

USE OF THE FALLING WEIGHT DEFLECTOMETER FOR THE NON-DESTRUCTIVE DEFLECTION TESTING OF JOINTED CONCRETE AIRFIELD PAVEMENTS

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A large portion of airfield pavements is constructed of concrete. Field surveys have shown that the majority of concrete failures occur at or near the joints and corners. This is primarily due to the loss of load transfer across the joints/cracks and loss of foundation support due to pumping. Overlaying a distressed concrete pavement is not always the best solution especially if the cause of distress is not corrected prior to the overlay.

This paper presents procedures for evaluating jointed concrete airfield pavements using nondestructive deflection testing (NDT).

Nondestructive Testing Devices and Testing Design

There is a variety of nondestructive pavement testing devices currently available. These devices can be categorized in terms of loading type as static (e.g. Benkelman Beam), vibratory (e.g. Dynaflect or Road Rater), and impulse (e.g. Falling Weight Deflectometer, FWD). At present, the FWD is considered to be the best suited device for testing airfield concrete pavements. The FWD has two advantages over other NDT devices; it can apply loads high enough to simulate a moving aircraft wheel load, and it provides a convenient way to measure joint load transfer, (References 1 and 2). The Dynatest FWD, (Reference 3), can apply up to 25,000 pounds force, Figure 1.a, with a duration of approximately 27 milliseconds, Figure 1.b. The Dynaflect can only apply a 1,000 pound peak-to-peak force and the heavy Road Rater up to 8,000 pounds Figure 2. The FWD has seven deflection sensors, one of which is at the center of the loading plate and the rest are movable along a bar, usually positioned at 12" intervals from the loading plate. The signals from the sensors are transmitted to a microcomputer in the tow vehicle. The same microcomputer is used to program the number and heights from which the weight is dropped. In a typical testing program, the weight is dropped from three to four heights producing loads from 9,000 to 25,000 pound force.

The number and location of tests are designed based on the purpose of testing. If the purpose is to locate voids, then intensive testing of 25 to 100 percent of the slabs could be justified. If

the purpose is to identify the load carrying capacity, then testing 5 to 10 percent of the slabs may be adequate. Ideally, each slab should be tested at four locations: slab center, adjacent to transverse and longitudinal joints and corner. The slab center location provides information for materials characterization such as determining the dynamic subgrade modulus and the concrete young's modulus. The joint testing provides information for determining load transfers which is essential for stress calculations. The corner testing is performed primarily for voids detection.

Procedures For Determining Subgrade Modulus, Load Transfer and Voids

The results of FWD testing are used along with mechanistic models (finite element) to determine; (1) modulus of subgrade support (k), (2) percent dynamic load transfer (LT%) joints across , and (3) whether voids exist and their location. Figure 3 is a summary flowchart of typical procedures used to determine the above items. The following sections provide a brief description of these procedures.

Determination of Dynamic Subgrade Modulus (k)

The ILLI-SLAB finite element program (Reference 2) is used to establish the relationship between " k " and the slab interior deflection " δ_i " based on the existing slab dimensions, concrete elastic properties, and applied load by the FWD. An example relationship is shown in Figure 4. In this example, the concrete elastic modulus " E " was assumed to be known. If " E " was not known then a different approach is used (Reference 4). The field measured δ_i is entered into Figure 4 and the k value is determined. To determine the working design k value for a given pavement with high confidence, Figure 4 is entered with the mean δ_i plus 2 standard deviations. A preferred method is to determine k_i for each δ_i then apply the confidence criterion to the k_i values.

Determination of Percent Load Transfer (LT%)

LT% is determined by applying the load adjacent to a joint (or crack) and measuring deflection under the center of the load (δ_c) and across the joint for the unloaded slab (δ_u). Percent LT% is computed as follows:

$$L.T.\% = \frac{\delta_u}{\delta_c} \times 100$$

The computed load transfer should be corrected for a referenced temperature, or time. Load transfer measured early in the day is usually lower than that measured later in the day, due to slab expansion in the afternoon. Figure 5 is an example load transfer variation measured at the same location at different times of day. Figure 6 is an example chart for correcting LT% for a referenced time.

