (IBR). The soil gains strength immediately because of the reaction between LKD, water and the soil. The increased soil strength provides the stability

The Caterpillar RM 350 Road Reclaimer mixes lime and soil 16" deep. Mt. Carmel maintains a fleet of 28 various makes and models of similar machines for soil stabilization.

necessary to create a solid working platform for pavement construction to continue and to facilitate other construction operations. On average, IDOT does about 1.5 million square yards of lime modification every year. This project was, however, a first in District 1.

IDOT District 1 includes Metro Chicago. The majority of transportation construction projects in District 1 are multi-phase reconstructions in high traffic volumes with extensive underground utilities. Though it is very common on similar projects across the country and certainly within the Midwest, the use of soil stabilization applications on these project is sometimes less applicable than in new alignment projects such as the Municipal Drive project in Sugar Grove. Mt. Carmel and the stabilization industry as a whole still believe that there is ample opportunity for the wide use of lime modification for both new construction and reconstruction within District 1 for the improved subgrade layer as well as for alleviating undercuts.

A major benefit of lime modification is the beneficial use of existing soil. There is no need to remove and waste poor soil - it can be treated in place and made stable. Speed of construction is another major benefit. Lime modification happens very quickly, there is no extensive curing period. Mt. Carmel will typically

complete a minimum of 10,000 square yards per day with a single crew. However, it is the economics of soil stabilization that has truly driven the industry's growth. Table 2 illustrates the significant cost savings on this project using lime modification vs. traditional cut and fill.

Spreading and mixing operations continue on Municipal Dr. in Sugar Grove, IL.

Treatment Method	Unit Price (SY)	Total Square Yards	Total Estimated Cost	Estimated Savings
Undercut 12" and Backfill with Coarse Aggregate*	$16.47	18,975	$312,518	--------
Lime Modification 16" Depth	$4.85	18,975	$92,029	$220,489

Table 2 - Cost savings using lime modification vs. cut & fill.
*This is the average awarded price in 2008 in IDOT District 1 for this process and is estimated to be representative of the cost on this project. The unit price for lime modification is the actual price paid on this project.

Lime Modification is Chosen Based on Economics

Mt. Carmel arrived on site with their equipment and personnel on a cold, 20° Monday morning in mid-November. The subgrade was rutting with moisture contents ranging as high as 30 – 35%. On the south end of Municipal Drive, the fat clay was rutting under light truck traffic and almost 2' of fill was needed to achieve subgrade elevation. On the north end of the extension the soil was much siltier and extremely unstable. Given the variation in soil types and conditions on this project, Mt. Carmel benefited from the experience of their Superintendant, Jim Pape, who has been working for Mt. Carmel in northern Illinois for nearly twenty years. There is virtually no project type or soil condition that Jim has not encountered during his tenure and he knew that this job was going to be a challenge. "In this part of Illinois soil types change constantly. I was not surprised to see the sandy, silty area right next the heavy clay soil, that's just the way it is up here. Special measures have to be taken because all soil types react differently with lime, water, mixing and compaction. Careful attention to detail is the key to quality."

Mt. Carmel began their operation around 7:00 am. By 10:00am the south end of Municipal Drive had been treated and compacted and was ready for the excavator, J&S Construction, Sandwich, IL, to begin placing the next lift of fill soil to bring the area to elevation. J&S finished placing the second lift of fill on the south end by mid afternoon while causing no damage to the subgrade that had just been treated. Needless to say this would not have been possible on the untreated, in-situ soil conditions. This is the same area that was rutting under light truck traffic just a few hours before and now it is supporting loaded scrapers and tractors.

Mt. Carmel completed the entire first lift of Municipal Drive on the first day of construction and treated a large stockpile of soil in the outlying areas that would later be picked up by J&S and used as fill in other areas of the project.

Just a short time after Mt. Carmel finished treating this area, J&S is already placing the next lift on the south end of Municipal Dr. This same area was rutting under light loads just hours before.

IDOT Personnel Recognize Dust Free Operation

Mt. Carmel invited personnel from IDOT District 1 Construction and Geotechnical departments to come and view the process on this project located about 40 miles west of Chicago. Even with the cold temperature and the wind gusting to 25 mph, several took the opportunity to see the soil stabilization process and equipment in action. All were impressed by the speed of construction and the noticeable improvement in just a few short hours. What stood out the most to them was the process was nearly dust free.

All of Mt. Carmel's 65 spreader trucks are designed and custom built in house by their people. The trucks that Mt. Carmel used on this job are equipped with a patented dust collection system that captures fugitive dust and sends it back to the material hopper.

