“It is my professional opinion that all subgrades should be stabilized and the EMC SQUARED system product is the most cost effective, easiest to handle and apply, and long lasting stabilizing product I have worked with.”

Ray Pederson - P.E. (FHWA & BIA)
The section of the Interstate 40 freeway just east of Grants, New Mexico, identified as Milepost 93 to 97 (MP 93-97), has in past years been a nightmare for the New Mexico Department of Transportation (NMDOT). Grants is at an elevation of approximately 6,500 feet, close to where Interstate 40 crosses the Continental Divide at the southern end of the Rocky Mountains. This section of freeway is impacted by a high frequency of heavy truck traffic and severe cold climate conditions in winter. Groundwater problems are extreme under the freeway alignment. The silty clay subgrade soils were regularly found to be in a highly saturated state when excavated during full depth repair and reconstruction efforts. While the average cycle for full depth reclamation of the I-40 freeway in this area was 4-6 years, the eastbound lanes of this particularly problematic section of freeway prior to year 2000 had required full depth removal and replacement of the entire pavement structural section on a three to five year cycle. NMDOT maintenance staff reported that the entire annual budget of the local maintenance station was exhausted taking care of this one segment of freeway in the year prior to the full depth reconstruction in 2000. NMDOT and the Federal Highway Administration (FHWA) determined that the EMC SQUARED® System could really be put to the test if it were evaluated in this severe service environment, one that featured four of the worst enemies of pavement performance; heavy loads, high frequency traffic, saturated subgrade soils and extremely cold winter conditions.

Out of the four mile length of the Interstate 40 eastbound lanes reconstructed in 2000, two miles were constructed above subgrade soils stabilized with the EMC SQUARED System treatment. The eastbound lanes of this section of freeway were particularly problematic, experiencing significantly more differential settlement (more rolls and dips, or roughness in the running surface) and higher frequency of repair than the westbound lanes. The EMC SQUARED System treatment was highly effective in bridging over saturated native soils below the subgrade layer, maintaining a working platform for the haul trucks and construction equipment involved in the base course placement and paving operations with only minimal repair requirements. The remaining two miles were constructed without application of any soil stabilization treatment. This unstabilized section consisted of two different subgrade conditions, one being areas of solid Malpais lava flows, the other saturated silty clay soils that had to be extensively reinforced with geosynthetic products. Geogrids were placed over geotextile fabric (mechanical stabilization) to provide the contractor with a functional working platform during construction. The base course construction and asphalt paving work were then completed and the eastbound lanes returned to service in early summer 2000. The westbound lanes were also completely reconstructed to full depth as part of the same construction contract. The silty clay subgrade soils for three of the four mile length were treated with lime. The rest of the westbound subgrade was either solid Malpais lava flow, or areas of saturated silty clay soils that were extensively reinforced with geosynthetic products. The thickness of the aggregate base course layers and the hot mix asphalt pavement layers were similar for both the reconstructed eastbound and westbound lanes, so this project provided an opportunity to compare the performance of the EMC SQUARED System subgrade treatment with the performance of the lime treatment, as well as with the sections of pavement constructed above the lava flows and geosynthetic...
reinforcement which are identified in the Performance Data chart on page 4 as “Unstabilized & Reinforced Subgrade”. The four mile long MP 93 - 97 Project was reconstructed as part of a program that included eleven more miles of adjacent sections of Interstate 40 Freeway. Since these sections adjacent to the MP 93 - 97 Project were built with the same pavement structural section design, incorporating base course and hot mix asphalt layers of similar thickness, but without stabilized or reinforced subgrade treatments, the project also provided the opportunity to compare the benefits of the stabilization and reinforcement treatments in prolonging the service life of the pavements.