Detection of Voids (Loss of Support)

Voids most likely occur near slab joints and corners. Existence of corner breaks may indicate existence of voids. One method to detect voids is to compare the measured corner deflection (δ_c) by the FWD with the theoretical corner deflection using mechanistic analysis. To compute the corner deflections mechanistically, a finite element program is used to establish the relationship between LT% and δ_c for various k values. Such a relationship is shown in Figure 7. The relationship is established based on given load position, load magnitude, slab dimensions, slab arrangement, and concrete elastic properties. The determined k and LT% values, as explained in the previous two sections, are entered in Figure 7 to compute δ_c . The computed and measured corner deflections are compared as illustrated in Figure 8. Points above the 45 degree line may indicate loss of support.

Summary and Conclusions

This paper presented procedures for use of the results from nondestructive deflection testing of concrete pavements to determine the foundation subgrade modulus, percent load transfer across joints and cracks, and location of voids beneath the slabs. The procedures are summarized in the flowchart in Figure 3. Other approaches and procedures have been introduced recently which also combine the field deflection data and mechanistic analysis for pavement evaluation (Reference 5).

References

1. Hoffman, M.S., and M.R. Thompson, "A Comparative Study of Selected NDT Devices", Transportation Research Board Annual Meeting, January 1982.
2. Tabatabaie, A.M., and E.J. Barenberg, "ILLISLAB Finite Element Program; Structural Analysis of Concrete Pavement Systems," Report prepared for the FAA and FHWA, U.S. Department of Transportation, Contract No. DOT-FG-11-8474-MOD4, 1978.
3. Smith, R.E. and R.L. Lytton, "Synthesis Study of Nondestructive Testing Devices", Federal Highway Administration, Report No. FHWA/RD-83-097, April 1984.

4. Shahin, M.Y., "Airport Pavement Management, A Total System", International Air Transportation Conference, June 1983.
5. Croveti, J.A., and Darter, M.I., "Void Detection for Jointed Concrete Pavements", Transportation Research Board Annual Meeting, January 1985.

Figure 1a. Schematic Diagram of the Falling Weight Deflectometer

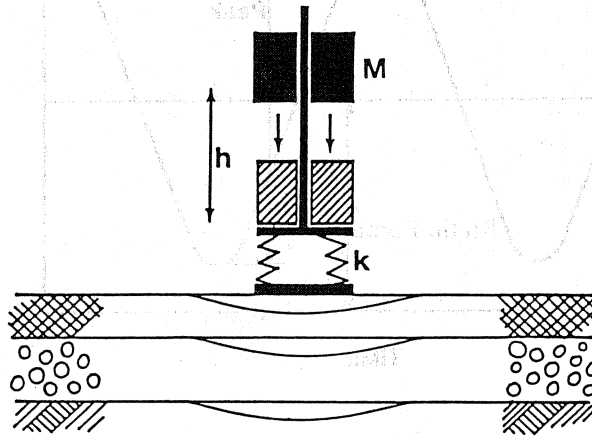
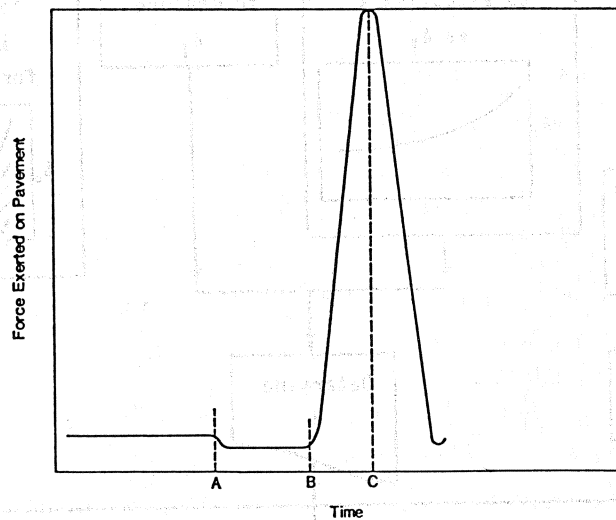


