PARTNERSHIP FOR GEOTECHNICAL ADVANCEMENT

IOWA STATE UNIVERSITY

Optimum Pavement Base Characteristics

tech transfer summary

RESEARCH PROJECT TITLE
Determination of the Optimum Base Characteristics for Pavements (TR-482)

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PRINCIPAL INVESTIGATOR
David White
Asst. Prof., Civil, Construction & Environmental Engineering
Iowa State University
515-294-1463
djwhite@iastate.edu

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MORE INFORMATION
http://www.ctre.iastate.edu/research/detail.cfm?projectID=546

PARTNERSHIP FOR GEOTECHNICAL ADVANCEMENT IOWA STATE UNIVERSITY
2901 South Loop Drive, Suite 3100
Ames, IA 50010-8634
515-294-8103

Objectives

- Determine optimum pavement base characteristics for desired stability and permeability.
- Develop pavement design tools to estimate the minimum required hydraulic conductivity of a pavement base layer and the time required to achieve a given percentage of drainage.
- Refine aggregate placement and construction methods to reduce segregation of fine material and optimize uniformity.
- Develop reliable quality assurance/quality control (QA/QC) protocols for testing pavement base stability and permeability.
- Evaluate the accuracy and feasibility of current in-situ permeability and stability testing devices.
- Develop a device and test procedures for rapid, in-place testing of permeability. The device is needed to fill a major technology gap that has prevented practical determination of the saturated hydraulic conductivity of granular bases.

Problem Statement

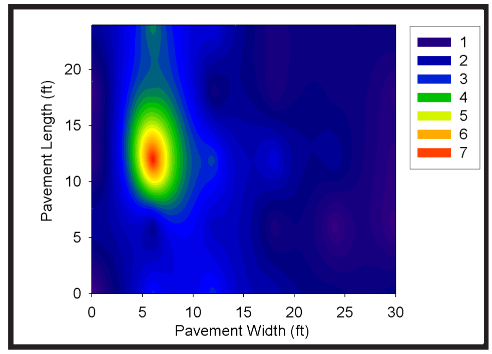
The presence of excess water can be extremely deleterious to pavements. Proper design, construction, and maintenance of pavement drainage can extend pavement service life.

For new pavements, drainage issues are addressed by incorporating subsurface drainage layers into the design of the pavement. In order to design for desired drainage, pavement designers must be able to accurately calculate the required permeability of the drainage layer and assess the hydraulic conductivity of the drainage materials to be used.

Aggregates used in pavement bases must be carefully selected and properly handled to provide not only permeability, but also uniform stability. Compaction of the drainage material can alter the gradation and create additional fines, which may result in lower permeability. Construction activities to deposit and spread the aggregate can also cause segregation and non-uniform permeability and stability.

To ensure the effectiveness of subsurface drainage layers after they have been spread and compacted, QA/QC protocols for simple, rapid, in-situ testing of permeability and stability are needed.

Segregation of fines in final base layer



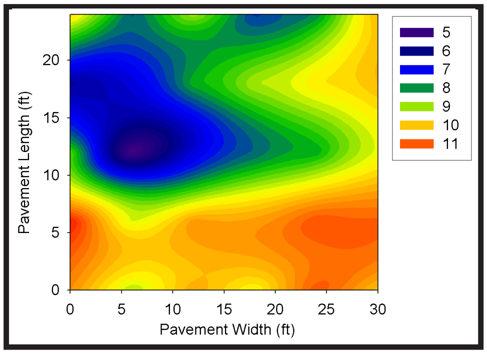
Spatial variation of hydraulic conductivity (cm/second) at pavement base test section

