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Stress and Strain Analysis for Stabilized Subbase and Wet Mix Macadam Pavement Using KENPAVE Computer Programme

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ABSTRACT: The primary function of a pavement is to distribute the loads applied by vehicles to the subgrade through superimposed strata of coursed material. One of the essential considerations in flexible pavement design is to limit the stresses, strains, and deflections due to the design wheel load through the pavement on top of subgrade soil. In the present investigation, an attempt has been made to reduce the stress and strain on the clayey subgrade using stabilized subbase and Wet Mix Macadam (WMM) on top of the subbase. The layered theory concept is used for computing elastic modulus and the KENPAVE computer program is used to find vertical stress and strain distributions.

KEYWORDS: Deflection, Stabilized subbase, WMM, KENPAVE, Compressibility.

I. INTRODUCTION

The stress and strain analysis using the deflection method is based on the idea of traffic-conditioned pavement sections deform elastically under load. When a wheel load is applied to the pavement's surface, the greatest vertical stresses are localized at the surface over a load-affected area. These vertical stresses decrease with depth due to dispersion. The increment layer of soil beneath the wheel load will therefore be compressed according to the intensity of vertical stresses and compressibility of the material. The total sum of vertical elastic compression of all incremental layers of soil under the centre of the load area is represented by the surface deflection. Fly ash is the non-combustible mineral part of coal that is produced in a coal combustion power plant. Its particles are glassy smooth, sphere-shaped, and typically finer than cement particles. Here an attempt has been made to use the fly ash to stabilize the subbase layer of the pavement. Depending on the project requirements, WMM construction includes placing and compacting clean, crushed, graded aggregate and granular material premixed with water to a dense mass over a prepared subbase layer. The study investigates the application of WMM to lower the stresses in the pavement structure's base layer. In 1993, a software package named KENPAVE was developed by Yang H. Huan. It has been used primarily for the analysis and design of pavement structures, in particular as a tool to calculate stresses, strain or deformation on both rigid and flexible pavements.

The limiting deflection method is used to estimate pavement thickness such that vertical deflection does not exceed the allowable limit. The Kansas state highway commission modified Boussinesq's equation and limited the deflection of the subgrade to 2.54 mm. The United States Navy applied Burmister's two-layer theory and limited surface deflection to 6.35mm. Deflection measurement in the field is advantageous and is used as a design parameter. However, pavement failures are caused due to excessive stresses and strains instead of deflections. This study employs Empirical-Mechanistic based authentic software such as KENPAVE to assess the stresses and strains on the subbase and base course layer.

II. REVIEW OF LITERATURE

Burmister, D. M. [1] two-layer theory discloses the two important ratios namely: (i) the ratio r/h_1 of the radius bearing area (r) to the thickness of the reinforcing or pavement layer (h_1); and (ii) the ratio E_2/E_1 of the subgrade modulus to that of the pavement. For practical design purposes, the theoretical conclusions were quantitatively analysed and expressed in fundamental influence curves, yielding values of the settlement coefficient f_w in terms of these fundamental ratios. The settlement coefficient is applied to the familiar Boussinesq equation for surface settlement at the centre of a circular flexible bearing area as a simple multiplication or correction factor. John H.

