EMC SQUARED® System
SUBGRADE STABILIZATION

TEXAS HIGHWAY PROJECTS
ADVANCED STABILIZATION TECHNOLOGY IN SERVICE

11 YEAR UPDATE 2011

- COMPARISON WITH LIME
- COMPARISON WITH CTB
- SPEEDED CONSTRUCTION
- COST SAVINGS
- EFFECTIVE WORKING PLATFORM
- MOISTURE BARRIER PERFORMANCE
- DISTRESS - FREE PAVEMENTS
- SMOOTH RIDE QUALITY
- MULTIPLIER EFFECT (EMC²)

INTERSTATE 30 | INTERSTATE 635 | PRESIDENT GEORGE BUSH TURNPIKE

SSPCo
Soil Stabilization Products Company, Inc.®

LABORATORY TESTING

Beginning in 1996, 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) Dallas District. The principal author of the study was Dr. Robert Lytton, Research Engineer for TTI, Director of the Center for Infrastructure Engineering at Texas A&M University, and more recently the Distinguished Lecturer for the Transportation Research Board (TRB) Annual Meeting. The study focused on identifying effective treatment for sulfate bearing expansive clay soils. Soils used in the laboratory testing were sampled from problem locations on Interstate 635 Lyndon B. Johnson Freeway (the "LBJ"), and the Highway 161 section of the President George Bush Turnpike (PGBT). 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 has historically led to sulfate-induced heave and costly damage to pavements.* For an 11 YEAR UPDATE on the performance of the field installations that followed, see pages 4 and 6.

The table and graph on the right 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, on the other hand, 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 8.9×10^{-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 graph at right), the **EMC SQUARED** System is obviously providing an effective moisture barrier (see page 8). 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 moisture susceptibility (affinity for water), a low permeability clay (or lime treated clay) will still wet itself over time as it suctions water.

In translating the **EMC SQUARED** System laboratory findings to the actual field service environment, the TTI report 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, which is achieved when upward and downward flow of water is controlled by a layer within the structural section that provides an effective barrier to moisture flow, and that 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 the **EMC SQUARED** System subgrade treatments. It promotes greater stability in soils below as well as within the treated layer. This is **QUANTUM LEAP®** technology for stability and trouble-free, smooth-running pavements.

* For a summary, access An Effective Solution at www.sspco.com/8588.pdf

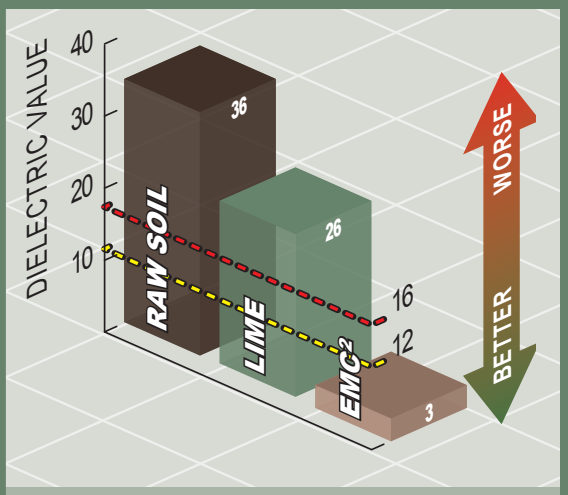
** For a summary, access Lime Treatment Tradeoffs at www.sspco.com/8392.pdf

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

STRENGTH AND STIFFNESS

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)

REDUCTION OF MOISTURE SUSCEPTIBILITY



As indicated above, the dielectric measurements for the **EMC SQUARED** System treated specimens were 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 and the lime treated soil greatly exceed the upper limit for Dielectric Value. The test values indicate that both the raw soil and the lime treated soil are highly moisture susceptible.

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EMC SQUARED FIELD TESTING

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 in 1999 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 front-end loader trips 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.

