Effective Treatment for High Sulfate Soils

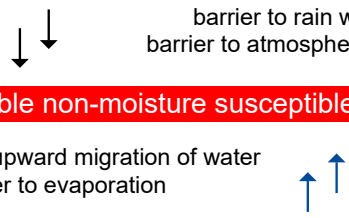
The **EMC SQUARED**® System (EMC2) — Advanced Stabilization Product Technology. Clean. Green. Concentrated power to improve the stability of earth materials at low cost. Applied as compaction water additives to aggregates, soils and recycled pavement materials with pre-established compaction controls and construction procedures, preconditioning aggregate materials to behave more like conglomerate rock, clays like claystone, sands like sandstone, and silts like siltstone, paralleling the natural processes of consolidation and lithification. These stabilizer products have been in use for over three decades for construction of city streets and expressways, county roads, interstate freeways, industrial and renewable energy sites, military supply routes and runways, remote unpaved highways, border roads, haul roads, forest roads, oilfield access roads, temporary and permanent closures of construction sites and landfills, and for other applications.

LABORATORY RESEARCH STUDY

The **EMC SQUARED** System was evaluated in a two year laboratory study at the Texas Transportation Institute (TTI), which was funded by the Texas Department of Transportation (TxDOT). The principal author of the study was Dr. Robert Lytton, Research Engineer for TTI and Director of the Center for Infrastructure Engineering at Texas A&M University. The study focused on identifying effective treatment for sulfate bearing expansive clay soils. Soils used in the laboratory testing were sampled from locations on Interstate 635 Lyndon B. Johnson Freeway (the "LBJ"), and the Highway 161 section of the President George Bush Turnpike (PGBT), where lime treatment of sulfate bearing soils had resulted in major pavement failures. The study found that the **EMC SQUARED** System treatment was superior to lime in strength, stiffness, swell resistance and permeability, and recommended its use for subgrade treatment in areas where application of lime treatment had historically led to sulfate-induced heave and costly damage to pavements.*

The table and graph on the next page show the results of TTI tests with the SH-161 project soils evaluating the effectiveness of lime treatment in comparison to the **EMC SQUARED** System in strength and stiffness, and in reducing moisture susceptibility, the most important difference between lime and the **EMC SQUARED** System product technologies. The **EMC SQUARED** System very directly targets moisture flow and moisture susceptibility problems. Research findings have clearly demonstrated that lime does little to impede moisture flow through treated subgrade soils and that lime, in fact, typically increases soil permeability.** Permeability, or "hydraulic conductivity" tests, were also conducted on the SH-161 soil specimens. At $8.9x10^{-10}$ cm/sec. permeability, the **EMC SQUARED** System treatment effectively reduced moisture flow to less than one thousandth of an inch per month. With the velocity of water flow reduced to this rate and soil moisture susceptibility effectively treated (see Dielectric Value test results on next page), the **EMC SQUARED** System treatment is obviously providing an effective moisture barrier. While the very low permeability is significant, keep in mind that it's the combination of lowered permeability and treated moisture susceptibility that creates a stable and effective moisture barrier layer. Without effective treatment of its affinity for water, a low permeability clay (or lime treated clay) will still slowly saturate itself as it suctions water.

EMC SQUARED SYSTEM STABILIZED SUBGRADE



Unlike lime treatment, **EMC SQUARED** System treatments reduce moisture infiltration and moisture susceptibility and promote moisture barrier benefits. A stabilized subgrade that also functions as a moisture barrier layer not only retains its own flexural stiffness, but also protects the stability of the soils below as it cuts off the atmospheric effects (wetting and evaporative) and fluctuations in moisture content that otherwise drive the swelling and shrinking in the soils below the treated subgrade and generate differential settlement, roughness and cracking in the pavement above.