Faber [2] described the use of power industry by-products such as fly ash, bottom ash, and boiler slag in highway construction can solve two noteworthy problems: (a) the rapidly depleting supply of natural building materials in the highway construction sector, and (b) the ever-growing quantities of fly ash, bottom ash, and boiler slag that need to be disposed of in the power sector. As indicated by the highway embankment projects described in this paper, the technology for using fly ash as a fill material is well-developed. Additionally, there are technologies that can be used to use all of these materials in numerous other elements of roadway construction. Thomas S. Lewis [3] developed a methodology for the construction of fly ash embankments that includes the distribution of fly ash in thin lifts, scarification, and compaction by a vibratory roller. A clay seal was used to aid in limiting the fly ash during construction and to provide a means of supporting vegetation. The performance of this roadway embankment has been satisfactory with respect to both structural stability and aesthetics. Johnny Bolden et al. [4] performed a questionnaire survey of construction industry specialists to assess current waste and recycled material practices in the construction sector. This study provides early knowledge of the practice's current strengths and shortcomings in order to assist the construction industry in formulating successful rules for the use of waste and recycled materials as construction materials. Salim Khan et al. [5] interpreted the advantage of WMM over WBM (water bound macadam) and concluded the cost of WMM is more, but it is more durable, constructed at a faster rate, get dry sooner, consumption of water is less and can be opened for traffic within less time as compared to the WBM roads which take about one month for getting dry. Also, materials used in the WBM are the stone aggregates, screenings, and binder Stone dust with water) while in WMM materials used are only stone aggregates and binders. Lunds and Ramsey [6] compared surface deflections on pavements with and without lime-stabilized subgrades and with and without lime-stabilized bases. To evaluate the impact of stabilized layer thickness, thickness modifications were done. This investigation concluded that the presence of a lime-stabilized subgrade or base led to noticeably lower deflections than the control section without a stabilized layer. Shiferaw G. W. et al. [7] calculated the stress, strain & deflection of pavement layers by Finite Element Model (FEM). Pavement materials' layer thickness, loads, elastic modulus, and Poisson's ratio are used as design parameters. This study investigated the sensitivity of road parameters for analysing the main causes of failure in asphalt pavement layers, such as fatigue cracking and rutting deformation caused by critical tensile-strains at the bottom of the asphalt layer and critical compressive-strains on the top of the subgrade. Barksdale [8] computed the vertical compressive-stress pulse width as a function of speed and depth using FEM and elastic theory. He discovered that the pulse form varied from about sinusoidal at the surface to almost triangular at depths below the centre of the base. It was discovered that the pavement geometry had no effect on pulse shape or duration. It was also discovered that changes in the resilient modulus values of pavement materials due to environmental changes had no effect on pulse shape and length. Loulizi, A., and Al-Qadi, I. L. [9] assessed vertical strains beneath the Hot Mix Asphalt (HMA) at various temperatures. To define the conditions under which the theory can be applied, four different sections were compared to those computed using linear layered elastic theory. The calculated values were found to be greater than those measured for low and intermediate temperatures. However, at high temperatures, the layered elastic theory drastically underestimates the vertical stresses. Touqeer A R et al. [10] calculated stresses and strain in the flexible and rigid pavements using the KENPAVE software. The goal of this research is to validate and compare KENPAVE design software to the existing empirical design approaches, as well as to investigate the effect of variation in wearing course and base course thicknesses on pavement performance and design life in terms of fatigue and rutting damage. Priyanka B A et al. [11] analysed stress and strain parameters for all layers of low-volume roadways in both conventional and critical situations using KENPAVE. For critical instances, the same thickness and materials as in the standard case were used, with only the material properties modified. In this study, the load was defined as a single axle single wheel load, and an analysis was made for the worst subgrade condition for a CBR value up to 2% for various load conditions.

III. METHODOLOGY

In the present study, the load application is limited to only incremental static loading under dual wheel assembly is as shown in Figure 1. Burmister's analysis makes the usual simplifying assumptions of homogeneity, isotropy and elasticity for the materials of accuracy. Thus, the extent to which such assumptions are applicable in actual practice will determine the relevance of this analysis. A basic assumption that is also used in nearly all conventional elastic analysis including that the values of elastic moduli in tension or compression are equal. The vertical compressive stress and strain value on the subgrade were calculated by using KENPAVE software.

IV. EXPERIMENTAL RESULTS

Compaction test results for soil subgrade and sub-base are shown in Tables 1 & 2. The wheel load tests were conducted on the subgrade, subbase, and base course to note down the deflections of each layer. The variation of deflection versus load at different sections for the subbase and base course is shown in Figures 3 & 4. Elastic Modulus values E_3 , E_2 , and E_1 along with deflection values are tabulated in Tables 3 & 4. Figures 5 & 6 show the values of vertical stress and strain on the base course.

Table 1: Compaction test result for soil subgrade

Particulars	Actual field density (g/cc)	Modified proctor density (g/cc)	Achieved density (%)
On clay subgrade	1.72	1.77	97.74

Table 2: Compaction test result for prepared sub-base course

Particulars	Actual field density (g/cc)	Modified proctor density (g/cc)	Achieved density (%)
Section 1	1.66	1.68	98.80
Section 2	1.65	1.71	96.49
Section 3	1.59	1.66	95.78
Section 4	1.60	1.71	93.57

