Evaluation of Vertical Compressive Stress on Stabilized Subgrade in Pavement System

Mohan M [1] , Dr.Manjesh L[2], Deeksha I M[3]

[1]Research Scholar,Department of Civil Engineering, University Visvesvaraya College of Engineerin (UVCE), Bangalore University, Bengaluru-560056, India.

[2]Associate Professor, Department of Civil Engineering, UVCE, Bangalore University, Bengaluru-560056, India

[3]PG Student, M.E (Highway Engineering) Department of Civil Engineering, UVCE, Bangalore University

---***---

Abstract:- *Soil stabilization is the one of the method to increase the strength of subgrade soil. It is necessary to study the contribution made by each pavement layer to reduction in stresses in the pavement system. In the present study an attempt has been made to study the reduction in vertical compressive stress in subgrade layer which has varied stabilizing materials used as reinforcement. Pavement is a two layered pavement system with GSB as the surface layer and subgrade is layer beneath. There are five test sections which compose of controlled subgrade section (un-stabilized), coir geotextile reinforced section, jute geotextile reinforced section, coir fiber reinforced section and jute fiber reinforced section. The cyclic plate load test is conducted on each layer of different sections of semi -field test track. The stress on subgrade is measured using pressure cells embedded at 200mm depth from the surface of the pavement, where one is along the axis of loading and another one 20cm offset from axis of loading. The theoretical method is also employed to determine the vertical stress using Bermister's two layer graphs and with the IIT PAVE software. The comparison of the vertical compressive stress between the field test, theoretical methods and IIT PAVE Software is made. From the test result stabilized subgrade distributes the stress more efficiently by increasing the load influencing area. The overall test results of the study shows improvement in spreadability of vertical compressive stress using natural coir and jute fiber and geotextile.*

Key Words: **Stabilization, Vertical compressive stress, Two layer pavement, Cyclic plate load test, Pressure cell.**

1. INTRODUCTION

The flexible pavements consist of wearing surface built over a base course and they rest on compacted sub grade. The various layers of the flexible pavement structure have different strength and deformation characteristics which make the layered system difficult to analyze in pavement engineering [1]. Deflection, stress and strain are three parameter developed due to application of load. Boussineq's equations represent an elastic solution to the one layer system, Burmister (1943) developed solutions first for two-layer and later for three-layer systems, which advanced pavement analysis considerable [2]. He obtained the solution

for maximum surface deflection for a two layer pavement system under a normal surface load uniformly distributed over a circular area. The vertical stress on the top of subgrade is an important factor in pavement design. The function of a pavement is to reduce the vertical stress on the subgrade so that detrimental pavement deformations will not occur [3]. The allowable vertical stress on a given subgrade depends on the strength or modulus of the subgrade.

1.1 Objectives of the present study

1. Evaluation of vertical compressive stress on subgrade in semi field model pavement.
2. Determination of effectiveness of pavement of different subgrade soil treated with Geotextiles.
3. To compare the vertical stress obtained from field studies, theoretical graphs and IIT PAVE Software.

1.2 Pavement sections of semi-field testrack

The pavement consists of subgrade and subbase layer. Granular subbase (GSB) course grade II used as a subbase. There are five different subgrade sections they are
SECTION A: Controlled subgrade section + GSB layer
SECTION B: Coir geotextile stabilized subgrade + GSB layer
SECTION C: Jute geotextile stabilized subgrade + GSB layer
SECTION D: Coir fiber stabilized subgrade + GSB layer
SECTION E: Jute fiber stabilized subgrade + GSB layer
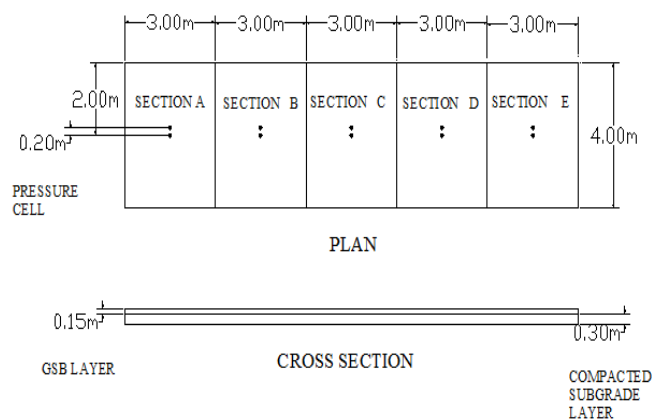
Fig -1: Plan and cross section of semi-field test track