Figure 1b. Typical Force Output of Falling Weight Deflectometer (Ref. 3)



- A - Time at which weights are released
- B - Time at which weight package make first contact load plate
- C - Peak load reached

Figure 2. Typical Force Output of Steady State Deflection Devices

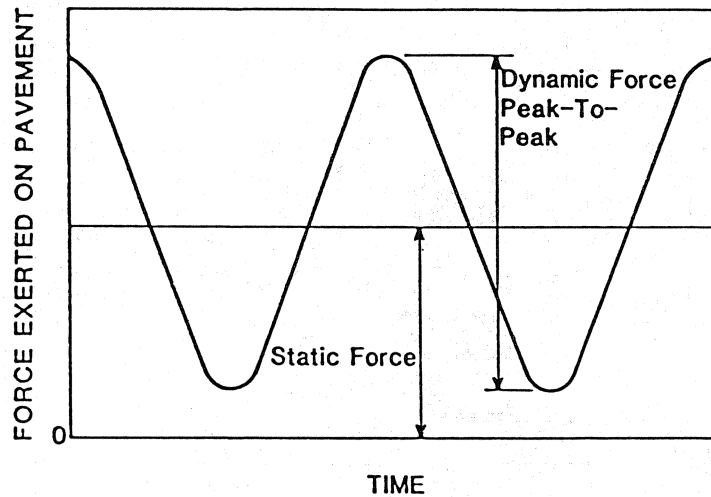
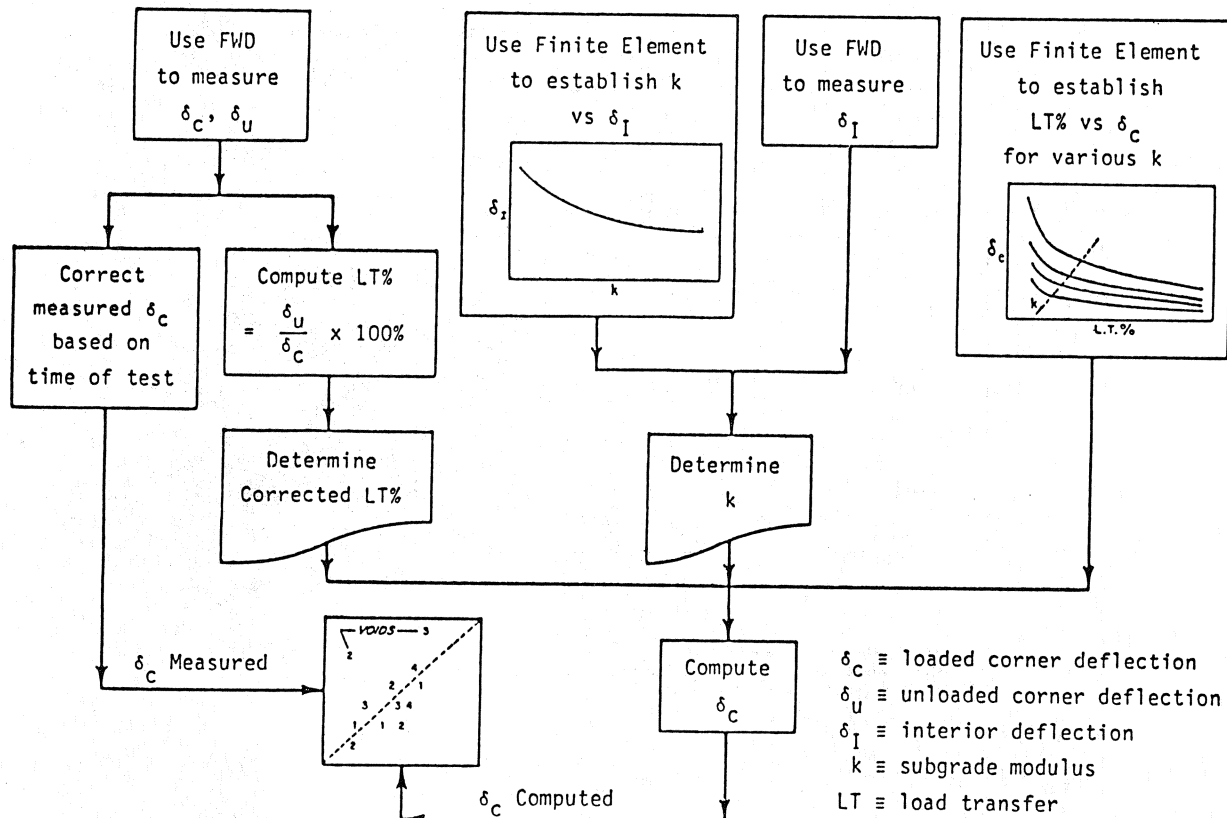
Figure 3. Flowchart of Typical Procedures Used to Determine Subgrade Modulus, (k), Load Transfer (LT) and Void Locations.