*Summary Of Research Report 3929-1 at https://stabilizationproducts.net/docs/18588.pdf

** Lime Treatment Tradeoffs at https://stabilizationproducts.net/docs/18392.pdf

STRENGTH AND STIFFNESS

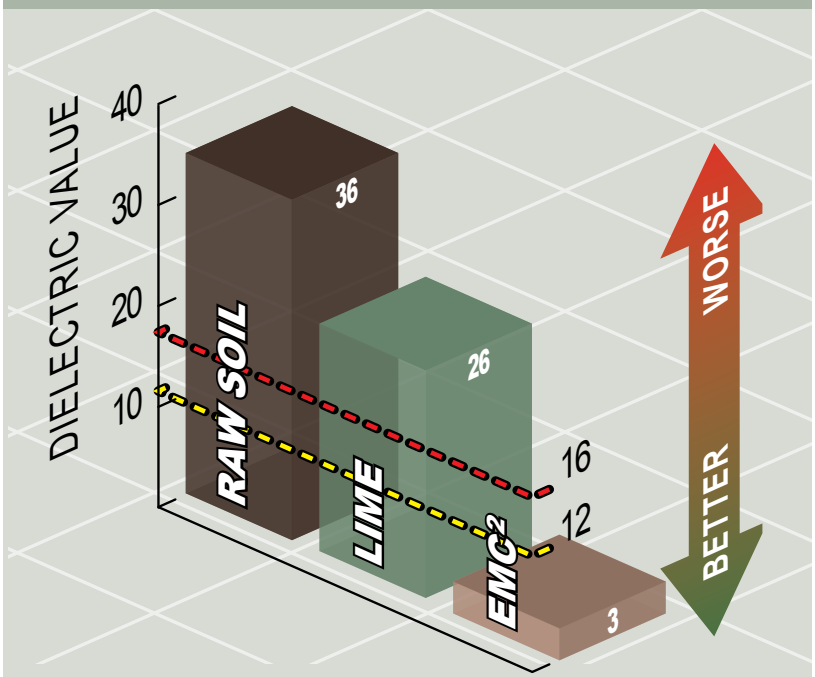
President George Bush Tollway
SH 161
Triaxial Testing by the Texas Transportation Institute

TREATMENT	STRENGTH psi (kPa)	STIFFNESS psi (kPa)
EMC SQUARED SYSTEM	399.04 (2,751.29)	5,000.00 (34,473.79)
LIME	341.55 (2,354.91)	3,166.67 (21,833.43)
NOT TREATED	232.56 (1,603.45)	588.24 (4,055.75)

The laboratory research study was conducted at the Texas Transportation Institute (TTI). This TTI research study used sophisticated test methods conducted over an extended period of time, allowing more accurate modeling of the field service environment and more profound evaluation than would be possible using conventional accelerated laboratory test methods. This research study resulted in a final report that recommended use of the **EMC SQUARED**® stabilization treatment in place of lime and other calcium-based stabilizers. The report also recommended that a stabilized test section be constructed and monitored prior to use on large scale freeway and highway projects.

REDUCTION OF MOISTURE SUSCEPTIBILITY

Dielectric Testing by the Texas Transportation Institute



As indicated above, the dielectric measurements for the **EMC SQUARED** System treated specimens averaged 3, which is well below 12, the value established by researchers as the upper limit for expansive clay soils if they are to be considered suitable for use as highway subgrade materials. This is also significantly below the dielectric value of 16, at which point it is predicted that plastic deformation will occur within the structure due to physical property changes in the soil which are driven by moisture infiltration and fluctuations in moisture content. Note also that the untreated or raw soil at 36 and the lime treated soil at 26 greatly exceed the upper limit for Dielectric Value. The test values indicate that the lime treated soil is still highly moisture susceptible.

FIELD TEST

District and area engineers in TxDOT Dallas District worked together to locate a field test pad location with representative problem soils and a situation where a stabilized subgrade layer could be directly subjected to an extended period of intensive truck traffic without a protective pavement cover. A highway construction project under TxDOT supervision provided the perfect opportunity as the contractor was planning to locate a large portable concrete batch plant operation to supply the concrete requirements for this highway pavement and other projects planned for the year ahead in the local area.