Mt. Carmel builds every one of their spreader trucks in house and has for over 60 years. For this project, Mt. Carmel chose two spreaders from their fleet of 65 that are specially designed to minimize dust during spreading. The back of the truck is equipped with a patented dust collection system that is constantly capturing any fugitive dust emitted during spreading back and recycling it back into the spreader's hopper. Gregg Shaw, Project Manager for Mt. Carmel explains the importance of these spreaders, "We take spreading accuracy and dust control seriously and we have spent a lot of money over the years trying to build the "perfect" trucks. For this project, given the location and the situation, these spreaders helped us provide a high quality product while minimizing dust for the surrounding community." Todd Wells of EEI commented that, "There's more dust coming from construction equipment driving around the site than from Mt. Carmel spreading lime."

Lime Kiln Dust is an extremely fine, lightweight, dry powder. On this job, a 5% application rate was used. This amounts to 65 lbs. of LKD spread per square yard. This spread rate is controlled by the truck operator and accuracy is critical for a high quality end product.

A Problem Solved with Time and Money Saved

Mt. Carmel completed the lime modification of approximately 30,000 square yards, including multiple lifts of fill in some areas, in less than three working days. It was determined based on the soil conditions that a consistent 5% application rate would achieve the desired results. Weather was of some concern during construction as the average high temperature was only 40° and the nightly lows dropped below 20° every night. What came as a surprise to some on the project was the way the lime modified soil held up to low temperatures and rainfall. Over ½" of rain fell during the first night of construction. Combine that much moisture with low temperatures and it typically spells trouble. The lime modified soil was very resilient in these conditions and showed no signs of weakness. "Once we have completed our process, including sealing with a smooth drum roller, the layer is virtually impervious to water. The beauty of lime modification is that you have chemically engineered the soil to behave how you want it to, it's not going to go back to what it was before we treated it." explains Ryan.

Improvements seen in the field demonstrated the many benefits that lime modification can bring to a project. Subgrade stability and minimum deflection were two of the obvious and most important benefits for pavement construction. Of some concern to EEI was the high

plasticity, fat clay on the south of Municipal Drive. This soil has a tendency to swell when exposed to moisture and is generally undesirable subgrade soil to build a pavement. Lime modification decreased the Plasticity Index of this soil, likely completely eliminating its potential to swell. Table 3 shows detailed results of the many improved engineering properties of the lime modified soil.

> ***"There's more dust coming from construction equipment driving around the site than from Mt. Carmel spreading lime."***
>
> Todd Wells, Senior Project Engineer with EEI

This Project Was a Success

According to all involved on the project, the use of Lime Modification was a success. The village of Sugar Grove and IDOT certainly realized a significant cost savings on this project by using Lime Modification in lieu of undercutting. Mt. Carmel also demonstrated to many that were unfamiliar with the process or the results, that soil stabilization applications can turn a wet, weak and rutting subgrade into a stable working platform capable of passing a proof roll in a matter of hours. The use of Lime Modification and soil stabilization applications is a very common, environmentally friendly and cost effective alternative for solving the problems that poor subgrade soils present in design and construction.

The Cat RM 350 and other similar machines designed for stabilization applications is the only way to thoroughly blend and pulverize the lime and soil. Thorough mixing is critical to the performance of the treated soil. Discs should never be used for soil stabilization.

The motor grader shapes the area to rough grade.

Mt. Carmel uses a Cat vibratory pad foot roller for initial compaction of the lime modified soil.

The last step in the soil stabilization process is final compaction and sealing with a smooth drum roller.

Laboratory Results of Lime Treated Project Soil

Soil samples were gathered from this project and taken to a laboratory for comparative testing. Table 3 shows the results of these tests and further illustrates the impact lime modification had on this soil.

	Untreated	5% LKD
Soil Classification	A-7-6; CL	A-6; CL
Plasticity Index	29	**12**
Percent Swell	1.13%	0%
Immediate Bearing Value (IBV)	0-3*	**22****
Illinois Bearing Ratio	3.5	**31**

Table 3 - Laboratory results showing the improved engineering properties of project soil treated with 5% lime. All testing was done in accordance with the Illinois Department of Transportation Geotechnical Manual, Appendix II.

*Based on in-situ moisture content of 25-30%

**Based on 110% of optimum moisture content or 20% moisture.

Immediate Bearing Value and Illinois Bearing Ratio

The Immediate Bearing Value (IBV) and the Illinois Bearing Ratio (IBR) are both unique to the Illinois Department of Transportation. The IBR is nearly identical to the CBR (California Bearing Ratio) which is a value used to measure the support of roadbed soils. According to the IDOT Geotechnical Manual, the IBR is assumed to have the same numerical value as the CBR for design purposes. Both the CBR and IBR are lab tests that measure a piston penetration rate into a sample that has been soaked for four days. The IBR and CBR values are widely acknowledged to correlate with pavement performance in that the higher the value, the better the pavement performs over its service life.