In response to the FHWA mandate to state highway agencies for annual reports on pavement smoothness, NMDOT conducts yearly profilometer testing of its highway system. Since the ultimate goal of subgrade stabilization is to maintain pavement smoothness, the profilometer testing therefore is the best examination of the effectiveness of a stabilizer treatment in highway system applications. Profilometer testing results were available for the stabilized and unstabilized subgrade segments of the Interstate 40 Freeway project over a thirteen year period of monitoring. Ray Pederson, the FHWA Area Engineer for the project at the time of construction (and then Area Engineer for the Bureau of Indian Affairs in the same region of New Mexico) continued to monitor project performance through visual observation and review of the annual IRI or profilometer data collected by NMDOT.

In addition to FHWA’s use of the data for its International Roughness Index (IRI) monitoring, the data is also useful for performance comparison of different subgrade treatments. NMDOT developed a formula to predict the percent of remaining pavement design life as related to the surface roughness of the pavement determined by the IRI data. A review by the Area Engineer monitoring the project indicates that the pavement constructed above the EMC SQUARED® System subgrade treatment has retained its smoothness better than the pavement above the adjacent unstabilized and reinforced sections of the eastbound lanes and better than the pavements in the westbound lanes constructed above the lime treated subgrade. Using the calculation formulas furnished by NMDOT and the FHWA, the IRI test results indicate that the EMC SQUARED System did the best job retaining pavement smoothness and extending the Theoretical Design Life of this heavily trafficked section of Interstate 40. This degree of improvement during the monitoring period translates into a gain in load carrying capacity over the lime treated section of 5,155,966 ESALs, or 4,687,242 truck passes*, according to the NMDOT Materials Bureau model. For sake of perspective, at one truck pass per minute, twenty-four hours per day, the EMC SQUARED System stabilization treatment would extend service life by approximately 9 years beyond the results achieved with the lime treatment.

NMDOT’s District Engineer responsible for this section of Interstate 40 Freeway provided additional perspective important to the evaluation of benefits of the soil stabilization applications under the Interstate 40 pavement structural

* using an estimated ESAL Factor of 1.1 ESALS (Equivalent Single Axle Loads) per truck (WSDOT) based upon 3/25/10 test results after ten years of monitoring.
section. He commented in December 2005 that NMDOT had
reconstructed approximately fifteen miles of the I-40 freeway
through this area, including the EMC SQUARED System
project. While all of the projects from 1999 forward utilized
NMDOT’s newer design with thickened layers of asphalt
pavement and aggregate base course materials, only the MP
93 - 97 Project constructed with a stabilized and reinforced
subgrade remained smooth running and free of pavement
damage. While the costly addition of thickened layers of
hot mix asphalt pavement has clearly contributed some
incremental improvement, the soil stabilization treatments are
providing a completely new level of pavement performance
and service life in the face of these highly problematic freeway
service conditions.

As detailed earlier, the EMC SQUARED System treatment
was effective as a construction work platform. It was less
expensive and less time-consuming to install in comparison
to the conventional design, which called for subgrade
cavitation and replacement of the silty clay soils with more
suitable road base materials. The EMC SQUARED System
was also less expensive and less time-consuming to install
than reinforcement with geosynthetic products. Finally, the
IRI data on the Interstate 40 project is clearly demonstrating
the effective performance of the EMC SQUARED System
in extending pavement surface life over worst case native
subgrade conditions.

Summary

The four mile long section of the MP 93 - 97 Project is clearly
outperforming eleven miles of adjacent sections of Interstate
40 freeway that were constructed with the same pavement
structural section but without subgrade stabilization or
subgrade reinforcement. The service life of the entire fifteen
mile section of Interstate 40 freeway has been improved by
NMDOT’s expensive new pavement structural section design
that incorporated a thicker aggregate base course layer and a
far thicker layer of hot mix asphalt pavement (eleven inches
thick) than had ever been used for previous Interstate 40
freeway construction projects. Of greater note, the relatively
inexpensive stabilization of subgrade soils under the MP 93
- 97 Project has demonstrated outstanding cost-effectiveness
in prolonging the service life of the pavement structure.
Finally, the EMC SQUARED System, the only sustainable
product used in construction of the MP 93 - 97 Project, and
the least expensive, has been shown to be significantly more
effective in prolonging the smooth running maintenance-free
performance of the freeway pavement installation.