An elevated two acre pad was constructed with the local highly expansive clay soils. An **EMC SQUARED** System treatment was mixed in and highly compacted to create an eight inch thick working platform. This platform supported heavy use by cement trucks, aggregate haul trucks, large front-end loaders and concrete delivery trucks without rutting, cracking or need for repair. As much as 20,000 tons of aggregate was hauled in and stored on the stabilized pad for each production run. The stabilized working platform supported the stockpiling operations as well as thousands of loaded truck trips and thousands of trips by a large wheel loader as stockpiled concrete aggregate was transported to the concrete batch plant. After a year in which three large projects were supplied, the batch plant was demobilized and the site reprofiled to restore agricultural operations. The **EMC SQUARED** System treatment proved to be highly effective, and at a fraction of the cost of cement or lime treatment.

MONITORING

AFTER 18 YEARS –
SURFACE CONDITION & IRI RATING

Synthesis Summary of Projects in Dallas, Texas — ARA Report No. 003563-1*

Following the Laboratory Research Study and the successful Field Test, a population of full scale highway projects in the Dallas Area were constructed on subgrades stabilized with **EMC SQUARED**® System stabilizer products. A follow-up study* conducted in 2018 by a highway research engineer that included four Dallas Area freeway projects and a major arterial road further confirmed the contribution of the **EMC SQUARED** stabilizer product technology to the construction of smooth running roads and highways. The study incorporated the most up-to-date International Roughness Index (IRI) data collected by the two public agencies responsible for the construction and maintenance of these highway projects, the Texas Department of Transportation (TxDOT) and the North Texas Tollway Authority (NTTA).

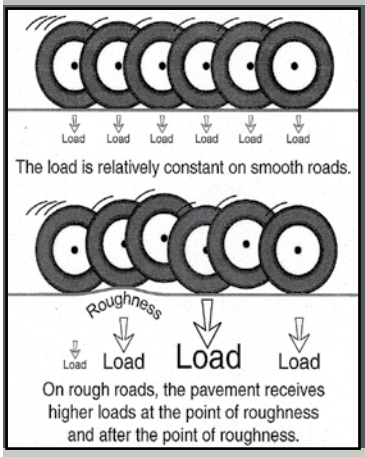
As of 2018, these five projects had all been in service for approximately 18 years. All five projects presented the challenge of constructing pavements over famously problematic high sulfate soils with a history of cracking, buckling up and heaving asphalt and concrete pavements constructed on top of them. Two of the four freeway projects were the subject of the Texas Transportation Institute (TTI) laboratory study that recommended the use of **EMC SQUARED** System products for subgrade stabilization. Lime treatment, the traditional chemical stabilizer used throughout Texas was found to be ineffective, and in fact counterproductive, when applied to these Dallas Area soils. The study was tasked with identifying an effective alternative to lime treatment. The study found that **EMC SQUARED** System products were superior to lime in strength, stiffness, swell resistance and permeability and recommended use of **EMC SQUARED** System products for all projects with similar problem soils.

Synthesis summary continues on next page.

INTERNATIONAL ROUGHNESS INDEX (IRI)

Pavement smoothness has become the most recognized international index for the evaluation of pavement performance. The rate at which a pavement develops roughness is a generally accepted index for predicting the limits of the remaining service life of a specific section of highway pavement. International Roughness Index (IRI) measurement have been in nationwide use since 1990 when the Federal Highway Administration (FHWA) mandated implementation by all state highway agencies. The ultimate goal of subgrade stabilization, beyond providing an effective working platform, is to maintain pavement smoothness by protecting against differential settlements. IRI testing evaluates this fundamental performance criteria more directly than any other field test.

The highway projects under the control of the Texas Department of Transportation (TxDOT) and the North Texas Tollway Authority (NTTA) have been monitored annually for pavement smoothness and the data was reviewed after eighteen years. As summarized in the yellow box at the top of the next page, the pavement installations above subgrades constructed with **EMC SQUARED** System treatments were free of distress and retained smooth running alignments.



HOW PAVEMENT ROUGHNESS GENERATES DYNAMIC LOADS

Pavement roughness leads to higher dynamic loads on localized pavement sections which increases pavement deterioration at those locations. This not only lowers ride quality, but also leads to a cycle of increasing deterioration rates and roughness severity.

