Soil Sub-Grade Modulus
The following are excerpts from the PCA publication *Concrete Floors on Ground* (EB075.03). For full treatment of the subject the reader is advised to consult the original text of the publication.

Subgrade-Subbase Strength
Soil bearing capacity, soil compressibility, and soil modulus of subgrade reaction are various measures of strength-deformation properties of soil. It is important to consider how these parameters apply to the design of floor slabs.

The allowable soil bearing capacity is the maximum pressure that can be permitted on foundation soil with adequate safety against soil rupture or excessive settlement. Allowable soil pressure may be based on:

- Laboratory shear strength tests (of soil samples) such as the direct shear test, triaxial compression test, or unconfined compression test
- Field tests such as the standard penetration test or cone penetrometer test
- Soil classification
- Moisture-density-strength relationships (established by conducting strength tests on soil specimens prepared for moisture-density testing)

Beyond the allowable soil pressure is the ultimate bearing capacity, the load per unit area (soil pressure) that will reduce failure by rupture of a supporting soil.

Another soil characteristic, compressibility of cohesive soils, determines the amount of long-term settlement under load. The usual method for predicting settlement is based on conducting soil consolidation tests and determining the compression index for use in the settlement computations. The compression index may be estimated by correlation to the liquid limit of the soil.
A third measure of soil strength, Westergaard's modulus of subgrade reaction, *k*, is commonly used in design procedures for concrete pavements and floors-on-grade that are not structural elements in the building (floors not supporting columns and load-bearing walls).

There is no reliable correlation between the three measures of soil properties-modulus of subgrade reaction, soil bearing capacity, and soil compressibility-because they are measurements of entirely different characteristics of a soil. The *k*-value used for floor-slab design reflects the response of the subgrade under temporary (elastic) conditions and small deflections, usually 0.05 inches or less. Soil compressibility and bearing capacity values (normally used to predict and limit differential settlements between footings or parts of a foundation) reflect total permanent (inelastic) subgrade deformations that may be 20 to 40 (or more) times greater than the small deflections on which *k*-values are based. Substantial pavement research has shown that elastic deflections and stresses of the slab can be predicted reasonably well when using *k*-value to represent the subgrade response. Consequently, the control of slab stresses based on the subgrade *k*-value is a valid design procedure.

Although the *k*-value does not reflect the effect of compressible soil layers at some depth in the subgrade, it is the correct factor to use in design for wheel loads and other concentrated loads because soil pressures under a slab of adequate thickness are not excessive. However, if heavy distributed loads will be applied to the floor, the allowable soil pressure and the amount of settlement should be estimated to determine if shear failure or excessive settlement might occur.

If there are no unusually adverse soil conditions, the design analysis requires only the determination of the strength of the subgrade in terms of *k*. The *k*-value is measured by plate-loading tests taken on top of the compacted subgrade (or subbase, if used). A general procedure for load testing is given in ASTM D

1196, *Standard Test Method for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements*. This method provides guidance in the field determination of subgrade modulus with various plate diameters. *Design of Slabs on Grade* (ACI 360R) is specifically oriented to the determination of modulus of subgrade reaction using a 760-mm (30-in.) diameter plate and gives more detailed information on test methods using this size plate. This plate is loaded to a deflection not greater than 0.05 inches, and the *k*-value is computed by dividing the unit load by the deflection obtained. A more economical test using smaller plates 12 inches that determines a modified subgrade reaction modulus is mentioned in ACI 360R. In each case, the units of *k* are given in pressure per length: MPa/m in the metric system, or in in.-lb units, pounds per cubic square inch, or psi per in. or, as commonly expressed, pounds per cubic inch (pci). The plate load test is no longer commonly run in practice. Instead, subgrade reaction values are estimated from the California Bearing Ratio or from the soil classification.

If a high-quality, well-compacted granular subbase is used under the floor slab, the *k*-value will increase. On large projects it may be feasible to construct a test section and perform plate load tests on top of the subbase.

Subbases

A subbase—the layer of granular material placed on top of prepared subgrade—is not mandatory for floors on ground. A granular subbase, however, can provide benefits during the construction process and afterwards (to the completed floor). During construction, the subbase functions as a stable work platform for heavy equipment. When grading and compaction operations do not produce a uniform subgrade, a granular subbase will provide a cushion for more uniform slab support by equalizing minor subgrade defects. The cushioning effect and increased uniformity can be very important for cohesive soils that are susceptible to reduced bearing support with increases in moisture content. A subbase also serves as a capillary break, reducing moisture migration towards the bottom of the completed slab. A granular subbase can also serve as a collection layer for radon gas.

Since uniform rather than strong support is the most important function of the subgrade and subbase for a concrete floor, it follows that floor strength is achieved most economically by building strength in to the concrete slab itself-with optimum use of low-cost materials under the slab.