EMC SQUARED IMPLEMENTATION

The **EMC SQUARED** System is unique as the only non-calcium based stabilizer product technology that has successfully passed a four step review by TxDOT. This deliberate review process started with preliminary investigation of laboratory and field service history in 1995, followed by the two year study at the Texas Transportation Institute, then the one year monitoring of the unpaved field test pad described above. Once the first three steps were completed, TxDOT Dallas District and the North Texas Tollway Authority began field implementation on major freeway, highway and road construction projects.

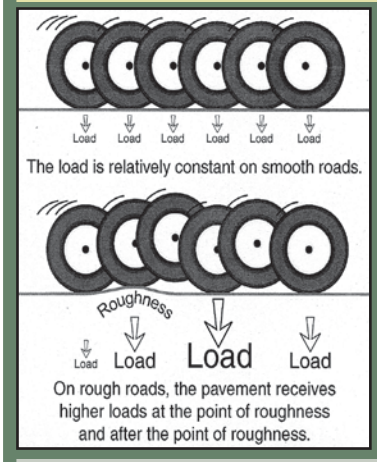
As noted in the project reviews which follow, the substantial research investment that TxDOT Dallas District has made is clearly paying dividends with application of the **EMC SQUARED** System. This innovative product technology is reducing construction costs and improving subgrade stability without subjecting expensive asphalt and concrete pavements to the risks of damage by sulfate-induced heave in treated subgrades.

EMC SQUARED MONITORING

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. IRI measurement has 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) are being monitored for pavement smoothness on an annual basis. The pavement installations above subgrades constructed with **EMC SQUARED** System Treatments are free of distress and are retaining smooth running alignment. To quote one well known highway researcher in regards to the comparative significance of testing in materials laboratory versus field monitoring of the smoothness of the actual pavement system, "Smoothness is what it's all about". Materials laboratory tests attempt to predict field performance, but actual field performance over time is the reality.



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.

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NORTH TEXAS TOLLWAY AUTHORITY PROJECTS

11 YEAR UPDATE 2011

PRESIDENT GEORGE BUSH TURNPIKE

COMPARISON WITH LIME AND LIME - FLY ASH (LFA) TREATMENT

The SH 161 segment of the President George Bush Turnpike, or "the PGBT," is one of two PGBT segments constructed to date with **EMC SQUARED®** System subgrade treatment. The total construction value of the SH 161 (DNT-346) and SH 190 (DNT-323) projects was approximately $100 million. The SH-161 segment is located on the eastern side of Dallas-Fort Worth International Airport (DFW) in an area where swelling clays and sulfate-induced heave (attributable to the incompatibility of lime and other calcium based stabilizers such as cement and fly-ash) have long buckled and cracked highway pavements and building foundations. The swelling clay problems alone are so severe in this area that researchers have suggested that nothing less than a four foot depth of lime treatment would be necessary to counteract the differential movement below the stabilized layer which would be generated by changing moisture conditions and resulting soil volume changes.

In response to these problems, TxDOT Dallas District funded a laboratory study that was conducted at the Texas Transportation Institute (TTI). Soils were sampled for the research study from two area projects in 1996. These projects included the SH 161 segment of the PGBT project and a nearby addition to the Interstate 635 Freeway, (the Lyndon B. Johnson Freeway), known locally as "the LBJ." The TTI research study was completed in 1998. It reported that the **EMC SQUARED** System was superior to lime treatment for these problem soils and recommended its use on both the SH 161/PGBT segment and on the Interstate 635 project. The two projects were subsequently constructed with **EMC SQUARED** System subgrade treatments. Both of these projects also included portions of subgrade constructed with calcium based stabilizers, and they illustrate the findings of the TTI research study regarding sulfate-induced heave generated by the addition of calcium based stabilizers.