IDOT no longer uses the IBR for Mechanistic Pavement Design as the MPD does not use the subgrade layer in the pavement structure. IDOT needed a method for measuring a subgrade's stability under heavy construction loads and thus created the IBV test to determine the bearing value of a subgrade soil immediately after compaction (without soaking). The IBV can be determined in the lab and also in the field using a DCP (dynamic cone penetrometer). IBV values help determine the treatment thickness; typically either Lime Modification or undercut & replace with granular material, for weak subgrade soils in the field. When lime modification is used, the minimum IBV is to be no less than 10-12%. According to both lab and field results, Mt. Carmel greatly exceeded this requirement. Chart 1 illustrates the dramatic improvement of the IBV of this soil.

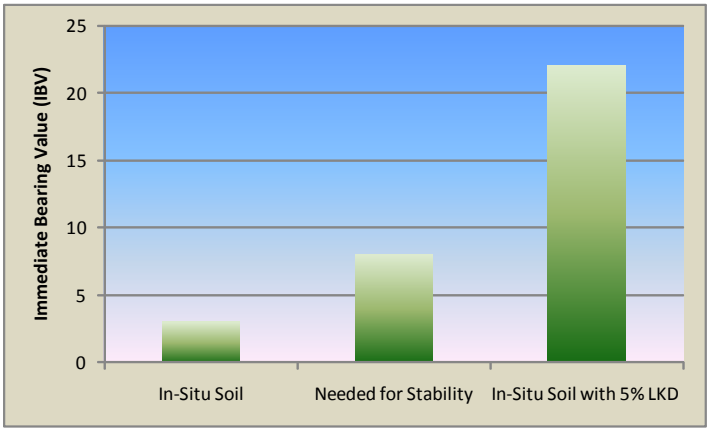

Chart 1 - Immediate Bearing Value (IBV) of soil before and after adding lime kiln dust.

Strength Gain by Adding Lime Kiln Dust

Lime Kiln Dust is a by-product generated from the production of quicklime which is a process that uses high temperature rotary kilns to calcine limestone. During this process Lime Kiln Dust is captured in the kiln air pollution control systems such as baghouses, cyclones and electrostatic precipitators. Lime Kiln Dust used on IDOT projects must conform to the IDOT specification 1012.03 By-Product Lime for Lime Modified Soils.

Lime products are high in available lime (available CaO as determined by ASTM C 25). When hydrated, calcium oxide becomes calcium hydroxide which reacts with the available silica and alumina in clay soil to form cementious bonds (the pozzolanic effect). Lime Kiln Dust is a unique lime product because of its chemistry. Lime Kiln Dust typically has a high percentage of silica and alumnina present in the material in addition to the

available lime. This means that Lime Kiln Dust is a lime product that is also self cementing, which makes it extremely effective in modifying and stabilizing soils with a lower clay content and plasticity index as well as high PI soils. Whereas quicklime or hydrated lime is largely dependent on the soil having a high clay content in order to get high strengths, Lime Kiln Dust is not. This versatility was important on this particular project because of the varying soil types.

Lime Kiln Dust has been widely used by the Illinois Department of Transportation and several other transportation departments and public agencies since the early 1980's. On average IDOT will perform over 1.5 million square yards of lime modification per year and all of those projects will use Lime Kiln Dust.

Lime Kiln Dust's Effect on Plasticity Index

Lime products high in available lime such as LKD have numerous beneficial effects on medium to high plasticity soils such as the soil encountered on this project. One benefit is a reduction in a soil's plasticity index or PI. The PI is a good indicator of a soil's stability at high moisture as well as it's potential to swell. The percent clay fraction and the clay mineralogy in a soil are the largest factors influencing the PI.

Flocculation & Agglomeration

In untreated clay soils, clay particles are aligned horizontally and are surrounded by water molecules. This horizontal structure is similar to that of polymers. As the moisture content goes up, the soil will enter a plastic state. This is the soils's plastic limit or PL as determined by AASHTO T-90. The soil will behave this way until it is altered chemically with material such as Lime Kiln Dust.

When Lime Kiln Dust is mixed with clay soil, a cation exchange takes place. This means that the calcium and magnesium atoms from LKD replace the sodium and hydrogen atoms in clay. The resulting flocculation and agglomeration leaves the soil much more granular and friable and with a reduced plasticity index. This effect was very evident on this particular project soil. The PI dropped from 29 (considered a fat clay) to 12 with the addition of 5% LKD. Flocculation and agglomeration happens virtually immediately and the change in the soil's physical characteristics is very noticeable in the field.