***Overview of PCC Pavement Projects Built with EMC SQUARED Liquid Chemical Stabilizer**
Harold L. Von Quintus, P.E.
Applied Research Associates, Inc.
Full report available upon request

Synthesis Summary of Dallas Projects

Project Identification	Surface Condition Category	IRI Category
Interstate Highway 30 (TxDOT - Dallas Fort Worth Turnpike)	Excellent	Good
SH 161 (NTTA - President George Bush Turnpike, DNT-346)	Excellent	Good
SH 190 (NTTA - President George Bush Turnpike, DNT-323)	Excellent	Good
Interstate Highway 636 Frontage Road (TxDOT - LBJ Freeway)	Excellent	Good
Luna Road (TxDOT)	Good	Good

The four freeway projects that were subsequently constructed in Year 2000 and evaluated in 2018, as shown in the yellow box above, were all constructed on top of highly problematic soils. They were constructed with proper drainage conditions. The alignment of the fifth project, a major six-lane arterial (Luna Road) located in the Trinity River Watershed, required construction of a tall embankment running through two lakes. The design consultant (HDR Engineering) protected the stability of the clay embankment soils by including a 12-inch thick **EMC SQUARED**® System moisture barrier layer within the lower portion of the embankment just above the water level of the lakes.

These freeway and highway projects have been in service under very heavy traffic volume since their construction. As shown in the yellow box above, results from ARA Report No. 003563-1 confirmed that the pavements constructed on top of subgrades stabilized with the **EMC SQUARED** System treatments remained in Excellent condition overall. The International Roughness Index (IRI) test results demonstrate that the pavements constructed above the stabilized subgrades are performing very well. The ARA Report validated the findings of the TTI laboratory study and confirmed the effective performance of **EMC SQUARED** System treatments in preserving the integrity of the pavement and its smooth-running ride quality.