Figure 4. Interior Deflection (δ_i) vs. Subgrade Value (k) Determined From the Finite Element Program.

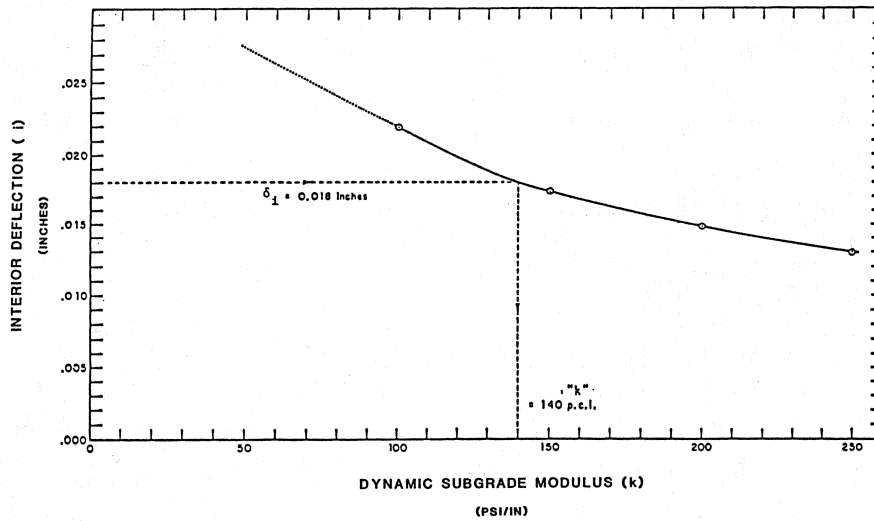


Figure 5. Example Load Transfer Variation During Different Times of a Day.