The President George Bush Turnpike is currently operating as a six lane tollway. While funded through TxDOT, the engineering, construction management, and operation of the tollway are under the direction of the North Texas Tollway Authority (NTTA). The thickness of NTTA's pavement structural section design for the SH-161 is impressive and necessary due to the serious nature of the local soil problems. A thirty-four inch thick treated subgrade supports a six inch thick base course constructed with hot mix asphalt, overlain by a thirteen inch thick continuously reinforced concrete pavement. The majority of the subgrade on this project was constructed with **EMC SQUARED** System treatments. A small area of subgrade was constructed with lime treatment. An additional area was treated with a lime-fly ash mixture (LFA), a combination of calcium based stabilizers thought to be slightly less reactive with sulfate bearing soils.

With nineteen inches of combined concrete and asphalt pavement structural section on the SH-161 segment of the PGBT, one might think that subgrade stabilization problems would be slow to surface. A project tour by NTTA, TxDOT and SSPCo personnel proved this is not necessarily true. While the main lanes built above subgrades constructed exclusively with **EMC SQUARED** System treatments were exhibiting no noticeable roughness or heave, this was not the case in areas where calcium based treatments were applied to the upper layer of the subgrade. The pavements above the lime-fly ash (LFA) treatment were exhibiting limited but noticeable roughness, which is not surprising given the calcium base of both lime and fly ash products. The pavement above the lime treated area has a prominent heave, or "roller coaster," as predicted by the TTI research study.

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DALLAS - FORT WORTH TURNPIKE

★★★ "THE BEST RIDING SECTION OF INTERSTATE 30" ★★★

The Dallas District Field Engineer who has been tasked with monitoring district soil stabilization projects since 1999, reported on the section of the Dallas - Fort Worth Turnpike constructed with the EMC SQUARED® System subgrade treatment (TxDOT CSJ 1068-04-112) as follows: "The project shows no signs of distress and the ride quality is smooth and is the best riding section of IH 30 in the district."

EMC SQUARED System treatment was utilized for stabilization of subgrade for the Interstate 30 Belt Line Road project in the year 2000. The completed project effectively doubled the width of the old highway. The new lanes in the former median area are HOV (High Occupancy Vehicles) lanes. The structural section incorporates continuously reinforced concrete pavement, hot mix asphalt base and an eight inch thick EMC SQUARED System subgrade.

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TEXAS DEPARTMENT OF TRANSPORTATION PROJECTS

11 YEAR UPDATE 2011

THE LYNDON B. JOHNSON FREEWAY

INTERSTATE 635

COMPARISON WITH LIME AND LIME - FLY ASH (LFA) TREATMENT

The performance of the **EMC SQUARED**® System subgrade treatment on the Interstate 635 (LBJ) Freeway project has also proven out the recommendations of the Texas Transportation Institute study. This project (TxDOT CSJ 2374-07-041) involves three lanes in each direction with concrete pavement constructed above a hot mix asphalt base course and stabilized subgrade. These lanes were added as a frontage road system to existing freeway lanes. **EMC SQUARED** System treatment was used for the majority of the subgrade construction requirements for lane additions on the eastbound freeway. Cement, lime and fly ash were used in various combinations for subgrade stabilization for the lane additions on the westbound side in an experimental effort to see if a new combination of calcium based stabilizers might be non-reactive with the sulfate bearing soil. Unfortunately, sulfate-induced heave soon manifested itself through the newly constructed westbound pavement. Distinct "roller coasters" and pavement cracking are apparent in the lanes built above subgrade treated with the calcium based stabilizers. Per the report from the TxDOT Dallas District office, the pavement above the **EMC SQUARED** System subgrade is retaining overall smoothness with no indication of heave or pavement distress. Of additional interest, the **EMC SQUARED** System treatment was a small fraction of the cost of the combination calcium based stabilizer treatment. Per reporting of the International Roughness Index (IRI) measurements (see page 3) for this section, it meets TxDOT's "smooth" classification.

