A COMPARATIVE STUDY BETWEEN THE RESULTS OF AN INNOVATIVE DESIGN METHODOLOGY BY LIMITING SURFACE DEFLECTION AND AASHTO DESIGN METHOD

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ABSTRACT
In this paper an innovative design procedure was used for designing several pavement sections covering various layer thicknesses, material and environmental variables. The designed sections are compared with the AASHTO procedure and the differences are discussed.

Keywords: *innovative design methodology, limiting surface deflecting, AASHTO method*.

1. INTRODUCTION
Pavement surface deflection represents the inversely combined strength of all the layers. On the whole, the higher the deflection, the weaker the pavement and vice versa. It is important to limit the pavement surface deflection not only for new constructions but also for rehabilitated pavements. This is because the pavement performance depends on the surface deflection. AASHTO design method deals with obtaining a weighted structural number as a function of sum of the products of layer thicknesses and their respective strength coefficients.

2. OBJECTIVES
The objectives of the paper are: (1) To develop an innovative design procedure for designing several pavement sections covering various layer thicknesses, material and environmental variables, and (2) The designed sections are compared with the AASHTO procedure and the differences are discussed.

3. MATERIALS AND TESTS
The supplier for Recycled Low Density Polyethylene (LDPE) [1,2] provided the test properties of the material with respect to density, tensile strength at break, elongation at break, impact strength, and melting point of the material. Repeated load tests on soils were conducted and Resilient Modulus was measured. Resilient Modulus was measured in Repeated Indirect tensile mode for asphalt specimens. Statistical average of three samples was taken to evaluate the test results [3. 4, 5]

4. METHODOLOGY
An iterative procedure [6,7] 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. 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 designed sections are compared with the AASHTO procedure and the differences are critiqued.

5. RESULTS AND DISCUSSION

5.1 Pavement design by AASHTO, untreated subgrade and crushed stone base
1. For the existing conditions and demands SN needed is calculated from the monograph as sown in Table 1.
   a) For E3 of 7570, the soil support value is 5.4
   b) Traffic is 10 million standard axles
   c) SN bar is determined.
   d) Regional factor is taken a 1.0
   e) SN weighted (SN needed) is calculated.
2. For the existing conditions and demands SN existing is calculated from AASHTO equation as shown in Table 1 and Table 2.
   SN existing = h1 * 0.44 (Plant Mix) + h2 0.14 (Crushed Stone)
3. Comparison of Surface deflection and AASHTO methods is shown in Table 1 and 2.

The comparison is for 5 sections for E3 = 7570 and 2 sections for E3= 1180 have failed.

Table 1 Soil 1 Pavement design by AASHTO , untreated subgrade and crushed stone base

E3:Soil	inch	E=ff(Asp %) psi	inch	SN needed	SN existing	Pass/Fail	Recommendation
	H2	E1, Surface	H1='				
7570	6	250000	7	4.2	3.92	**fail**	**Increase base by 1 inch**
7570	6	305000	11	4.2	5.68	pass	
7570	6	277000	9	4.2	4.8	pass	
7570	6	495000	19	4.2	9.2	pass	
7570	6	490000	18	4.2	8.76	pass	
7570	6	500000	20	4.2	9.64	pass	
7570	6	100000	2	4.2	1.72	**fail**	**Treat SG with lime**
7570	6	121000	6	4.2	3.48	**fail**	**Treat subgrade with lime**
7570	6	131600	7	4.2	3.92	**fail**	**Increase base by 1 inch**
7570	12	250000	7	4.2	4.76	pass	
7570	12	305000	11	4.2	6.52	pass	
7570	12	277000	9	4.2	5.64	pass	
7570	12	495000	19	4.2	10.04	pass	
7570	12	490000	18	4.2	9.6	pass	
7570	12	500000	20	4.2	10.48	pass	
7570	12	100000	2	4.2	2.56	**fail**	**Treat SG with lime**
7570	12	121000	6	4.2	4.32	pass	
7570	12	131600	7	4.2	4.76	pass	

Table 2 Soil 2 Pavement design by AASHTO , untreated subgrade and crushed stone base

E3:Soil	inch	E=ff(Asp %) psi	inch	SN needed	SN existing	Pass/Fail	
	H2	E1, Surface	H1='				
1180	6	250000	7	3.4	3.92	pass	
1180	6	305000	11	3.4	5.68	pass	
1180	6	277000	9	3.4	4.8	pass	
1180	6	495000	19	3.4	9.2	pass	
1180	6	490000	18	3.4	8.76	pass	
1180	6	500000	20	3.4	9.64	pass	
1180	6	100000	2	3.4	1.72	**fail**	**Treat SG with Cement**
1180	6	121000	6	3.4	3.48	pass	
1180	6	131600	7	3.4	3.92	pass	
1180	12	250000	7	3.4	4.76	pass	
1180	12	305000	11	3.4	6.52	pass	
1180	12	277000	9	3.4	5.64	pass	
1180	12	495000	19	3.4	10.04	pass	
1180	12	490000	18	3.4	9.6	pass	
1180	12	500000	20	3.4	10.48	pass	
1180	12	100000	2	3.4	2.56	**fail**	
1180	12	121000	6	3.4	4.32	pass	
1180	12	131600	7	3.4	4.76	pass	

