

An Identification Method for the Viscoelastic Characterization of In-Situ Pavement Layers using Surface Only Experimental Modal Analysis Tests

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1 INTRODUCTION & SCOPE OF WORK

The purpose of a pavement is to provide a functional surface for the safe operation of a vehicle (Yang, 1972).

The operator of the vehicle does not care what material the pavement structure consists of, but is sensitive to the vehicle rattling/vibrating at the speed of travel, and is aware of the rough country road compared to a smooth highway.

A scientific solution for designing a suitable pavement structure, would require an engineering model to determine the deflections and stresses for a vehicle load on an elastic layered system as characterized by the layers' engineering properties; modulus of elasticity, Poisson's ratio and geometry (thickness).

Introducing a non-destructive mixed numerical experimental technique (MNET) for evaluating the soil subgrade support condition of pavements which is theoretically and experimentally correlated to the destructive static plate load bearing test.

Knowledge of the soil subgrade strength as characterized by the modulus of elasticity is key to reliability, life and construction cost estimates for initial design and rehabilitation of pavements.

2 METHODOLOGY

Applying Experimental Modal Analysis (EMA) to enhanced data from existing surface only Falling Weight and Frequency Sweep non-destructive tests, combined with the theoretical analysis of the multi-layered pavement systems, the MNET is able to characterize the material properties of the pavement layers and the soil subgrade support.

EMA returns experimental surface deflection equivalent to the theoretical multi-layered pavement surface deflection which the MNET uses to find the pavement layer strengths.

With the MNET, a larger number of tests can be performed to improve statistical reliability of the mean and standard deviation of the soil subgrade strength.

For a thickness design example, if the sample mean of the subgrade modulus of elasticity is 7000 pounds/inch² (psi), and the sample standard deviation is 1300 psi.

In addition, if the construction cost for a 3 layered pavement is \$1.00 / inch / yard² with the surface layer cost at 80% and base and subbase layer cost at 20%.

Assuming all design pavements are to be eventually strengthen by overlay to a common standard of 99.5% reliability with an additional indirect cost of 50% due to pavement being out of service.

The following table show how the natural variability of soil strength impacts the reliability and cost of the thickness design example of pavements.

Table. 12000 pounds force on an 18 inches diameter plate on a 3 layered pavement surface.

3100	5700	7000	8300	10900	Subgrade modulus of elasticity, psi (mean 7000, s. d. 1300), infinite thickness
22.4	20.0	18.0	14.9	12.1	Thickness of surface layer, inches, modulus of elasticity, 4000 ksi
8.0	8.0	8.0	8.0	8.0	Thickness of base layer, inches, modulus of elasticity, 40 ksi
99.5	84.1	50.0	15.9	0.50	Reliability of service %, normal distribution
19.52	17.60	16.00	13.52	11.28	Initial construction cost, \$
0.00	0.44	2.61	7.52	12.24	Maintenance cost, \$, 99.5% reliability
19.52	18.04	18.61	21.04	23.52	Total cost, \$, 99.5% reliability

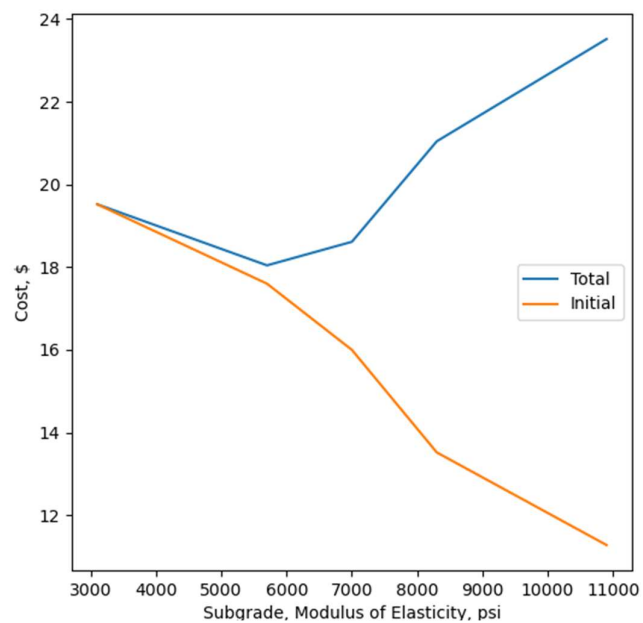


Figure. Initial Construction and Total Cost vs Subgrade Modulus of Elasticity (mean 7000, s. d. 1300).

3 RESEARCH OUTCOMES

The most economical subgrade modulus of elasticity for design is the mean minus one standard deviation.

By introducing cost analysis in pavement design, a statistical analysis requires a sufficient number of tests to determine the mean value and standard deviation.

With the MNET, a larger number of tests equivalent to the static plate load bearing test can be performed and grouped together based on the use of pavement.

An optimal subgrade modulus of elasticity for design can be developed for each group.

The MNET is applicable to both highway and airfield pavement tests as both require the soil subgrade strength to be evaluated.

The load weights are considerably different which is accounted for in applying the MNET.

Periodic MNET tests can be used for Structural Health Monitoring of pavement inventory and used for functional life predictions based on traffic forecasts.

REFERENCES

Yang, D. (2013). An Identification Method for the Viscoelastic Characterization of Materials, Conference Paper, *Society of Experimental Mechanics, Springer*, pp. 41-53.

Yang, N. C. (1972). Design of Functional Pavements, *McGraw-Hill*.