# AN INNOVATIVE DESIGN METHODOLOGY OF PAVEMENT DESIGN BY LIMITING SURFACE DEFLECTION

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## ABSTRACT

An iterative procedure is followed to predict the pavement deflections at the surface under the wheel load. Using a computer program, “KENPAVE”stresses, strains, and deflections are determined at all the important points in the pavement system. A strategy is designed to assign the stiffness values to various layers of the pavement system such that there exist negligible tensile stresses in the subgrade and base layers. The layer thicknesses are designed targeting the surface deflection within the acceptable limit. Several pavement sections are designed covering various environmental and traffic variables.

The minimum surface course thickness of 2 inches corresponded to lowest surface course stiffness which is 100, 000 psi. The highest surface course thickness of 20 inches corresponded to 500,000 psi of surface course stiffness. The average surface course thickness was 11 inches. The average surface course stiffness was 296,600 Psi.

**Keywords:***Surface Deflection, Innovative Design Methodology, Pavement Design*.

## 1. INTRODUCTION

Highway engineers have been constantly working for development of a rational method to estimate life of a given pavement through full scale road tests, model studies, laboratory experiments and theoretical analysis. Unlike steel and concrete whole structural properties are well defined, the behavior of crushed rock, water bound macadam (WBM) and other granular material, etc. is extremely complex and was little understood till about fortyyears ago resulting in slow progress in the development of rational method to find the relationship between life period of pavements and design thickness of constituent layers.

Flexible pavements design methods are still empirical or semi-empirical, based on past experience with similar subgrades, pavement materials and traffic loads. These methods are satisfactory as long as materials, traffic loading conditions and layer thicknesses do not differ from those for which the methods were developed. Because of considerable increase in frequency and intensity of axle loads, coupled with the use of new pavement materials the semi-empirical design methods have become irrelevant.

### Development of pavement design methods

During the last forty years considerable progress has been made in the theoretical approach to the development of fundamental methods of designing road pavements, Burmister [1,2,3] Fox [4] and Hank and Scrivner [5] gave tables and charts of influence values for determining stresses and deflections. Acum and Fox [6], Jones [7] and Peattie [8]presented tables and graphs for three layer systems. In all these investigations, Poisson’s ratio is assumed as 0.5,pertaining to an incompressible body and influence values have been given for points along the axis of symmetry. Verstraeten [9] gave generalized expression for determining stresses and deflections in a flexible pavement. Computer programs like BISAR [10], CHEVRON [11], ELSYM [12],EPVAE [13], MPAVE [13] and NPAVE [13], etc. have been developed by various researchers for analyzing stresses and deflections in multilayer pavement. All these computer programs assume the pavement to be linearly elastic. Duncan, Monismith and Wilson [14], Barksdale [15] and Crawfor [16] analyzed pavements having materials with non-linear structural properties. The rigorous analytical methods have gone a long way in bridging the gap between the theory and practice in pavement design.

## 2. METHODOLOGY

An iterative procedure is followed to predict the pavement deflections at the surface under the wheel load. Using a computer program, “KENPAVE”[17]stresses, strains, and deflections are determined at all the important points in the pavement system. A strategy is designed to assign the stiffness values to various layers of the pavement system such that there exist negligible tensile stresses in the subgrade and base layers. The layer thicknesses are designed targeting the surface deflection within the acceptable limit. Several pavement sections are designed covering various environmental and traffic variables. Repeated load tests and repeated diametral tests were conducted on soils and surface course materials respectively.

### Pavement design by the Method of Limiting Surface deflection

The following procedure was used.

1. Surface layer (h1) thicknesses was calculated by limiting surface deflection to 0.047 inches. (Matthews and Pandey) [18].
2. Two types of soils were selected.
3. Crushed stone was selected as the base material. Since crushed stone cannot take tensile stresses, their resilient moduli were calculated as double the value of subgrade resilient moduli.
4. Base thickness was taken as 6 and 12 inches.
5. Surface course stiffness was determined as a function of asphalt withlow density polyethylene (LDPE) content.
6. The required Surface course thicknesses were determined by limiting the surface deflection as 0.0466 (1 mm) inches. . For this purpose KENPAVE [17] software was used. These values were cross checked by a procedure shown by Yoder and Witczak [19].

## 3. RESULTS AND DISCUSSION

The required surface course thicknesses were shown in Table 1. In order to compare the results, vertical stress at the bottom of the surface layer (Sigma z1), tensile stress at the bottom of the surface layer (sigma r1), and vertical stress at the bottom of base course (sigma z2) were calculated as shown in Tables 2 and 3. The results of KENPAVE [17] and the procedure shown in Yoder and Witczak[19] agreed within 95% accuracy. It is important to note that the variation in soil stiffness used in this study could not affect the surface course thickness. In future, more study is needed involving a wide variety of soils for determining the effect of subgrade stiffness on surface course thickness.