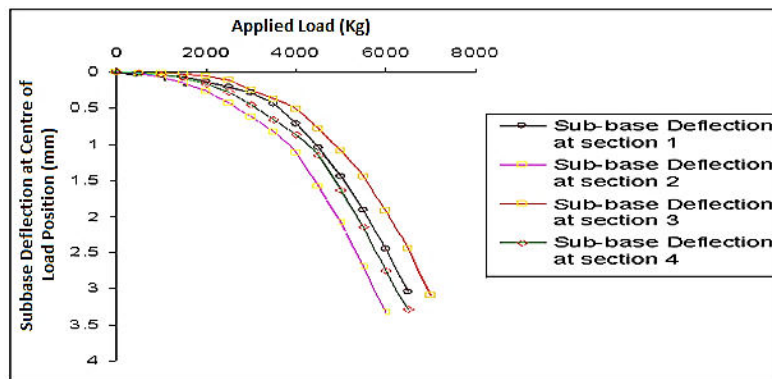


Figure 3: Sub-base Deflections at Sections 1, 2, 3 and 4

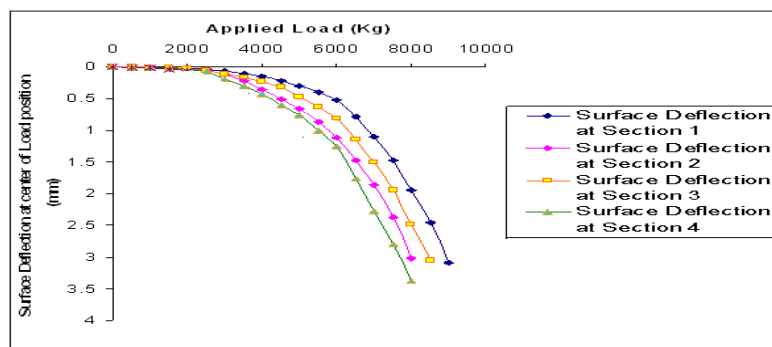


Figure 4: Base Course Deflections at Sections 1, 2, 3 and 4

Table 3: Calculated E_3 and E_2 values

Section	DEFLECTION AT SUBGRADE (cm)	DEFLECTION AT SUB-BASE (cm)	MODULUS OF ELASTICITY OF SUBGRADE E_3 (Kg/cm ²)	F_w	E_2/E_3	MODULUS OF ELASTICITY OF SUB-BASE E_2 (Kg/cm ²)
1	0.332	0.072	380	0.38	15	5700
2	--	0.111	--	0.45	10	3800
3	--	0.051	--	0.31	20	7600
4	--	0.086	--	0.42	12	4560

Table 4: Calculated E_1 and E_2 values

Section	DEFLECTION AT SUB-BASE (cm)	DEFLECTION AT SURFACE (cm)	MODULUS OF ELASTICITY OF SUB-BASE E_2 (Kg/cm ²)	F_2	E_1/E_2	MODULUS OF ELASTICITY OF SURFACE E_1 (Kg/cm ²)
1	0.304	0.09	5700	0.35	50	285000
2	0.301	0.112	3800	0.38	40	152000
3	0.309	1.51	7600	0.42	36	273600
4	0.329	1.26	4560	0.45	28	127680

Here F_w = Deflection Factor

E_3/E_2 = Modulus of elasticity ratio (calculated from influence values – two-layer theory chart)

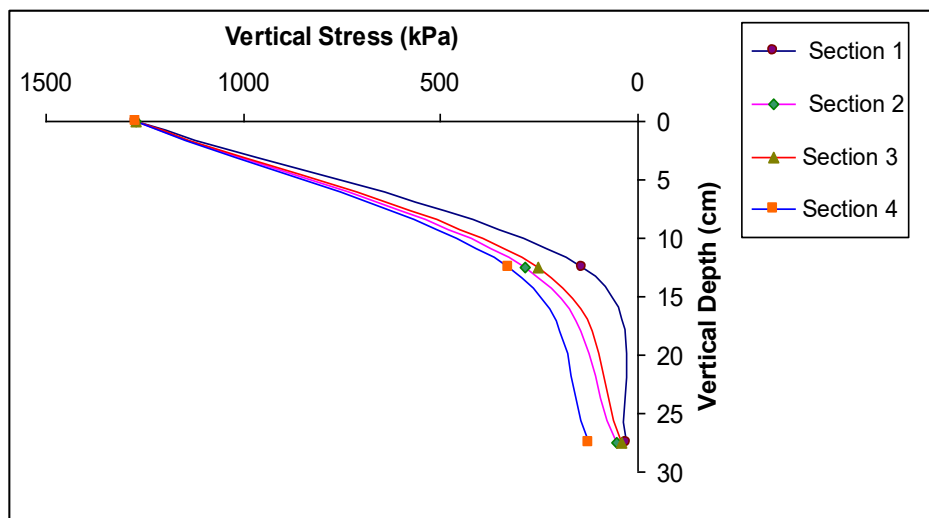


Figure 5: Vertical Stress distribution for Section1, 2, 3 and 4 at Pavement Vertical Depths