1.3 Instrumentation of subgrades

- Pressure Cells are designed to measure stresses or pressure in soil.
- The conversion of pressure into an electrical signal is achieved by the physical deformation of strain gauge which are bonded into the diaphragm of the pressure cell and wired into a wheat stone bridge configuration.
- Pressure applied to the pressure cell produces a deflection of the diaphragm which introduces strain to the gauge. The strain will produce an electrical resistance which changes proportional to the pressure.
- Cells are embedded at a depth of 5cm below the subgrade or 20cm below the top of granular subbase layer.
- Two pressure cells are embedded one is at centre of loading and another one at distance of 20cm offset from centre of loading.

Fig - 2: Pressure cell installation

2. Approaches for evaluation of vertical stresses

- Burmister's layer theory
- IIT PAVE Software
- Field test method by Plate load test

2.1 Computation of vertical stress on subgrade by two layer theory

- In two layer system considering subgrade and subbase as two layers where GSB layer as a second layer.
- The thickness of GSB layer (h) is 150mm and thickness of compacted subgrade layer is 300mm.
- Plate load test by 75cm diameter plate and radius (a) is 37.5cm.
- The pressure cells installed at 200mm depth from the surface of the GSB layer so z is 200 mm.
- For the analysis modulus of elasticity of GSB layer E_1 and modulus of elasticity of subgrade E_2 taken from cyclic plate load test by conducting in each section[5][6].
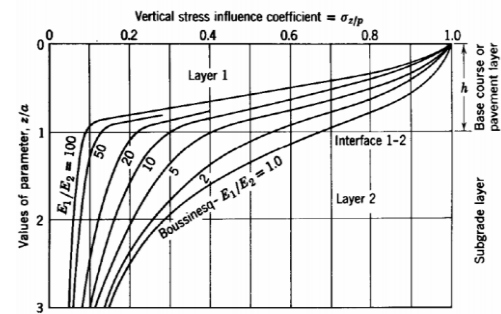- From Burmister's two layer chart vertical stress distribution calculated for each sections [1][2][3].

Fig -3: Vertical stress distribution charts (two layers)

Table -1: Vertical stress from distribution chart

load kg	z/a	E_1/E_2	Pressure p kg/cm²	σ/p	Stress, σ kg/cm²
SECTION A					
1000	0.533	13	0.23	0.72	0.163
2000	0.533	13	0.45	0.72	0.325
3000	0.533	13	0.68	0.72	0.488
4000	0.533	13	0.90	0.72	0.651
5000	0.533	13	1.13	0.72	0.814
SECTION B					
1000	0.533	9	0.23	0.76	0.172
2000	0.533	9	0.45	0.76	0.344
3000	0.533	9	0.68	0.76	0.515
4000	0.533	9	0.90	0.76	0.687
5000	0.533	9	1.13	0.76	0.859
SECTION C					
1000	0.533	9	0.23	0.76	0.172
2000	0.533	9	0.45	0.76	0.344
3000	0.533	9	0.68	0.76	0.515
4000	0.533	9	0.90	0.76	0.687
5000	0.533	9	1.13	0.76	0.859
SECTION D					
1000	0.533	6	0.23	0.86	0.194
2000	0.533	6	0.45	0.86	0.389
3000	0.533	6	0.68	0.86	0.583
4000	0.533	6	0.90	0.86	0.778
5000	0.533	6	1.13	0.86	0.972
SECTION E					
1000	0.533	7	0.23	0.84	0.19
2000	0.533	7	0.45	0.84	0.38
3000	0.533	7	0.68	0.84	0.57
4000	0.533	7	0.90	0.84	0.76
5000	0.533	7	1.13	0.84	0.95

2.2 Computation of vertical stress on subgrade by IIT PAVE Software

- The reqired input entered in software and run the data. The output of the sofware noted[4].
- IIT PAVE Software is used to determine vertical stress using plate load data.
- The inputs for IIT PAVE Software are modulus of elasticity of two layers in MPa, poisson's ratio $\mu = 0.45$ for subbase and $\mu = 0.5$ for subgrade respectively and thickness of subbase h = 150mm.
- For a 5000kg load, for each section input in terms of Newton and corresponding tyre pressure in MPa.
- Analysis point to be taken as two, depth of analysis will be 200mm for test on subbase. Two radial distances where taken, r = 0 and r = 200cm
- In the result sheet all the input will be displayed and σ_z, σ_t, σ_r, ε_z, ε_t, ε_r and displacement are output.