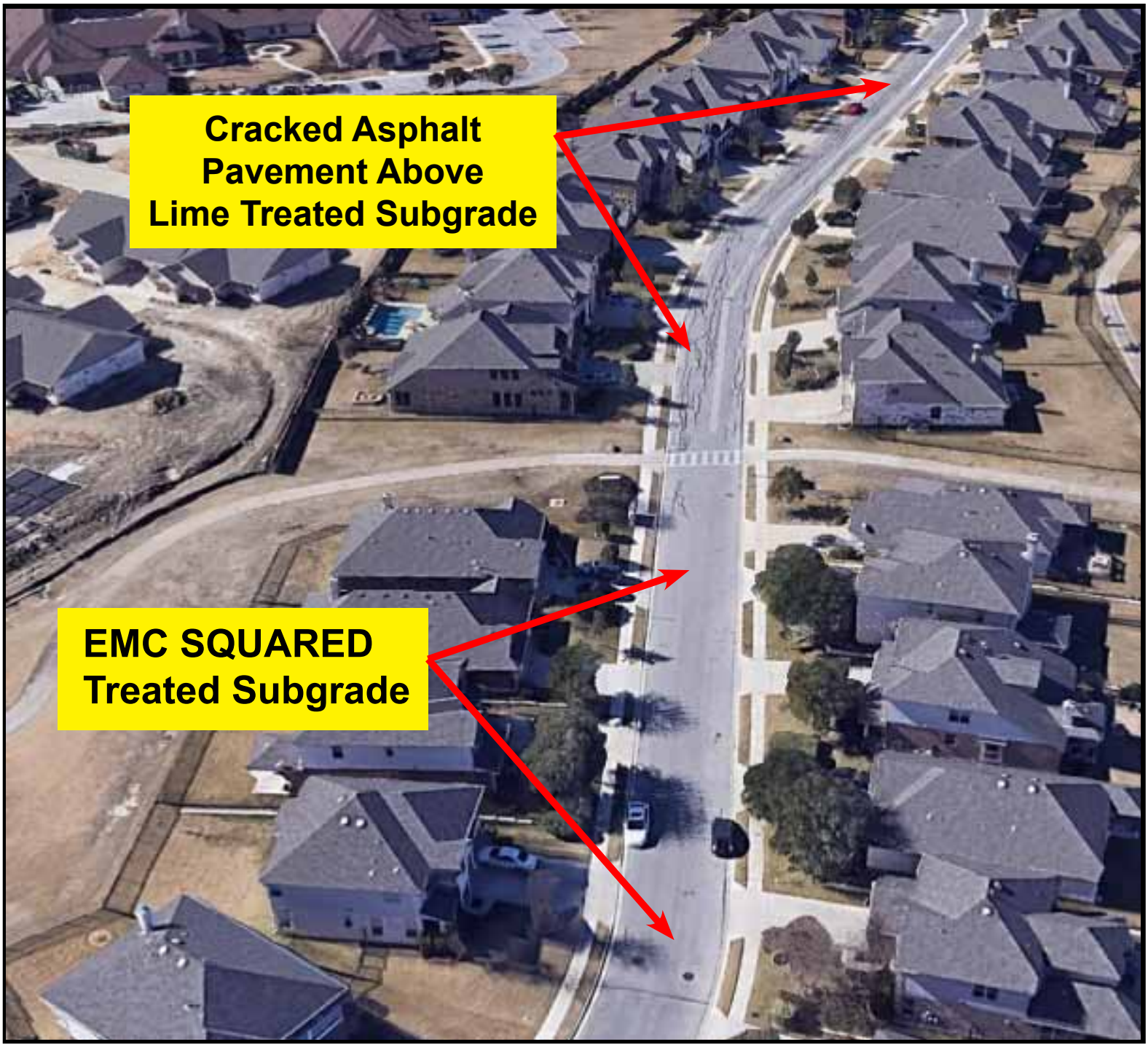
Austin Area

Teravista Community is a master-planned development on the northeast side of Austin, Texas, in an area known for expansive clay soils with high sulfate and high organic content. Conventional design approaches proved unsatisfactory before the geotechnical engineering consultants identified an effective option after reviewing the test results of the TTI research study.

The first option was a conventional structural section under the asphalt pavement that required importation of 18" of low-plasticity soil covered by 18" of crushed aggregate base course materials. While this pavement design proved effective and durable over time in many of the first phases of the development, it was prohibitively expensive. The next pavement design lowered costs by reducing the thickness of the base course by including geogrid reinforcement, but this left the asphalt pavement subject to cracking. Then another design was attempted with asphalt pavement placed on an 8" aggregate base course constructed on top of 8" of lime-treated soil. While the use of lime reduced costs, the asphalt pavements soon exhibited extensive cracking as well as differential settlement. Although 27 different soil types were detected in different areas of this 1500 acre development, a large portion of the development included a trend of expansive clay soils that run almost the entire length of Texas, north to south. These soils with organic and sulfate content are well-qualified to be the most problematic of soils on the North American Continent for built structures such as roads and highways. With a high degree of volume change (shrinking and swelling) behavior driven by fluctuations in soil moisture content, these expansive soils further endanger the integrity of built structures because their soil chemistry generates an extreme heaving phenomenon when cement, lime or fly ash are added to the soils in an attempt to reduce the volume change behavior. The damages from the heaving these products generate are worse than the problems created by the volume changes they were intended to solve. These three calcium based chemicals may effectively dry up overly wet soils, however, those benefits are short-lived. The heaving reactions they cause tilt large buildings and buckle and crack pavements, both enormously expensive to correct.

Following the recommendation of the TTI research study to conduct a field test before proceeding to full scale construction, the project geotechnical engineering consultants designated a street construction project to compare the performance of asphalt pavements constructed above a lime treated subgrade to pavements immediately adjacent constructed above subgrade stabilized with an **EMC SQUARED** stabilizer treatment (see photo next page). The pavement constructed above the lime treatment exhibited extensive cracking within a year of construction. During the fifteen year build-out of the road and street system for the Teravista Community, the **EMC SQUARED** System became the stabilizer treatment of choice, providing an effective alternative to the costly conventional design and to the rough-riding and extensively cracked pavements built above lime treated soils.