Key Findings

- Stability is enhanced by the use of aggregate that is angular, does not degrade under repeated loading, and has a dense gradation that does not separate large particles. A dense gradation can enhance stability but reduces permeability.
- Recycled concrete aggregate samples were found to have lower permeability, lower strength, and lower resistance to particle degradation compared with limestone and gravel samples.
- The effect of spatial variation on pavement performance is not adequately understood. In particular, what level of spatial uniformity is required for desired pavement performance is not known.
- Lab and field measurements show that as fines content (material passing No. 200 sieve) increases, permeability decreases dramatically.
- Trimming operations appear to contribute the most to aggregate segregation, leading to spatial variation. Trimmers add to segregation problems in several ways. During trimming, they shake the aggregate, causing fine particles to migrate to the bottom of the layer. Then they remove the top, relatively coarse aggregate and leave behind finer aggregate.
- Aggregate placement and spreading operations are other likely contributors to segregation of fines.

Parameter	Mean	Coefficient of Variation
Hydraulic conductivity (cm/second)	4.4	97
Modulus (MPa)	83	41
Stiffness (MN/m)	9.6	41
DCP penetration index (mm/blow)	21	68
CBR (%)	18	83
Clegg hammer impact value	18.6	48
Fines content (%)	5.4	64
Moisture content (%)	6.7	54
Dry density (kg/m^3)	1665	7
Saturation (%)	32	54

Summary of field measurements



Spatial variation of fines content (%) at pavement base test section

Design Recommendations

Pavement designers should consider changing certain design parameters to promote good base drainage. Parameters that could be adjusted include

- subgrade cross-slope
- base thickness
- edge drain placement
- material gradation

For example, greater drainage capacity should be provided for many multilane pavements.

A computer program (Pavement Drainage Estimator) was developed as part of this research to help designers quickly explore alternatives for improving base drainage.

Pavement Drainage Estimator (PDE)

The PDE is an Excel-based spreadsheet program that can be used to estimate the minimum required hydraulic conductivity of a pavement base layer and/or the time required to achieve a given percentage of drainage.

The program walks the user through the options and steps. Input factors including aggregate properties, pavement dimensions, rainfall intensity, and amount of drainage desired are used to produce estimates of the required hydraulic conductivity (K) of the base (based on steady-state flow analysis) and the time it would take to achieve any given percentage of drainage (based on unsteady-state flow analysis).

Construction Recommendations

- Instead of spreading aggregate longitudinally along the pavement section, use a motor grader to push the aggregate transversely from a center pile. A motor grader with a sharp angle (45º) can facilitate this process.
- Do not use recycled PCC for permeable granular base in areas where construction traffic must haul over the placed aggregate (for example, where there are narrow or no shoulders).
- Ensure that aggregate is delivered to the site with sufficient water content (7%–10%) to bind the fines so they do not settle to the bottom of the layer during trimming.
- As an alternative to trimming equipment, use a motor grader with stakeless, GPS-guided grading control.

Recommended QA/QC Protocols

In-situ testing of permeability and stability is important for quality assurance/quality control. Tests should be performed at a frequency of at least every 200 feet along the length of the final compacted granular subbase layer.

In developing a QA/QC specification, it is desirable to set testing limits that will provide an adequate "factor of safety" between the desired material properties and the average test results. Test protocols and engineering properties that produce more variation should have a larger factor of safety.

Permeability Testing

This study recommends that the minimum permeability for design purposes be set at 0.2 or 1 cm/second to achieve 50% or 90% drainage in less than 2 hours, respectively. Because permeability measurements exhibit relatively high variation in the field, the average in-place permeability should be set higher than the minimum design values. For in-place permeability, as determined from the newly developed Air Permeameter Test (APT) device, the average values should be set at 0.8 or 4 cm/second in order to achieve 50% or 90% drainage in less than 2 hours, respectively.

Few practical methods of measuring in-place permeability of granular materials exist. To fill this gap in technology, a portable, in-situ test device (the APT device) was developed as part of this research to provide a practical and rapid method of testing base course permeability.

Air Permeameter Test (APT)

The Air Permeameter Test (APT) device is the only rapid permeability testing device successfully developed in the world. The APT device can determine the saturated hydraulic conductivity of granular bases in a matter of seconds. APT tests can also be performed at various locations in a few minutes to ensure spatial uniformity of the final base layer.