  Where

  σ_z = vertical stress

  σ_t = Tangential horizontal stress

  σ_r = Radial horizontal stress

  ε_z = vertical strain

  ε_t = Tangential horizontal strain

  ε_r = Radial horizontal strain

Table -2: Vertical stress from IIT PAVE Software

SECTION	r (mm)	σz (Mpa)	σz (kg /cm²)
SECTION A	0	0.084	0.857
	200	0.071	0.724
SECTION B	0	0.115	1.173
	200	0.088	0.898
SECTION C	0	0.109	1.112
	200	0.085	0.867
SECTION D	0	0.146	1.489
	200	0.102	1.040
SECTION E	0	0.134	1.367
	200	0.097	0.989

2.3 Field test method by plate load test (IS: 5249-1992)

- Cyclic plate load test conducted on GSB layer of each section. A 75cm diameter plate is used in the semi-field test track to conduct cyclic plate load test.
- The equipment for the test shall be assembled according to IS 1888: 1982.
- After the set-up has been arranged the initial readings of the dial gauges should be noted and the first increment of static load should be applied to the plate.

- The loading was done with increment of 250kg up to 5000kg and unloading also done at the same interval.
- At the stage of loading and unloading rebound deflection value and pressure cells value were recorded.
- Like this there are six loading and unloading cycles were conducted and corresponding stress level readings were recorded.

Fig - 3: Cycilc plate load test

Table -3: Vertical stress from pressure cell

Load kg	Applied Stress, kg/cm²	Measured pressure cell value, kg/cm² SECTION				
		A	B	C	D	E
Loading cycle, pressure cell at centre						
2500	0.57	0.49	0.42	0.44	0.32	0.38
5000	1.13	0.97	0.84	0.84	0.67	0.79
Loading cycle, pressure cell at 20cm offset from centre						
2500	0.57	0.23	0.27	0.33	0.20	0.26
5000	1.13	0.62	0.48	0.66	0.42	0.54
Unloading cycle, pressure cell at centre						
5000	1.13	1.06	0.79	0.84	0.60	0.85
2500	0.57	0.51	0.40	0.44	0.30	0.61
Unloading cycle, pressure cell at 20cm offset from centre						
5000	1.13	0.78	0.48	0.63	0.47	0.60
2500	0.57	0.31	0.22	0.29	0.26	0.36

2.3.1Comparison of vertical stress on subgrade for different sections

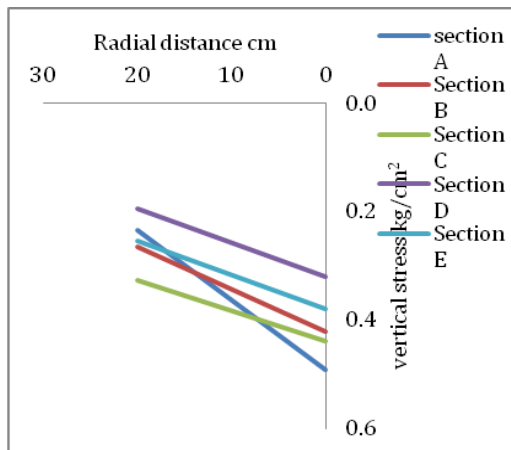Pressure cell reading at 2500kg loading and 5000kg loading grapical representation shown.

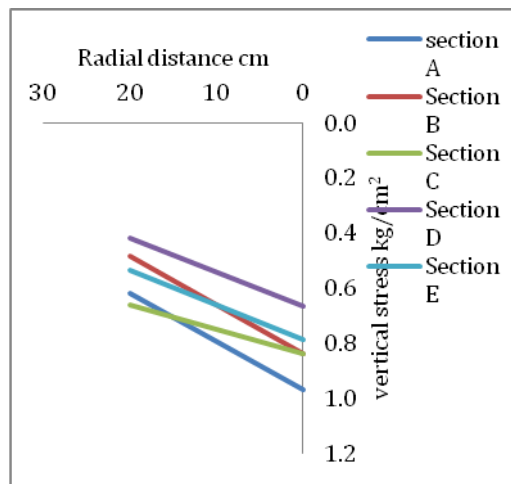**Chart -1**: Vertical stress on subgrade at 2500kg loading