Additional Notes from Area Engineer (September 2013):
There is a dip that has been forming for some years near MP 96 eastbound in
the transition area between the subgrade stabilized with the EMC SQUARED
System treatment and a section of unstabilized subgrade. This section of
subgrade was constructed just prior to starting the EMC SQUARED System
treatment program and its consists of silty clay soils that were not treated with a
stabilizer or reinforced with geosynthetic products.

International Roughness
Index (IRI)

Pavement smoothness has become the most recognized
international index for the evaluation of pavement performance.
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. IRI
testing evaluates this fundamental performance criteria more
directly than any other field test or test method in the materials
laboratory.

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. The development of roughness between successive
IRI measurements is translated into the percent of Theoretical
Design Life that is lost and the decrease in load carrying
capacity, or ESALs (Equivalent Single Axle Loads). Finally,
these relationships can be converted into the number of truck
passes, something more simple to visualize in regards to lost
carrying capacity.

How Pavement Roughness
Generates Dynamic Load

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 with increasing roughness severity.

The load is relatively constant on smooth roads, while on
rough roads the pavement receives higher loads at and after
the point of roughness
### Interstate 40 Freeway 10-year Performance Data

**Monitoring Dates***

<table>
<thead>
<tr>
<th>Monitoring Dates</th>
<th>February 19, 2001</th>
<th>February 26, 2008</th>
<th>March 18, 2009</th>
<th>March 25, 2010</th>
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<table>
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<tr>
<th>Average IRI Measurement</th>
<th>Smoothness Lost</th>
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<tr>
<td>Lime Stabilized Subgrade</td>
<td>31.59%</td>
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<tr>
<td>Unstabilized &amp; Reinforced Subgrade</td>
<td>30.41%</td>
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<tr>
<td>EMC2 Stabilized Subgrade</td>
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<th>Percent of Theoretical</th>
<th>Design Life Lost</th>
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<td>Lime Stabilized Subgrade</td>
<td>38.2%</td>
</tr>
<tr>
<td>Unstabilized &amp; Reinforced Subgrade</td>
<td>36.9%</td>
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<td>EMC2 Stabilized Subgrade</td>
<td>24.6%</td>
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<table>
<thead>
<tr>
<th>Number of Theoretical</th>
<th>Design ESALs Lost</th>
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</thead>
<tbody>
<tr>
<td>Lime Stabilized Subgrade</td>
<td>14,486,268</td>
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<tr>
<td>Unstabilized &amp; Reinforced Subgrade</td>
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<td>EMC2 Stabilized Subgrade</td>
<td>9,330,302</td>
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*Testing conducted by New Mexico Department of Transportation on an annual basis starting in 2001.

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**Comment from FHWA Area Engineer after 13 years of Project Monitoring**

The test results in 2013 show that the westbound lime stabilized section is 1.2% design ESALs greater than the un-stabilized section. The eastbound EMC SQUARED stabilized section is 11.1% design ESALs greater than the westbound lime treated section.

Clearly the freeway pavements constructed on top of the stabilized subgrades have out-performed the typical four to six year expected life span for reconstructed sections of freeway in this area of the State and the eastbound EMC SQUARED stabilized section has greatly out-performed the sections of this project that were built to the same standard, but without application of the stabilizer treatment, and out-performed the westbound lime treated section.

The above are my statements regarding the New Mexico, I-40 MP 93 to MP 97 project, which I have watched with great interest for the last 13 years. It is my professional opinion that all subgrades should be stabilized and the EMC SQUARED system product is the most cost effective, easiest to handle and apply, and long lasting stabilizing product I have worked with.