The piece of equipment weighs 40 lb. and consists of the contact ring, console, two flow meters, and two differential pressure gauges (DPGs). The DPGs are connected to the outflow end of the contact ring. A compressed air tank with regulator is connected to the APT by a 1/4-inch-diameter hose. Neoprene foam is attached to the bottom of the contact ring to prevent leakage between the bottom of the contact ring and the ground surface.

Air Permeater Test (APT) device

The device can be used to perform about 50 tests per hour with one operator. It can be carried by one person and be transported in a pickup truck.

APT test procedures and a form for recording data were developed and are available with the full project report. The test requires in-situ dry density and moisture content as inputs to determine the saturated hydraulic conductivity of the material. Approximate values for these parameters for a wide range of base materials are available, but for best accuracy, actual measurements should be taken.

Stability Testing

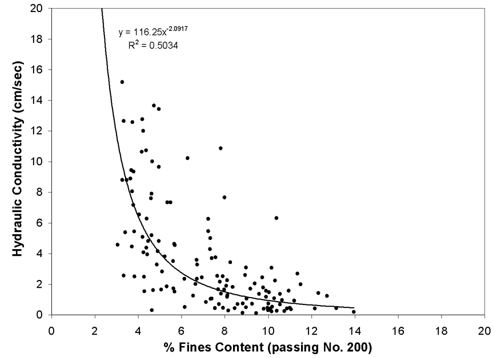
Three base course stability test methods were evaluated: (1) dynamic cone penetrometer (DCP), (2) Clegg impact hammer, and (3) GeoGauge. The DCP was developed by the U.S. Corps of Engineers and provides a rapid means of determining strength to a depth of 1,000 mm. The Clegg impact hammer method uses a drop weight and an accelerometer to indirectly determine stiffness at the surface. The GeoGauge also provides a surface measurement, but uses high-frequency vibrations to determine stiffness.

Based on a portland cement concrete pavement design assumption, a target California bearing ratio (CBR) of 15% was selected for the average in-place stability of granular subbase materials. The following values of the three tests are required to achieve this target:

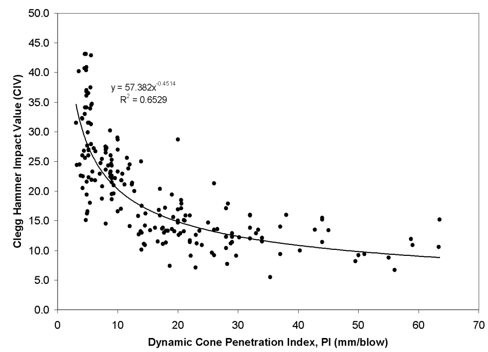
- DCP penetration index ≤ 14 mm/blow
- Clegg impact value ≥ 20
- GeoGauge modulus ≥ 80 MPa

Of the three methods, the DCP provides the most reliable results; however, its use is the most labor intensive. The Clegg impact hammer method and GeoGauge allow the operator to make more tests in a shorter period of time. Of the latter two methods, the Clegg impact hammer was found to have the best correlation with standard test results.

Therefore, it is recommended that stability be tested by conducting DCP tests every two stations and supplementing those tests with Clegg impact hammer tests to identify areas of local weakness.



Relationship between hydraulic conductivity and fines content



Relationship between DCP penetration index and Clegg impact value

Additional Research Needs

- Additional research is needed to observe the in-place condition of several drainable bases currently in service. This could be accomplished by coring through the pavement, infiltrating the base with epoxy, and then coring the epoxy impregnated base. New testing equipment could be used to determine the configuration of aggregate and voids.
- The use of recycled concrete as a drainable base course needs to be more fully investigated. A field and laboratory study of the performance (e.g., plastic strain development and degradation) under repeated loading is recommended.
- Additional research to determine how much spatial uniformity is required for desired pavement performance would also be of great benefit.