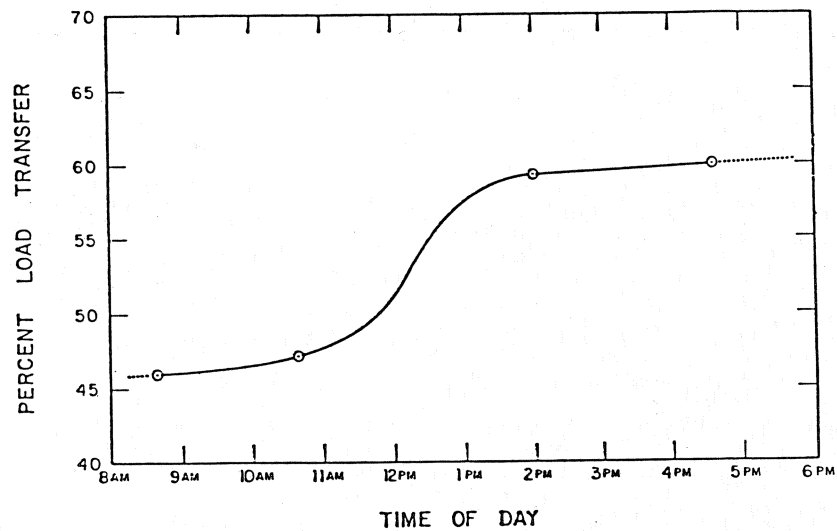


Figure 6. Example Chart for Correcting Load Transfer for a Referenced Time of Loading of 2:00 p.m.

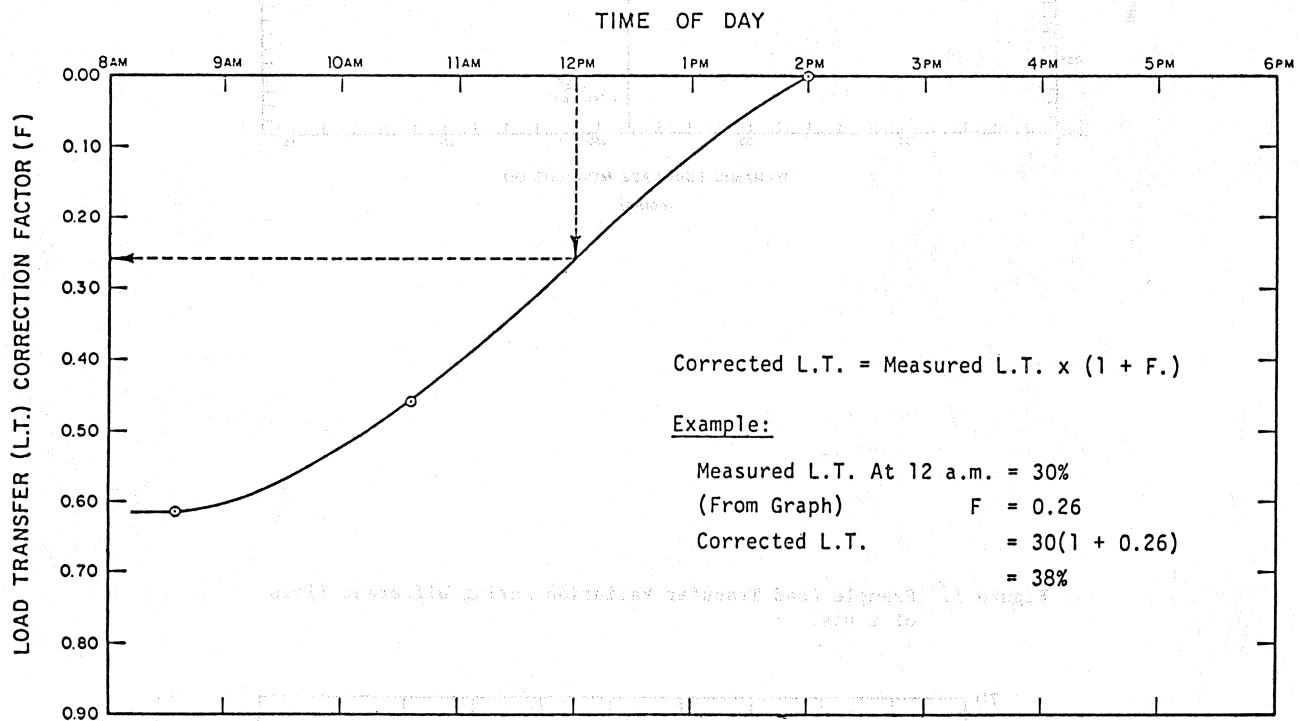


Figure 7. Relationship of Load Transfer vs. δ'_c for Various Dynamic Subgrade Modulus (k).