Below is a schematic exmple of flocculation and agglomeration when adding LKD to clay soil.

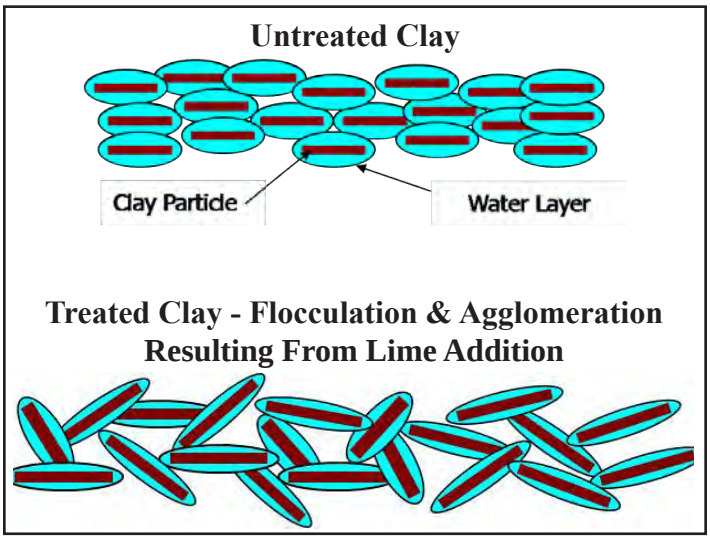

Photo courtesy of Carmeuse Lime.

A field example shows the effects of flocculation and agglomeration resulting from lime treatment. The soil in his right hand is what went into the mixer, the soil in his left hand is what came out. PI reduction happens very quickly when using lime products and proper mixing equipment.

Summary

1. IDOT personnel, consultants for the Village of Sugar Grove and Geneva Construction were faced with wet, weak and unstable subgrade conditions that required treatment for pavement construction to continue in the cold weather of late fall in northern Illinois.

2. The options for subgrade treatment were cut and fill with coarse aggregate or lime modification performed by Mt. Carmel Stabilization Group.

3. Lime modification was chosen as the most cost effective solution on this project. The estimated total savings resulting from the use of lime modification vs. cut and fill was over $220,000. Lime modification allowed for the use of existing soil on the site and alleviated the need for removing this soil and importing replacement material. Lime modification is an environmentally friendly construction practice.

4. Mt. Carmel completed the project quickly and effectively utilizing custom built spreading equipment that is designed to minimize fugitive dust during lime spreading and high powered rotary mixers designed for soil stabilization applications.

5. Lime modification on this project was considered a success by all involved and the use of soil stabilization applications such as 1) Soil Drying, 2) Soil Modification and 3) Soil Stabilization is a common, economical and effective method of solving the problems that poor subgrade soils present in design and construction.

5. Soil samples were taken from the project and tested in a geotechnical laboratory. Testing showed the many improvements that resulted from the addition of 5% Lime Kiln Dust on this project's soil. These include:

a) Moisture Reduction
b) Plasticity Reduction
c) Swell Reduction
d) Increase in Immediate Bearing Value
e) Increase in Illinois Bearing Ratio

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5. Lawrence W. Cole, P.E. (2007). *Effects of Lime Kiln Dust and Self-Cementing Fly Ash to Dry and Modify Soil.* Pittsburgh, PA: Carmeuse Lime .

All laboratory testing was completed by:

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Production – Our typical daily production is unmatched by any competitor. With 65 spreaders and 28 mixers we can also tailor our production to meet any requirements.

Flexibility – Getting to the job quickly and getting the job done right is what keeps our customers satisfied. To serve our customers in locations across the country, we mobilize our crews on and off different projects more than 20 times a week.

Customer Service - When you call Mt. Carmel, you will speak to one of five project managers that will be your point of contact from project start to finish.

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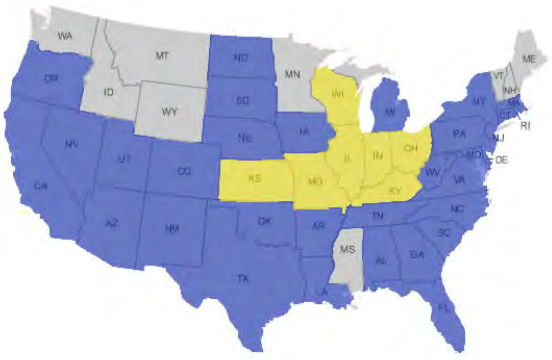

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