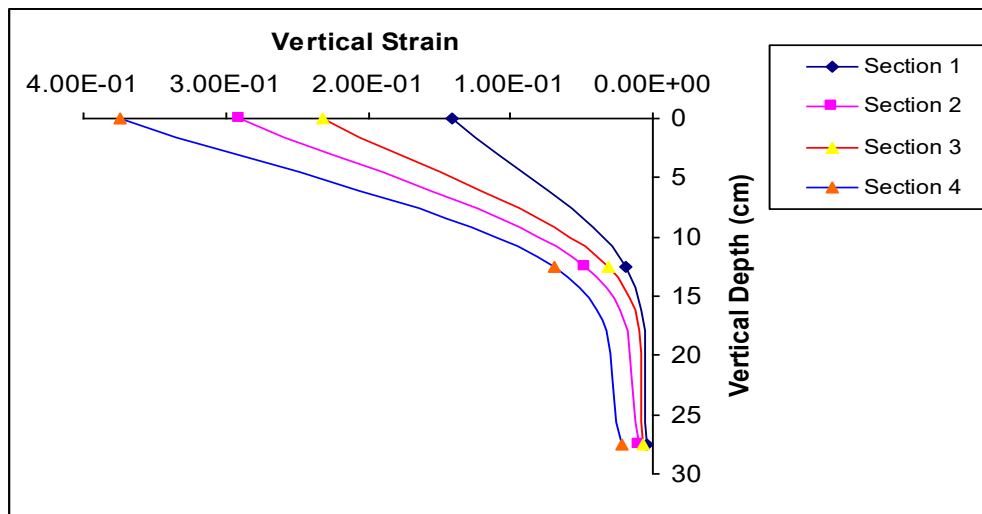


Figure 6: Vertical Strain Distributions for Section 1, 2, 3 and 4 at Pavement Vertical Depths

The study's findings are as follows:

Fly ash soil stabilisation is a common method used to improve the engineering qualities of soils, particularly cohesive or clayey soils. Because of its pozzolanic qualities, fly ash, a by-product of coal combustion in power plants, can be used as a stabilising agent. From the above observation section 3 yields 27, 73, and 42% lesser deflection as compared to sections 1, 2 & 4. The deflection value of the sub-base falls due to an increase in thickness even at a slight reduction in fly ash percentage.

WMM provides a robust and long-lasting foundation that can sustain large loads and traffic. The application of binding agents promotes aggregate bonding, increasing stability and load-bearing capability. Furthermore, WMM provides for efficient water drainage, lowering the risk of waterlogging and moisture damage. From the above observation section 1 yields 55, 29, and 31 % lesser deflection values compared to sections 2, 3 & 4. Here the higher thickness of WMM and 50:50 proportion of soil-fly ash decreases the deflection value.

A computer programme called KENPAVE is used for pavement analysis and design; it applies to determine stresses and strains. From the observation stress in section 1 is 55, 42 and 76 percent lesser value compared to 2, 3 & 4. Similarly, the strain on section 1 is 57, 54 & 78 percent lesser value compared to 2, 3 & 4.

V. CONCLUSION

The following conclusions were drawn.

1. An increase in fly ash content to stabilize the sub-base has resulted in a reduction of surface deflection, vertical compressive stress, and strain on the subgrade.
2. The surface deflection, vertical stress, and vertical strain on subgrade for test section 1 are lower compared to test section 3. Since the fly ash and clayey soil mix proportion of sections 1 and 3 remained the same, the higher thickness of the subbase and lower thickness of wet mix macadam in section 3 contributed to a small increase in deflection value.
3. The surface modulus value for test section 1 is higher when compared to test section 3. This indicates that test section 1 has a better elastic property compared to section 3.
4. The semi-field test track studies and the analysis using a computer program has revealed that test section 1 is stronger when compared with other sections and section 4 is the weakest.

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