COCKRELL HILL ROAD

COMPARISON WITH CEMENT TREATED BASE (CTB)

A year 2000 cooperative construction effort of TxDOT and the City of Dallas (TxDOT CSJ 0918-45-387) provided an opportunity to further test the **EMC SQUARED** System in an area noted for having some of the worst expansive clay soils in the Dallas area. With a construction project already in progress extending Cockrell Hill Road north to tie in to the Interstate 30 Freeway, the contractor submitted a value engineering proposal to speed construction and reduce costs. The original design called for concrete pavement on top of a cement treated base (CTB), a typical structural section for many road and street projects in Dallas. With the concrete pavement already in place for all six lanes from Interstate 30 south to the first intersection, and for the full extension of the northbound lanes, TxDOT and the City of Dallas supported a proposal to eliminate the cement treated base for the southbound lanes yet to be constructed. *This portion of the project was constructed without a base course layer.* Instead, the concrete pavement was placed directly on subgrade treated to an eight inch depth with an **EMC SQUARED** System application.

Per the report of the TxDOT Dallas District, the concrete pavement built on top of the cement treated base has already required complete replacement in three sections and has areas with significant roller coasters, or heaves, that are described as very rough riding, as well as extensive transverse and diagonal cracking. On the other hand, the adjacent concrete pavement built on the **EMC SQUARED** System subgrade continues to provide a smooth running surface with just a few areas that are medium rough riding and no need for repairs.

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LUNA ROAD EXTENSION

PERFORMANCE THROUGH FLOODED WETLAND

Luna Road is a major arterial in the northwestern Dallas area which now connects with Old Denton Road via an extension project which added a new segment of six lane highway and an overpass above Interstate 35E Freeway. This construction project (TxDOT CSJ 8037-18-002) presented a classic soil stabilization challenge. Alignment requirements dictated construction through a wetland area and water ponds created by gravel mining operations. Pavement designers were forced to plan for construction of a tall embankment over saturated ground conditions. Once constructed, the embankment would be subjected to deeply ponded water on both sides. Controlling moisture content within the embankment was a concern due to the risk of volume change and differential settlement in the highly moisture susceptible expansive clay soils.

After reviewing the recently completed research study conducted at the Texas Transportation Institute (TTI) under the direction of Dr. Robert Lytton, design engineers made the decision to stabilize two different layers with **EMC SQUARED**® System applications. The first stabilized layer was constructed just above the elevation of the ponded water. The second stabilized layer was constructed at the top of the embankment (the actual pavement subgrade). The intent was to provide stable construction work platforms and to partially encapsulate the layer of untreated embankment soils between the two stabilized moisture barrier layers. As an additional response to the ponded water, they specified placement of a rock riprap cover to protect the embankment slopes against wave attack.

According to the report of the TxDOT Dallas District office "Even with the abundance of water along this roadway, no distress is evident in the pavement and the ride quality is very smooth. The conclusion could be drawn here is that the **EMC SQUARED** System treatment is effective in reducing and/or preventing water from entering the embankment".

MOISTURE BARRIER PERFORMANCE

For highway engineers who have previously asked the question as to how well an EMC SQUARED System moisture barrier would perform with a lateral source of water ponded against the embankment below the moisture barrier, the Luna Road Extension project clearly answers this question with successful performance.

Soil stability, at its essence, has water as its common denominator. The engineering properties of any soil material are governed by variations in water content. The most direct and cost-effective route to stabilizing a soil is to stabilize its moisture content. This is the most fundamental benefit offered by the EMC SQUARED System in treatment of expansive clay soils. When moisture content in subgrade and embankment soils is maintained in a "near optimum" state, the soil platform is unaffected by volume change (expansion and shrinkage) and provides consistent support for the pavement. Key to this approach to stability is the selection of product technology that reduces soil moisture susceptibility and improves moisture barrier performance. This is not a benefit normally offered by cement, fly ash or lime treatment. TxDOT and other state transportation agencies have previously used plastic liners with some success to encapsulate expansive soils to control volume change, but the cost and complexities during construction were prohibitive. As indicated in the TTI research study, and verified in the field monitoring, the EMC SQUARED System treatment is performing well as a moisture barrier. The additional good news - *it's more economical and faster to apply than lime treatment.*