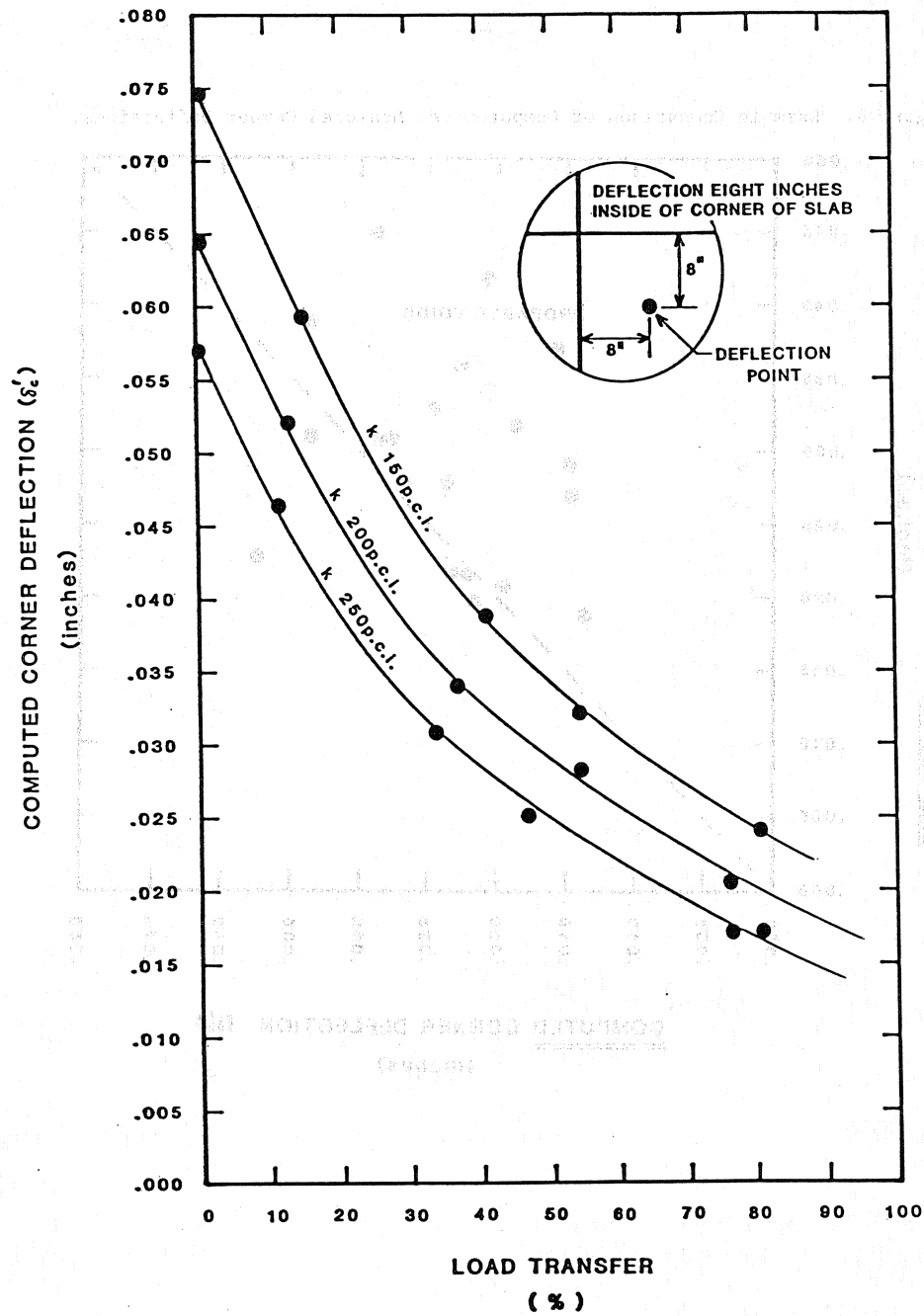


Figure 8. Example Comparison of Computed vs. Measured Corner Deflections.