5.2 Pavement design by AASHTO , Cement treated subgrade and untreated crushed stone base

1. SN needed is calculated as 2.5 form the monograph as shown in Table 3 and Table 4for Soil 1 and 2 respectively.
   a) For lime treated subgrade E3 = 2800 psi, and soil support value is s=9.
   b) Traffic is 10 million standard axles
   c) SN bar is determined.
   d) Regional factor is taken a 1.0
   e) SN weighted (SN needed) is calculated
   f) Existing SN is shown in Tables 3 and 4.
2. Determination of base thickness is shown in Tables 3 and 4.
   H1 is taken as 2 inches for the design of most economical pavement

5.3 Crushed Aggregate Base

The base thickness (H2) required to meet the SN needed (2.5 and 3.4) for **Crushed Aggregated Base** is calculated from the AASTO equation as shown in Table 3 and 4.

(i) H1 (2 inches) * 0.44 (plant mix) + H2 * 0.14 (crushed stone) = *2.5 (SN needed)*
S= 9, For E3 = 28,000 psi, 7570 psi virgin + cement treated subgrade), traffic 10 million SN bar = 2.5, R =1, SN Weighted= SN needed = 2.5

H2 required = 11.57 inches Table 3.

(ii) H1 (2 inches) * 0.44 (plant mix) + H2 * 0.14 (crushed stone) = 3.4 (SN needed)
S=7, For E3=14000 psi, 1180 psi virgin+ lime treated subgrade), traffic =10 million SN bar =3.4, R=1, SN weighted =SN Needed= 3.4.

H2 required = 18 inches Table 4.

Table 3 Soil 1 Pavement design by AASHTO , Cement treated subgrade (E3 = 28Ksi) and untreated crushed stone base

E3:Soil	**inch**	**E=ff(Asp %) psi**	**inch**	**AASHTO design**		**crushed aggregate base**
	H2	**E1, Surface**	**H1='**	**LIME TREATED SOIL**		**h2=(p-(2*.44))/0.14**
				S=9, SN needed=2.5	**SN existing**	**base thickness inch**
7570	6	250000	7	2.5	2.5	11.57
7570	6	305000	11	2.5	2.5	11.57
7570	6	277000	9	2.5	2.5	11.57
7570	6	495000	19	2.5	2.5	11.57
7570	6	490000	18	2.5	2.5	11.57
7570	6	500000	20	2.5	2.5	11.57
7570	6	100000	2	2.5	2.5	11.57
7570	6	121000	6	2.5	2.5	11.57
7570	6	131600	7	2.5	2.5	11.57
7570	12	250000	7	2.5	2.5	11.57
7570	12	305000	11	2.5	2.5	11.57
7570	12	277000	9	2.5	2.5	11.57
7570	12	495000	19	2.5	2.5	11.57
7570	12	490000	18	2.5	2.5	11.57
7570	12	500000	20	2.5	2.5	11.57
7570	12	100000	2	2.5	2.5	11.57
7570	12	121000	6	2.5	2.5	11.57
7570	12	131600	7	2.5	2.5	11.57

Table 4 Soil 2 Pavement design by AASHTO ,Lime treated subgrade (E3= 14 Ksi) and untreated crushed stone base

E3:Soil	**inch**	**E=ff(Asp %) psi**	**inch**		**crushed aggregate base**
	H2	**E1, Surface**	**H1='**		**h2=(p-(2*.44))/0.14**
				SN existing	**base thickness inch**
1180	6	250000	7	3.4	18.00
1180	6	305000	11	3.4	18.00
1180	6	277000	9	3.4	18.00
1180	6	495000	19	3.4	18.00
1180	6	490000	18	3.4	18.00
1180	6	500000	20	3.4	18.00
1180	6	100000	2	3.4	18.00
1180	6	121000	6	3.4	18.00
1180	6	131600	7	3.4	18.00
1180	12	250000	7	3.4	18.00
1180	12	305000	11	3.4	18.00
1180	12	277000	9	3.4	18.00
1180	12	495000	19	3.4	18.00
1180	12	490000	18	3.4	18.00
1180	12	500000	20	3.4	18.00
1180	12	100000	2	3.4	18.00
1180	12	121000	6	3.4	18.00
1180	12	131600	7	3.4	18.00

5.4 Lime Treated Base

The base thickness (H2) required to meet the SN needed (2.5 and 3.4) for **Lime Treated Base** is for lime treated base calculated from the AASTO equation as shown in Table 5 and Table 6.