Ray Pederson - P.E. (FHWA & BIA)
September 8, 2013
Prior to approval of EMC SQUARED® System, the NMDOT Materials Bureau testing laboratory in Santa Fe conducted compaction control testing and standard Unconfined Compressive Strength (UCS) tests. Tests were also conducted by the district materials testing laboratory. The EMC SQUARED System easily passed the Materials Bureau’s laboratory index requirements of 200 psi after 7 days of curing with a 310 psi result (AASHTO T-99 ASTM D 698 Compaction Energy), as well as testing at 496 psi after 7 days using the compaction energy specified for EMC SQUARED System field application (AASHTO T-180 ASTM D 1557).

The EMC SQUARED® System product technology is very much focused on treatment of subgrade moisture susceptibility. The goal of the treatment is to create an effective moisture barrier layer that protects the native subgrade below from rainwater and that resists saturation by the upward flow of capillary water from groundwater sources. The laboratory study conducted under the direction of Dr. Robert Lytton at the Texas Transportation Institute (TTI), clearly addressed this aspect of moisture barrier performance of the EMC SQUARED System treatment.

**Compressive Strength Tests**

**EMC SQUARED System**

by NMDOT Materials Bureau

<table>
<thead>
<tr>
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<th>T-99</th>
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<tr>
<td>7 Day</td>
<td>310 psi</td>
<td>496 psi</td>
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<td>14 Day</td>
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<tr>
<td>21 Day</td>
<td>472 psi</td>
<td>646 psi</td>
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Date: 13-Jul-00      Project Number: IM-040-2(56)93

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**Compressive Strength Testing Device**

**EMC SQUARED SYSTEM**

**STABILIZED SUBGRADE**

barrier to rain water
barrier to atmospheric effects

impermeable non-moisture susceptible subgrade

barrier to upward migration of water
barrier to evaporation
The moisture barrier approach is not a new concept for construction over saturated clay subgrades. It has long been understood that there are two very different routes to stabilizing clay soils. Cement and lime are used in attempts to overwhelm volume change problems with cementation and reduction of plasticity. The moisture barrier approach instead controls volume change by maintaining the moisture content of the clay within the treated subgrade layer in a state of “near-optimum” condition.

Cement and lime treatment have been successful in providing rigid construction platforms, but less successful in addressing the development of roughness in highway pavements over time. The interest in application of moisture barrier technology has in large part been driven by the desire to construct pavement structural sections that would retain smoothness better over time in comparison to results with lime and cement treated subgrades. The limitation until recent years with the moisture barrier approach is that flexible membrane liners (also known as FML’s or plastic liners) were the only technology available. Unfortunately, flexible membrane liners are expensive and a nightmare for contractors to install. The availability of the EMC SQUARED® System technology, which is low cost and relatively simple to install, has changed this picture. Moisture barriers have an additional advantage over cement and lime treatment as they effectively stop the upward flow of capillary water from the groundwater sources by sealing off the underlying native subgrade soils from atmospheric contact. The native subgrade is then far less influenced by seasonal weather fluctuations ranging from arid to monsoon conditions, as soil volume change is controlled by limiting fluctuations in soil moisture content. The net effect of the moisture barrier layer is improvement of the stability of the native subgrade as well as the treated subgrade.
OTHER HIGHWAY PROJECTS CONSTRUCTED ON SUBGRDES STABILIZED WITH EMC SQUARED SYSTEM TREATMENTS

“The best riding section of Interstate 30 . . .”

EMC SQUARED® System products are used in combination with natural earth materials such as aggregates and soils and mixtures of reclaimed asphalt and concrete pavements. The products are components in the construction of a final product. Engineering and construction controls are vital to the selection of all the ingredients and construction processes which will deliver the final product, and the excellence of that end result is, in large measure, dependent upon engineering judgements and construction quality control measures. This publication is solely for use by professional personnel who are competent to evaluate the significance and limitations of the information provided. It was reviewed carefully prior to publication. Stabilization Products LLC and Milieu Road Technologies, Ltd., assume no liability for its accuracy or completeness. Final determination of the suitability of any information or material for the use contemplated, or for its manner of use, is the sole responsibility of the user.