A forty-one mile length of Texas State Highway 130 (SH-130), a four lane divided tollway southeast of Austin that runs



from Mustang Ridge to Seguin, an alignment that includes soils with high sulfate and high organic content, is an example of just how expensive a mistake in stabilizer product selection can prove to be. Despite treating subgrade soils under the 9" asphalt pavements and 12" aggregate base course layers with lime chemicals to a depth of three feet under the main drive lanes, the current owners of the privately financed highway recently completed a second round of reconstruction of 35 sections of the highway to depths as deep as eight feet at a reported cost of $90 million. Total reconstruction costs are projected to be $130 million. The original lime treatment proved to be ineffective, or worse, but was used again during the reconstruction program. Additional measures taken during the reconstruction included vertical impermeable barriers constructed along both sides of the tollway in order to keep water from penetrating into the lime treated soils and generating the shrinking and swelling problems. This area of Texas experienced extreme drought conditions in recent years, followed by flooding. In addition to sulfate related heaving and water related swelling in the lime treated subgrade, shrinkage cracking in the lime treated subgrade during the drought conditions also generated cracking in the base course and asphalt pavement layers above via a pavement failure mechanism known as reflective cracking.

Summary

These subgrade stabilization projects in Texas are particularly noteworthy given the severity of the soil problems being addressed by **EMC SQUARED®** System treatment. When it comes to the subject of soil stabilization and the comparative effectiveness of various stabilization treatments, the Dallas-Fort Worth and Austin areas are the epicenter of problematic soil conditions and attempts to solve those problems with various stabilization treatments. This area of Texas is known for its highly expansive clay soils and extreme weather conditions. Extended periods of hot dry weather and heavy flooding rainfall bring out the worst behavior of expansive clay soils. As a consequence, costly cement and lime treatments have traditionally been utilized in the construction of almost every highway subgrade. To complicate matters, many soils have sulfate chemistry that negatively reacts with lime and cement and creates heaving of highway pavements and damage that is far worse than the problems generated by untreated expansive soils.

EMC SQUARED System subgrade treatments are performing well in extremely adverse conditions and outperforming cement, lime, and lime-fly ash (LFA) treatments in comparative field installations. These **EMC SQUARED** System applications provided serviceable working platforms during the highway construction phase. They were faster to install and far less expensive than lime, cement, lime fly-ash (LFA) soil treatments, and cement treated base (CTB) materials. They eliminated the risks of sulfate-induced heave and pavement failure associated with lime and cement treatment. Subgrades treated with the **EMC SQUARED** System are now supporting highway pavements that retain smoother alignments and require less maintenance in spite of the extremely problematic soil conditions.

As briefly addressed here, the **EMC SQUARED** System provides a method of improving pavement subgrade performance that is unique and distinctly different from lime treatment. Intelligent evaluation requires a basic understanding that this fundamental difference mandates utilization of tests and construction procedures that are compatible with proper application of the **EMC SQUARED** System stabilization methodology.

The IRI performance reports from these projects located in the Dallas District clearly show how investments in more sophisticated laboratory procedures and in field implementation of research recommendations pay off in construction cost savings and improved highway pavement performance. (**https://stabilizationproducts.net/docs/18791.pdf**)

In translating the EMC SQUARED System laboratory findings to the actual field service environment, the final report from the research study conducted at the Texas Transportation Institute (TTI) went on to state, "The stabilized subgrade has a lower permeability and a lower suction than the untreated soil below it. This means that it will shed water and not soak up water from the soil below it...." The statement points out the fundamental advance in stabilization technology that is achieved when upward, downward, and lateral flow of water is controlled by a layer within the structural section that provides an effective barrier to moisture flow. This moisture barrier layer helps further protect against pavement roughness by promoting a more consistent and stable moisture distribution in the untreated native subgrade soils below. This is the multiplier effect of EMC SQUARED System subgrade treatments. This moisture barrier performance promotes greater stability in soils below as well as within the treated layer, which is a major advance in the construction of trouble-free, smooth-running pavements.

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