(iii) H1 (2 inches) * 0.44 (plant mix) + H2 * 0.14 (crushed stone) = 2.5 (SN needed)
S= 9, For E3 = 28,000 psi, 7570 psi virgin + cement treated subgrade), traffic 10 million SN bar = 2.5, R =1, SN Weighted= SN needed = 2.5
H2 required = 5.40 inches, shown in Table 5.
(iv) H1 (2 inches) * 0.44 (plant mix) + H2 * 0.14 (crushed stone) = 3.4 (SN needed)
S=7, For E3=14000 psi, 1180 psi virgin+ lime treated subgrade), traffic =10 million SN bar =3.4, R=1, SN weighted =SN Needed= 3.4.
H2 required = 8.40 inches, Table 6. Plant mix (0.44) and crushed stone (0.14) materials are used.

Table 5 Soil 1 Pavement design by AASHTO , Cement treated subgrade (E3= 28 Ksi) and lime treated base

E3:Soil	**inch**	**E=ff(Asp %) psi**	**inch**	**lime treated base**
	H2	**E1, Surface**	**H1='**	**h2=(p-(2*.44))/0.3**
				base thickness inch
7570	6	250000	7	5.40
7570	6	305000	11	5.40
7570	6	277000	9	5.40
7570	6	495000	19	5.40
7570	6	490000	18	5.40
7570	6	500000	20	5.40
7570	6	100000	2	5.40
7570	6	121000	6	5.40
7570	6	131600	7	5.40
7570	12	250000	7	5.40
7570	12	305000	11	5.40
7570	12	277000	9	5.40
7570	12	495000	19	5.40
7570	12	490000	18	5.40
7570	12	500000	20	5.40
7570	12	100000	2	5.40
7570	12	121000	6	5.40
7570	12	131600	7	5.40

Table 6 Soil 2 Pavement design by AASHTO , Lime treated subgrade (E3 = 14 Ksi) and lime treated base

E3:Soil	**inch**	**E=ff(Asp %) psi**	**inch**	**lime treated base**
	H2	**E1, Surface**	**H1='**	**h2=(p-(2*.44))/0.3**
				base thickness inch
1180	6	250000	7	8.40
1180	6	305000	11	8.40
1180	6	277000	9	8.40
1180	6	495000	19	8.40
1180	6	490000	18	8.40
1180	6	500000	20	8.40
1180	6	100000	2	8.40
1180	6	121000	6	8.40
1180	6	131600	7	8.40
1180	12	250000	7	8.40
1180	12	305000	11	8.40
1180	12	277000	9	8.40
1180	12	495000	19	8.40
1180	12	490000	18	8.40
1180	12	500000	20	8.40
1180	12	100000	2	8.40
1180	12	121000	6	8.40
1180	12	131600	7	8.40

6. CONCLUSIONS

1.For the pavement sections with untreated subgrade and crushed stone base, 5sections failed for soil with 7570 Psi stiffness and two failed for soil with 1180 Psi stiffness. The failure was attributed to lack of minimum SN value. More specifically, the two sections with 3.92 SN needed only one inch increase in the thickness of the base. For other sections with significantly smaller SN strengthening the SG with lime is recommended. For the soil with 7570 Psi stiffness lime treatment is recommended over cement treatment because of cost considerations. For the soil with 1180 Psi stiffness cement treatment is recommended as the first choice and lime treatment is recommended as the second choice.

2.When sections with soil of 7570 Psi stiffness are treated withcement their stiffness increases to 28,000 Psi, then11.6 inches of untreated crushed stone base was needed to handle 10 million standard axles of traffic.

3. When sections with soil of 1180 Psi stiffness weretreated with lime,their stiffness increases to 14,000 Psi1, then 18 inches of untreated crushed stone base was needed to handle 10 million standard axles of traffic.

4. When sections with soil of 7570 Psi stiffness are treated with cement their stiffness increases to 28,000 Psi, then 5.4 inches of lime treated crushed stone base was needed to handle 10 million standard axles of traffic.

5. When sections with soil of 1180 Psi stiffness weretreated with lime, their stiffness increases to 14,000 Psi1, then 8.4 inches of lime treated crushed stone base was needed to handle 10 million standard axles of traffic.

In all these calculations, the general principle of pavement design is validated as the subgrade stiffness decreases the base thickness increases for the same surface course thickness and traffic.

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