### Importance of limiting surface deflection

One of the important functions of the surface curse is to provide reasonably good friction and steering qualities for the vehicle riding the surface. Over the time, if the surface course in the transverse direction is deformed, dangerous conditions may result. Water may accumulate in the deformations. Depending on the depth of water, speed and weight of the vehicle travelling on the road surface, aquaplaning or Hydroplaning can occur on standing water. The wheels of the vehicle simply surf on the water. This phenomenon makes the wheels to lose their contact with the road. This is because the instantaneous stiffness of water increases considerably to support the vehicle. When the driver loses contact still travelling at high speeds, severe accidents may occur. Therefore it is important for the design and construction engineers to limit the surface deflection as shown in this study.

***Table 1. Calculation of Surface Course Thicknesses for Soil 1and 2***

| Soil 1 Stiffness Psi | Soil 2 Stiffness Psi | Base Stiffness Psi | Base Thickness Inches | Surface Stiffness Psi | Surface Course Thickness Inches |
|---|---|---|---|---|---|
| 7570 | 1180 | 15140 | 6 | 250000 | 7 |
| 7570 | 1180 | 15140 | 6 | 305000 | 11 |
| 7570 | 1180 | 15140 | 6 | 277000 | 9 |
| 7570 | 1180 | 15140 | 6 | 495000 | 19 |
| 7570 | 1180 | 15140 | 6 | 490000 | 18 |
| 7570 | 1180 | 15140 | 6 | 500000 | 20 |
| 7570 | 1180 | 15140 | 6 | 100000 | 2 |
| 7570 | 1180 | 15140 | 6 | 121000 | 6 |
| 7570 | 1180 | 15140 | 6 | 131600 | 7 |
| 7570 | 1180 | 15140 | 12 | 250000 | 7 |
| 7570 | 1180 | 15140 | 12 | 305000 | 11 |
| 7570 | 1180 | 15140 | 12 | 277000 | 9 |
| 7570 | 1180 | 15140 | 12 | 495000 | 19 |
| 7570 | 1180 | 15140 | 12 | 490000 | 18 |
| 7570 | 1180 | 15140 | 12 | 500000 | 20 |
| 7570 | 1180 | 15140 | 12 | 100000 | 2 |
| 7570 | 1180 | 15140 | 12 | 121000 | 6 |
| 7570 | 1180 | 15140 | 12 | 131600 | 7 |

***Table 2. Calculation of Sigma z1, Sigma r1, and Sigma z2 for soil 1***

| **Soil Stiffness Psi** | **sigma z1** | **sigma r1** | **sigmaZ2=sigmaz3** |
|---|---|---|---|
| 7570 | 25.94 | -97.79 | 10.74 |
| 7570 | 7.99 | -93.40 | 4.99 |
| 7570 | 20.14 | -95.98 | 10.05 |
| 7570 | 1.90 | -30.85 | 1.70 |
| 7570 | 2.03 | -30.81 | 1.90 |
| 7570 | 1.71 | -31.14 | 1.60 |
| 7570 | 97.44 | -73.22 | 44.88 |
| 7570 | 53.35 | -70.38 | 16.67 |
| 7570 | 43.75 | -79.98 | 14.65 |
| 7570 | 24.00 | -94.56 | 7.10 |
| 7570 | 6.00 | -93.40 | 2.30 |
| 7570 | 11.45 | -81.14 | 5.60 |
| 7570 | 1.40 | -30.73 | 0.85 |
| 7570 | 1.60 | -30.62 | 1.20 |
| 7570 | 1.14 | -31.07 | 0.71 |
| 7570 | 82.30 | -82.59 | 14.20 |
| 7570 | 46.68 | -72.07 | 10.30 |
| 7570 | 38.10 | -80.66 | 8.25 |

***Table 3. Calculation of Sigma z1, Sigma r1, and Sigma z2 for soil 2***

| **Soil 2 Stiffness Psi** | **sigmaZ1** | **Sigmar1** | **sigmaZ2=sigmaz3** |
|---|---|---|---|
| 1180 | 20.1 | -88.51 | 8.33 |
| 1180 | 2.15 | -84.12 | 2.58 |
| 1180 | 14.3 | -86.7 | 7.64 |
| 1180 | 1.66 | -21.57 | -0.71 |
| 1180 | 1.79 | -21.53 | -0.51 |
| 1180 | 1.47 | -21.86 | -0.81 |
| 1180 | 97.2 | -63.94 | 42.47 |
| 1180 | 47.51 | -61.1 | 14.26 |
| 1180 | 37.91 | -70.7 | 12.24 |
| 1180 | 18.16 | -85.28 | 4.69 |
| 1180 | 0.16 | -84.12 | -0.11 |
| 1180 | 5.61 | -71.86 | 3.19 |
| 1180 | 1.16 | -21.45 | -1.56 |
| 1180 | 1.36 | -21.34 | -1.21 |
| 1180 | 0.9 | -21.79 | -1.71 |
| 1180 | 76.46 | -73.31 | 11.79 |
| 1180 | 40.84 | -62.79 | 7.89 |
| 1180 | 32.26 | -71.38 | 5.84 |

## 4. CONCLUSIONS

1. The minimum surface course thickness of 2 inches corresponded to lowest surface course stiffness which is 100, 000 psi.
2. The highest surface course thickness of 20 inches corresponded to 500,000 psi of surface course stiffness.
3. The average surface course thickness was 11 inches. The average surface course stiffness was 296,600 Psi.

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