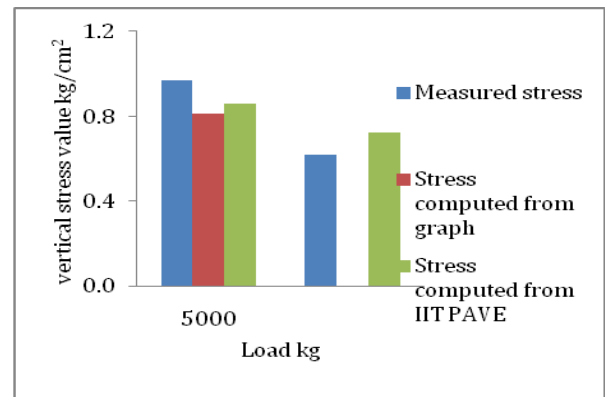**Chart -2**: Vertical stress on subgrade at 5000kg loading
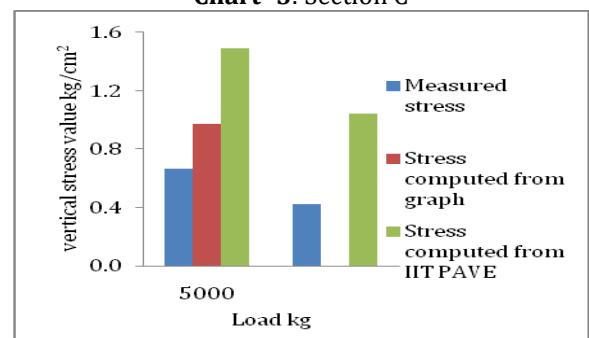
2.4 Comparison of the vertical stress value on subgrade by three approches

Table -4: Vertical stress comparison by three approaches

Section	Stress from semi field kg/cm² (Pressure cell)		Computed stress from graph kg/cm²	Computed stress from IIT PAVE kg/cm²	
	r = 0 centre	r = 20cm offset	r = 0 centre	r = 0 centre	r = 20cm offset
A	0.969	0.618	0.814	0.857	0.724
B	0.839	0.452	0.859	1.173	0.898
C	0.838	0.659	0.859	1.112	0.867
D	0.667	0.420	0.972	1.489	1.040
E	0.787	0.545	0.950	1.367	0.989

Comparison of the vertical stress value between field stress by pressure cell reading using 75cm plate for cyclic plate load test, computed stress from graphical method and IIT PAVE software for 5000kg stress level.
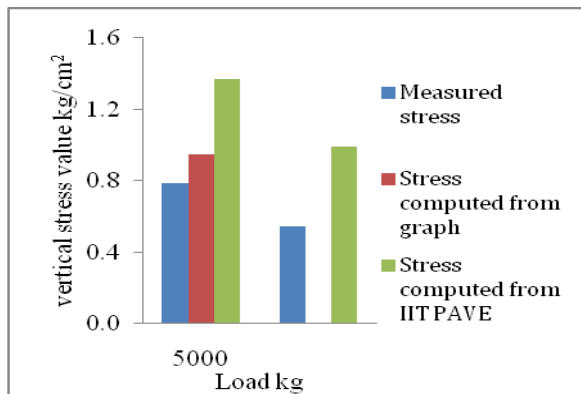

Chart -3: Section A

Chart -4: Section B
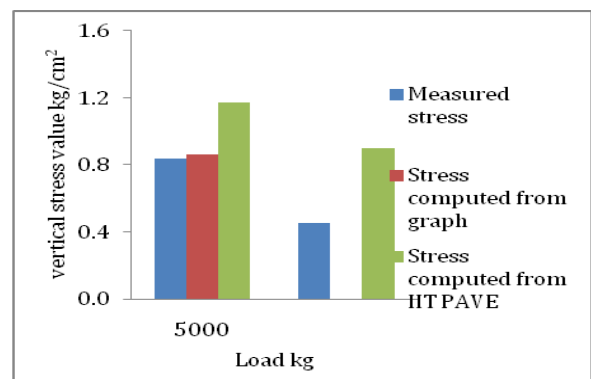
Chart -5: Section C

Chart -6: Section D

Chart -7: Section E

3. CONCLUSION

The magnitude of stress to be transferred on subgrade less compared to that of applied stress. The stress directly under loading is higher compare to that of stress at offset. From Burmister's two layer graphical method, vertical stress transmitted on subgrade decreases considerably with increase in the value of (E_1/E_2) ratio. Among five sections, section A having higher modular ratio and section D having least modular ratio. Hence section A transfers lower vertical stress value compared to stabilized pavement sections. Section D shows higher load spreadability compared to other sections.