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EMC SQUARED SUMMARY

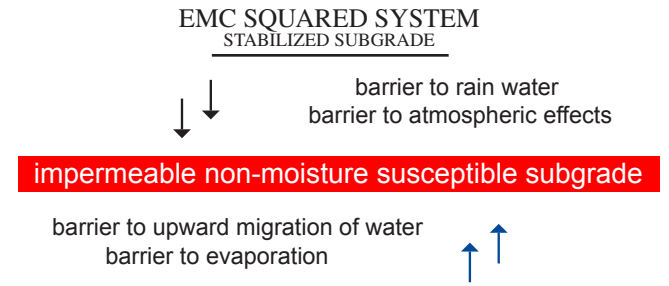
11 YEAR UPDATE 2011

The **EMC SQUARED®** System has proven effective in stabilizing a wide variety of soil, aggregate, and recycled pavement materials at locations across the country and as far north as Alaska. This 11 YEAR UPDATE on highway subgrade stabilization projects in Texas is 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 area is the epicenter of problematic soil conditions and the 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 chemical treatments have traditionally been utilized in the construction of almost every highway subgrade. To complicate matters, many soils have soluble sulfate chemistry that negatively reacts with lime, cement and fly ash additives and creates heaving of highway pavements that is far worse than the problems generated by the expansive soils.

The effort by the Texas Department of Transportation (TxDOT) Dallas District to research and implement stabilizer technology that works without risk of "sulfate-induced heave" problems is paying dividends. This 11 YEAR UPDATE publication summarizes laboratory testing and the field performance of six highway projects in the Dallas District where subgrades were stabilized with **EMC SQUARED** System treatments in Year 2000 as part of this program to eliminate the risks associated with lime treatment. **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 considerably less expensive than lime, cement, and LFA treatment and less expensive than cement treated base (CTB). They were faster to apply. 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 are free of distress and which retain their smooth alignment, in spite of the extremely problematic soil conditions.

The TxDOT Dallas District funded an extensive two year research study completed in 1998 at the Texas Transportation Institute (TTI). This study documented the effectiveness of the **EMC SQUARED** System treatment. The study noted that the soils treated with the **EMC SQUARED** System had a lower permeability and a lower suction, or moisture susceptibility, than the untreated soils below, with the results being that subgrade soil stabilized with the **EMC SQUARED** System treatment would shed water off its surface and not soak up water from the soil below.



Unlike lime treatment, which typically increases moisture flow though the soil layer, a negative trade off that comes along with the positive benefits it offers, **EMC SQUARED** System treatments typically reduce moisture flow and moisture susceptibility and promote moisture barrier benefits. A stabilized moisture barrier layer not only retains its own flexural stiffness, but also protects the stiffness of the clay soils below as it cuts off the wetting and evaporative effects that otherwise drive volume change below the treated subgrade and differential settlement and roughness in the pavement above. This is the *multiplier effect* (EMC^2) of **EMC SQUARED** System treatment.

Typical accelerated laboratory testing programs limit their scope to "swell" index tests in artificially induced laboratory conditions. These tests present lime treatment in the best possible light, while ignoring other test methods that demonstrate the limitations of lime treatment and the success of other product technologies in addressing important engineering concerns related to the preservation of pavement performance. 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.

As briefly addressed in this 11 YEAR UPDATE, 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.

Eleven years after application of these **EMC SQUARED** System treatments on major highway construction projects, the performance reports from the Dallas District clearly show how their investments in more sophisticated laboratory procedures and in field implementation of research recommendations are paying off in construction cost savings and improved highway pavement performance.

To learn more about Soil Stabilization Products Company and the EMC SQUARED System visit www.sspco.com

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