Proposed Research Relating to Composite Pavements

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•THE intent here is to enumerate specific areas in which knowledge is deficient and in which "scientific break-through" would be most welcome and fruitful. There are implications from the use of laminated industrial products that laminated structures would be more capable of preventing stress concentrations or stress-risers, of redistributing stresses, of mobilizing more uniform fiber-stresses and of relieving thermal stresses (1) than a solid mono-layer would be. The more practical aspects of these ideas have been summarized in HRB Circular 473, "Suggestions for the Study of Composite Pavements," July 1962. The suggestions offered here are intended to supplement Circular 473 and the preceding proposals regarding experimental pavements.

SOME IMPLICATIONS IN BASIC THEORY

Recourse is made to Baker's treatment of elastic theory (2).

1. "...the influence of changing a perfectly rigid system to a flexible one is that of varying the vertical stress distribution beneath the pavement."
2. "...the importance of stiffness ratio is in the control which...relative rigidity exercises over the vertical stress distribution."
3. "Vertical deflections are...essentially defined by the load, the stiffness ratio, and the subgrade modulus...."
4. "...changing the subgrade modulus necessarily changes the stiffness ratio and thus the entire deflection curve. If the subgrade modulus k is altered, but simultaneous changes in pavement modulus or pavement thickness are also made in order to keep the stiffness ratio constant, the deflection curve is again changed.... However, if together with a change in k the stiffness ratio is also altered so as to recreate the original deflection curve, these different stresses will be produced for the same deflection curve."
5. "...Increasing or decreasing the thickness, keeping all other conditions constant, produces a change in stiffness ratio and...in the maximum movement due to the change in stiffness ratio and...in flexural stress due to changes in moment and in the thickness. However, if a change in thickness is balanced by a corresponding change in Young's modulus for the pavement so as to keep the stiffness ratio and... the maximum moment constant, then the variations in stress will be due to thickness changes only. Thus, for constant subgrade conditions, pavement flexural stresses are not a direct function of thickness unless a change in pavement modulus is also involved."

Translating the foregoing discussion into its significance or application to composite pavements, for a given value of k, the three dominating parameters are thickness, pavement modulus, and allowable flexural stresses. The concept of composite pavements inherently involves the possibility of being able to control the modulus of the pavement as well as the allowable flexural stresses; that is, through reinforcement of the extreme fibers and perhaps reducing the pavement modulus. For instance, a relatively thin but heavily reinforced-concrete mat overlaid by a relatively thicker course of bituminous concrete might greatly extend the range of allowable flexural stress than might otherwise be achievable with much greater thicknesses of bituminous concrete alone and remain so throughout all seasonal temperatures. Although this might well enhance the maximum allowable stresses at the bottom of the pavement, it would not greatly enhance the tensile strength at the top fibers to resist reversals of stresses or otherwise enhance the corner condition. Thus, the corner or edge condition might necessitate a similar type of reinforcement at the top of the pavement. At least, it is apparent that the modulus of the pavement as well as its flexural strength might be altered in this or some other way.

The elastic theory thus evokes some challenging opportunities for conjecture, insofar as concepts of composite pavements are concerned. The theory offers no clue as to how the pavement itself might best be built up, except that it should have high-tensile-strength layers at both the top and bottom, i.e., envisioned as a filled-in truss or sandwich. Of course, composite pavements, as presently defined by the Committee, are restricted to bituminous overlays or "open-sandwich" construction. However, the "full-sandwich" concept should not be ignored or rejected by the Committee without due investigative processes.

FATIGUE

As in the design of conventional types of pavements, the elements of fatigue are of concern. The EWL-concept of mixed traffic offers several interesting possibilities for analysis.

$$EWL = n_1 f_1 + n_2 f_2 + n_3 f_3 + \ldots = N f = N (r)^{P-b} \quad (1)$$

in which

- n = number of applications;
- f = severity factor for respective loads;
- N = equivalent number of applications of load P;
- r = ratio of successive factors;
- P = axle load in tons or wheel load, in kips;
- b = basic axle load in tons or wheel load, in kips; and
- $f = (r)^{P-b}$.

The original California factors f were based on Bradbury's earlier work. Table 1 gives these factors in comparison to AASHO Test Road factors.

The smoothed ratio between successive AASHO factors is approximately 1.5; whereas, the ratio between the original California factor is 2.0. However, the EWL's are easily converted from one system to the other.

TABLE 1

P	California Factors		AASHO Factors (9-ton basis), (P_t = 2.0)	
	Original (5-ton axle)	Converted (9-ton axle)	Rigid D_2 = 9	Flexible SN = 5
5	1	0.0625	0.08	0.08
6	2	0.125	0.18	0.17
7	4	0.250	0.34	0.34
8	8	0.500	0.60	0.60
9	16	1.000	1.00	1.00
10	32	2.000	1.58	1.57
11	64	4.00	2.38	2.35
12	128	8.000	3.47	3.40

The EWL-concept of mixed traffic seems to be wholly in accord with Miner's law of fatigue in metals (3). This is so, provided that load-equivalency factors are reliably determined and provided that the loads imposed are within the fatigue range.

There is a need for research and experimentation in the region of loading which will produce failure near the upper limit of the fatigue range. This is as true perhaps in regard to rigid and flexible pavements as it is to so-called composite pavements. For instance, assume that:

$$\text{EWL (9-ton axle)} = n_1 f_1 + n_2 f_2 + \ldots = 1,100 \text{ per day}$$
$$1,100 \times 7,300 \text{ (days in 20 yr)} = 8.03 \times 10^6$$
$$8.03 \times 10^6 = N\,(1.5)^{P-9}$$
$$P = \text{axle load in tons}$$
$$\text{Let } N = 1$$
$$P = 48.4 \text{ tons}$$

This implies that a 48.4-ton axle would cause failure, in one application, of a pavement designed to carry 8.03×10^6 equivalent, 18-kip axles. In the same way, a load P of 40.6 tons would produce failure in 2 applications, etc.

This task group suggests that research and experimentation in this region of loading would be worthwhile in substantiating fatigue concepts of pavement behavior.

DYNAMICS OF CARGO HAULERS

The principal mass, i.e., cargo and body of a vehicle, supported on springs and tires and undergoing translational motion will undulate and thus transmit variable forces to the pavement. Dynamic forces may then be alternately greater and less than the weighed or static force. Measurements on pavements have indicated that for a given load, deflections and strains decrease as the translational velocity of the vehicle increases. To infer from this that the dynamic forces exerted on the pavement are continuously less than the static force would be wholly irrational. The true inference here is that the response of the pavement varies as the speed of the vehicle increases. The nature of this response remains obscure and proper explanation for this phenomenon should be sought in viscoelastic, time-dependent deformation studies on pavements and in the effect of forward thrust and traction upon elastic stress distribution with the pavement.

Extraneous disturbances and pavement excitations tend to force the principal mass into sinusoided oscillation having one or more modes—depending on the number of spring elements and their stiffnesses. The ratio of the peak dynamic force of the principal mass to the static force or weight of the mass is customarily termed the impact factor. Values ranging between 1.2 and 1.3 are in common usage. It is suggested that reliable impact factors are essential to the stress-analysis problem as well as to the fatigue problem. However, the effects of dynamic forces remain hidden in the EWL-parameter when the relationship between pavement performance and traffic is established empirically.

REFERENCES

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3. Monismith, C., Secor, K., and Blackmer, E., "Asphalt Mixture Behavior in Repeated Flexure." AAPT Proc. (1961).