ACKNOWLEDGEMENT

REFERENCES

[1] S.K Khanna, C. E. G. Justo and A. Veeraragavan, "Highway engineering", Revised 10th Edition, Nem Chand and sons publications.

[2] H. Yang Huang, "Pavement Analysis and Design", University of Kentucky.

[3] E. J. Yoder, M. W. Witczak , "Principles of pavement design",A wiley – Intercience publication

[4] IRC – 37 -2012 Guidelines for the design of flexible pavements

[5] IS 1888 (1982) Method of load test on soils, Indian Standard Institution, New Delhi, 110002.

[6] IS: 5249 (1992) Determination of dynamic properties of soils – Method of test, Indian Standard Institution, New Delhi, 110002.

[7] Y. Murad, Qiming Chen,"Evaluation of Geogrid Base Reinforcement in Flexible Pavement Using Cyclic Plate Load Testing", Department of Transportation and Development Louisiana Transportation Research Centre.

[8] Y. Murad, Abu-Farsakh, Qiming Chen,"Evaluation of the Base/Subgrade Soil under Repeated Loading" Department of Transportation and Development Louisiana Transportation Research Centre.

[9] Ahmed Abou-Zeid, "Distributed Soil Displacement and Pressure Associated with Surface Loading", The Department of Agricultural and Bioresource Engineering University of Saskatchewan.

[10] Tyler Olmstead, Erika Fischer, "Estimating Vertical Stress on Soil Subjected to Vehicular Loading", U.S. Army Engineer Research and Development Centre, Cold Regions Research and Engineering Laboratory.

[11] Amara Loulizi, L. Imad Al-Qadi and Mostafa Elseifi, "Difference between in Situ Flexible Pavement Measured and Calculated Stresses and Strains", Journal of transportation engineering .

[12] L. Freddy Roberts, T. John Tielking, Dan Middleton, L. Robert Lytton And Kuo-Hung Tseng, "Effects of Tire Pressures on Flexible Pavements", U. S. Department of Transportation", Federal Highway Administration.

[13] K. Shashidher,D.Rajashekar Reddy, "Improvement of Sub-Grade Material Using Additives", M.E, Transportation Engineering, University College of Engineering, Osmania University (India).

[14] Komershetty Goutami, KSR Murthy, D. Sandhya Rani, "Flexible Pavement Design and Comparison of Alternative Pavements using IRC 37-2012 IIT PAVE", Sree Dattha Institute of Engineering and Science, Sheriguda, Ibrahimpatnam, Telangana, India.

[15] G.R. Harish, "Analysis of Flexible Pavements using IIT PAVE", Assistant Professor , New Horizon College of Engineering, Bengaluru.

[16] M Mohan, L Manjesh, "A Study on Durability Characteristics of Natural Fiber Reinforced in Weak Soil", IJSRST 1737131, September-October-2017 [(3) 7: 760-765.

[17] M Mohan, L Manjesh, "A Study on Stabilization of Subgrade Soil Using Natural Fibers (Coir And Jute)" (September2017),ISSN: 2347-6710, ijirset.2017.

BIOGRAPHIES

Mohan M did his ME, Highway engineering at Department of Civil Engineering, UVCE and he is currently a Research Scholar at UVCE, Bangalore University and an active member of IRC.

Dr.Manjesh L is Associate Professor at Department of Civil Engineering, UVCE, Bangalore University. He is also holding the post of Co-ordinator, Centre for Transportation Engineering, Bangalore University. He did his M.E. Highway, and PhD at Department of Civil Engineering, UVCE. and member of IRC (Indian road congress).

Deeksha I.M is a Post Graduate student, M.E(Highway Engineering) Department of Civil Engineering, University Visvesvaraya College of Engineering, Bangalore University.