# Joint Transportation Research Program

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# Subgrade Stabilization Alternatives

## Introduction

In 2009, INDOT adopted the *Mechanistic-Empirical Pavement Design Guide* method (MEPDG or PavementME after 2012). The main design objective in the PavementME is to optimize pavement design by assigning pavement support layers that meet the performance criteria. One of the issues of this method is that it requires the input of design parameters that reflect the actual conditions of the subgrade in the field. Current application of the PavementME in Indiana neglects the changes in the nature of the soils that occur with chemical treatment. If accounted for in the PavementME, such changes would decrease the susceptibility of the soil to moisture and temperature variations.

This study addresses this issue by exploring engineering properties, namely fines content, plasticity index, unconfined compression strength, and resilient modulus of subgrade stabilization alternatives. The effects of changes in moisture content and temperature on the subgrade's stiffness is also considered.

This research focuses on treatment with Lime Kiln Dust (LKD), Portland cement (PC), or a combination of LKD and cement. Treatment with Quick Lime (QL) is also investigated. The soils targeted are A-6 and A-7-6, which have low bearing capacity and are sensitive to changes in moisture content; thus, they are often treated with a chemical agent.

## Findings

- The A-6 soil was obtained from Hartford City (HC) in Blackford County, while the A-7-6 soils were collected from Fort Wayne (FW) in Allen County, and from Bloomington (BM1, BM2, BM3) in Monroe County. For these soils, the LL ranged between 26.0% and 66.0%, while the PI was between 14.4% and 45.2%.
- For the soils investigated, the optimum amount of treatment ranged between 5% and 6% for LKD, between 3% and 5% for cement, and between 2% LKD + 2% cement when both chemicals were used.
- The plasticity index decreased with treatment for all the soils, but there was not a clear trend regarding which treatment had a larger effect on the soils' plasticity. Curing time had no major effect on the soils' plasticity. The largest reduction in PI occurred before 28 days of curing. The soil grain size always increased with treatment. Although with the optimum amount of treatment the plasticity decreased (up to 20%) and the grain size increased (up to 37% with respect to the untreated soil), the type of soil did not change for most of the soils investigated (i.e., the soil remained as A-6 or A-7-6).
- After 28 days of curing, the increase in strength with respect to the untreated soil ranged from 123% for HC + LKD to 613% for BM2 + cement. For most soils, the largest unconfined compression strength was observed on mixtures with cement. The increase in strength with curing time of the soil mixtures with LKD or cement did not depend on soil plasticity, as soils with relative similar plasticity (BM1 vs. FW) had different strengths.
- All treated soils exhibited an increase of the resilient modulus, $M_R$, with respect to that of the untreated soil. At the optimum amount of treatment, the $M_R$ was larger for mixtures with cement than with LKD. The $M_R$ of the treated soils increased with the increase of the deviatoric stress. Such effect was more remarkable for samples containing cement. There was no clear trend between $M_R$ and curing time.
- When the optimum amount of treatment was doubled (overdosing), the decrease in plasticity and fines content was more remarkable than using the optimum amount of treatment. The type of soil always changed, transforming a fine-grained soil into a granular soil (e.g., from A-6 to A-2-4).
- Overdosing produced a larger increase in the unconfined compression strength of the soil compared to the optimum treatment. The strength obtained from overdosing could be twice the strength of optimum

treatment. Overdosing produced a larger increase in soil stiffness compared with the optimum treatment.

- Considering realistic conditions for natural and treated subgrades, calculations using the PavementME could result in an increase in the IRI or in a larger design life of the pavement. This would result in a reduction of the cost of the pavement, as a smaller pavement thickness would be required for the same design life. The improvement is clear when the treatment is doubled (overdosed), especially with cement.
- When strictly following the standard ASTM D559/D559M for wetting and drying (WD) cycles at the optimum amount of treatment, the treated specimens failed during the wetting stage in the first three to five cycles. A modified test protocol was proposed for the WD process. The samples were subjected to twelve wetting-drying cycles. After that, $M_R$ tests were conducted. The WD cycles resulted in a significant decrease of the resilient modulus of the treated soils to values similar to those of the untreated soils. After the twelve WD cycles, soil specimens overdosed with quick lime had an increase in stiffness of 55% on average, while those overdosed with cement had a reduction of stiffness down to about 20% compared to the untreated soil without WD cycles.
- Strictly following the Standard D560/D560M to determine the stiffness of compacted treated specimens subjected to repeated freezing and thawing (FT) cycles, treated soil specimens presented premature failure due to excessive deformations. A modified test protocol was adopted. The samples were subjected to twelve freezing/thawing cycles and then $M_R$ tests were conducted. The FT tests resulted in a reduction of the stiffness of the treated soils to values similar or smaller than those of the untreated soils without FT cycles.

## Implementation

The research clearly showed the benefits of overdosing (i.e., of doubling the amount of chemicals). Overdosing changed the type of soil from clayey to granular, and improved the resilient modulus of the soil, even under the harsh conditions in the laboratory during the cycles of WD, especially for soils with lower plasticity. Clearly, overdosing increases the cost of construction and calls for more stringent field monitoring to make sure that the quality and uniformity of the treatment are as expected. However, these costs may be easily offset with a much longer life of the pavement structure, with less maintenance, or even with a less thick structure. It is recommended to implement this research. A section of a new pavement construction should be built using overdosing and its performance monitored to verify the discussed changes and their benefits, during both the short and long term.

## Recommended Citation for Report

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