CONCLUSIONS

The k-Value Guidelines

Based on the results of these analyses using the data from the LTPP GPS-3, -4, and -5 pavement sections, the following improvements to the NCHRP 1-30 k-value guidelines are recommended and have been made in the proposed supplement to the AASHTO Guide (see the appendix).

- **R-value vs. k-value correlation eliminated.** The LTPP data analyses indicated not only that the R-k correlation showed no agreement with the available data, but also that the available data did not demonstrate any significant trend in k-value with R-value.

- **Plate load testing on a test embankment** is only recommended if the embankment is at least 10 ft [3.0 m] thick. Otherwise, the k of the underlying subgrade should be determined based on testing or correlations and adjusted as a function of the thickness and density of the embankment. Testing on top of a granular embankment only a few feet thick may result in k-values too high for use in design.

- **A minimum static k-value of 25 psi/in [6.8 kPa/mm] is recommended** for fine-grained soils at 100 percent saturation. Deflection testing and backcalculation of all of the LTPP sections and many other pavements around the United States have never yielded k-values lower than this.

- **A summary table** was developed that lists soils by AASHTO soil class, unified soil class, and descriptive name, and identifies corresponding reasonable ranges for dry density, CBR, and static elastic k-value.

- **The correlation of CBR to k-value** was plotted with CBR on a log scale to better illustrate the relationship of CBR to k in the CBR range of 1 to 10.

- **The best fit backcalculation algorithm** yielded more consistent results than the AREA algorithm with respect to differences in sensor configuration, basin radius, inclusion of deflections under and very near the load plate, coefficient of variation with multiple load levels and load drops, and coefficient of variation along the project length. In general, use of the best fit methods is preferable to use of the AREA methods, but depends on software availability. For highway pavements, the Best Fit 4 solution is recommended.

- **The AREA$_7$ method is proposed for use in the AASHTO Guide** because it involves a few equations that can be easily presented on paper and solved by calculator or spreadsheet. Also, among the AREA methods, AREA$_7$ yielded the closest results to the best fit methods. The AREA$_7$ method can therefore be considered a quick and reasonable approximation of the results that best fit analysis would yield.

- **A slab size correction is strongly recommended** to correctly backcalculate the k-value, because all of the solution methods reviewed in this study are based on the assumption of infinite slab behavior, which is not realistic for highway slabs. It should be noted, however, that the slab size correction procedure originally developed by Crovetti and modified in this study still does not consider the effect that transverse and longitudinal joint load transfer and edge support, such as a tied PCC shoulder, may have in increasing the effective slab size. Crovetti has researched this topic, but further investigation is needed to develop a reliable and easy-to-use procedure to correct backcalculated k-values for rectangular slab sizes and partial load transfer.

- **The k-values backcalculated from FWD deflections exceeded plate load k-values**, for those LTPP sections for which plate load data were available, by factors averaging very close to 2 for all of the backcalculation algorithms. Thus, the simple rule for dividing the backcalculated k by 2 to estimate the plate load k is considered valid.

Concrete Pavement Performance Model

The predictive capability of the proposed new rigid pavement design model (developed under NCHRP Project 1-30) has been evaluated using the LTPP data from GPS-3 (JPCP), GPS-4 (JRCP), and GPS-5 (CRCP). These data were carefully retrieved and cleaned prior to use in the evaluation. Data were retrieved or calculated and entered in a spreadsheet for all required inputs to the new rigid pavement design model. This required a major effort to estimate all of the inputs required for the model.

The predicted log W was then calculated for each section in the LTPP database and compared to the accumulated ESALs for that section. Plots of predicted log W versus log ESALs were prepared for a variety of comparisons. These plots (Figures 26-39) show the overall quality of prediction for the new model and also of the 1986 AASHTO model. In addition, paired t-tests were conducted to determine if there were significant differences between predicted log W and actual log ESALs for the GPS-3 (JPCP). The following conclusions were reached after all of the data analyses were completed.

- The initial IRI (and, therefore, estimated PSI) was not available for most of the LTPP sections, and thus this value had to be estimated. For all of the analyses, a value of 4.25 was used. However, the specific 500-ft [152-m] LTPP sections could have an initial PSI ranging from 3.8 to 4.8. The impact of this variable was tested through predicted vs. actual runs for GPS-3 data. Results showed the following:

Initial PSI	**Mean Actual ESALs**	**Predicted ESALs**
4.5	4,500,000	6,600,000
4.25	4,500,000	4,500,000
4.0	4,400,000*	2,600,000

* This slightly different value is due to four sections being dropped from the analysis because the current PSI was greater than 4.0.

Therefore, if the mean PSI was 4.25 for all of these sections, the new prediction model, on average over all the data, predicts the actual ESALs on the sections from the time that they were opened to traffic. Since most of these sections were constructed in the 1960s, 1970s, and early 1980s (before the time when many states adopted smoothness specifications), an average initial value of 4.25 is certainly typical.

- Predicted log W vs. actual log ESALs plots were prepared for the following comparisons for GPS-3 (JPCP). The results achieved are provided for each.

  Slab thickness — Both thicker slabs (≥10 in [25 cm]) and thinner slabs (<10 in [25 cm]) show unbiased prediction (i.e., data evenly scattered on either side of the 1:1 line).

  Base type — Treated and non-treated aggregate base show unbiased prediction.

  Climate zone — Predictions in wet and dry freeze zones (northern United States) and wet and dry non-freeze zones (southern United States) show unbiased results.

- Data were also obtained for GPS-4 (JRCP) and GPS-5 (CRCP). Since the new recommended model was really applicable to JPCP, there is some interest in making the comparison for JRCP and CRCP. The main problem is in the selection of a hypothetical joint spacing for input. The evaluation and results show some potentially valuable conclusions that may be useful for design purposes.

  JRCP — Predicted log W vs. actual log ESALs plots were prepared for the GPS-4 data for a range of joint spacings (from actual to 15 ft [4.6 m]), all for an initial PSI of 4.25. The results clearly show that a joint spacing of 30 ft [9.1 m] maximum should be used for design purposes so that the mean log W is equal to the mean log ESALs.

  CRCP — Predicted log W vs. actual log ESALs plots were prepared for the GPS-5 data for a range of joint spacings (from 15 to 30 ft [4.6 to 9.1 m]), all for an initial PSI of 4.25. The results show that a joint spacing of 15 ft [4.6 m] should be used as a design input for CRCP so that the mean log W is equal to the mean log ESALs.

The predictive capability of the proposed new rigid pavement design model (developed under NCHRP 1-30) has been evaluated using the wide-ranging LTPP data from GPS-3 (JPCP), GPS-4 (JRCP), and GPS-5 (CRCP). The overall results show that the prediction error is about the same as that for the 1986 AASHTO model. An approximate analysis of the components of variation associated with the model was conducted. The results show significant variation associated with estimation of historical ESALs and with model inputs from each section, random variation between replicate sections, and, of course, true model error (or the inability of the model to predict actual performance). The new design/performance model includes many additional design capabilities and more realistically considers various design features such as joint load transfer, the base cover as a structural layer, thermal gradients in the slab, and cracking from undoweled joints. Overall, the model provides a much better accounting of the many concrete pavement design details that ultimately affect performance.