COMPARISON BETWEEN FALLING WEIGHT DEFLECTOMETER AND STATIC DEFLECTION MEASUREMENTS ON FLEXIBLE PAVEMENTS AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY (NAPTF)

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ABSTRACT

Pavement surface deflection basins provide valuable information for the structural evaluation of flexible pavements. The pavement surface deflections are easily measurable compared to other responses, such as stresses and strains, and are the basic response of the pavement structure to the applied load. It is frequently used as an indicator of the load-carrying capacity of the pavement. Surface deflection measurements are rapid and nondestructive. Falling weight deflectometer tests and static load tests (using the National Airport Pavement Test Facility test vehicle) were performed on the multidepth deflectometers in the flexible pavements at the National Airport Pavement Test Facility before the start of traffic tests. The falling weight deflectometer is an impulse-type testing device that imparts a transient load on the pavement surface, and the duration and magnitude of the force applied is representative of the load pulse induced by an aircraft moving at moderate speeds. Static load tests are more representative of stationary or very slow moving aircraft. The National Airport Pavement Test Facility has nine pavement test items and 10 transition sections built on three different subgrades (California Bearing Ratio of 4, 8, and 20). There are six flexible pavement test items and three rigid pavement test items. The falling weight deflectometer tests were performed at load levels of 12,000, 24,000, and 36,000 lb. Static load tests were performed at load levels ranging from 12,000 to 60,000-lb wheel load. The falling weight deflectometer tests were performed on the top of the multidepth deflectometers, and the pavement deflections were measured by sensors mounted on the falling weight deflectometer equipment and the multidepth deflectometers. For the static load tests, the wheel was positioned over the multidepth deflectometers and the multidepth deflectometers measured pavement deflections. This paper summarizes the test results from falling weight deflectometer and static load tests performed on the six flexible pavements (three with conventional P-209 crushed stone base and three with P-401 asphalt stabilized base) at the National Airport Pavement Test Facility. A comparison of surface deflections for the six flexible pavements under falling weight deflectometer and static loading is presented.

KEYWORDS

Flexible Pavement, Heavy Weight Deflectometer, Static Tests, Deflection

INTRODUCTION

Pavement surface deflections have been used in the past as an indicator of the airport pavement life. A study [1] conducted at Waterways Experiment Station (WES) showed a strong relation between elastic (or recoverable) deflection and allowable load repetitions on flexible pavements. Other studies [2] at WES showed that an aircraft wheel load which would cause an elastic deflection of about 0.25 inch could be expected to fail the pavement with repeated loading in excess of 2,000 coverages. For wide-tire, low-pressure loads, the limiting deflection might exceed 0.33 inch, and for narrow-tire high-pressure loads, the limiting deflection might be less than 0.15 inch. In summary, the elastic deflection values have long been recognized as indicators of the total life of the pavement as it is subjected to repeated applications of the load that caused the deflection.

Static load tests and heavy weight deflectometer (HWD) were performed on the flexible pavements at the National Airport Pavement Test Facility (NAPTF). Multidepth deflectometers (MDD) were used to measure the pavement deflections under static loads. This paper summarizes the results from static tests and HWD tests performed on the six flexible pavements.

NATIONAL AIRPORT PAVEMENT TEST FACILITY

The NAPTF is located at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey. A 1.2-million-lb pavement testing machine spans two sets of railway tracks that are 76 feet apart. The vehicle is equipped with six adjustable dual-wheel loading modules. A hydraulic system applies the load to the wheels on the modules. The major specifications for the test track are as follows:

- Test pavement 900 feet long by 60 feet wide.
- Nine independent test items (six flexible and three rigid) along the length of the track. (The test pavement cross-sectional details are given in Table 1.)
- Twelve test wheels capable of being configured to represent two complete landing gear trucks having from two to six wheels per truck and adjustable up to 20 feet forwards and sideways.
- Wheel loads adjustable to a maximum of 75,000 lb per wheel.

Table 1. NAPTF Pavement Cross-Sectional Details.

Item	Surface Layer		Base Layer		Subbase Layer		Subgrade		
ID	Type	Thickness inch	Type	Thickness inch	Type	Thickness inch	Soil Type	CBR	Strength
LRS	P-501	11.0	P-306	6.13	P-154	8.38	MH-CH	4	Low
LFS	P-401	5.0	P-401	4.88	P-209	29.63	MH-CH	4	Low
LFC	P-401	5.13	P-209	7.75	P-154	36.38	MH-CH	4	Low
MFC	P-401	5.13	P-209	7.88	P-154	12.13	CL-CH	8	Medium
MFS	P-401	5.0	P-401	4.88	P-209	8.5	CL-CH	8	Medium
MRS	P-501	9.75	P-306	5.88	P-154	8.63	CL-CH	8	Medium
HRS	P-501	9.0	P-306	6.0	P-154	6.63	SW-SM	20	High
HFS	P-401	5.13	P-401	4.5	-	-	SW-SM	20	High
HFC	P-401	5.25	P-209	7.88	-	-	SW-SM	20	High

P-501: Portland cement concrete; P-401 Surface: asphalt concrete surface; P-401 Base: asphalt stabilized base; P-306: econocrete base; P-209: crushed stone base; P-154: subbase

Additional details about the NAPTF and the test machine can be obtained from the FAA website: http://www.airporttech.tc.faa.gov.

HWD TESTS ON FLEXIBLE PAVEMENTS AT THE NAPTF

A KUAB Model 240 HWD device was used for evaluation of the test pavements at the NAPTF (Figure 1). The equipment details are presented in reference 3. The requirements for measurements at the NAPTF are for an HWD capable of determining the uniformity of the test pavement structures and for making measurements of pavement response as traffic testing proceeds. Both, 18- and 12-inch-diameter segmented plates can be used. The load pulse width can be varied from 20 to 60 msec. The standard configuration (for the routine tests) for the FAAs HWD has been established with the following parameters: the segmented 12-inch loading plate, a pulse width of 27-30 msec, and four drop heights consisting of a 36-kips “seating drop” followed by impact loads of 12, 24, and 36 kips. The first 36-kips drop “seats” the pavement by settling out residual permanent deformations within the pavement structure and is not used in the analysis. The peak loads and deflections are recorded for all four drops along with air and pavement surface temperatures. The seismometers are placed at 12-inch intervals for recording response data. The deflections are measured at the center of load plate (D0): at a 12-inch offset (D1), a 24-inch offset (D2), a 36-inch offset (D3), a 48-inch offset (D4), and a 60-inch offset (D5). An additional sensor is placed at a 12-inch offset in the front of the loading plate.

HWD tests were conducted on November 18, 1999. Pavement surface deflections were measured at three different load levels: 12, 24, and 36 kips. The test locations were at offsets of 5, 15, and 25 feet on either side of pavement centerline (longitudinal, west-east direction) at 10-foot intervals along the test section. Deflections D0 and D5 were studied. Deflection D0 is generally a function of diameter of loading plate, applied load, and pavement structure as a whole. Deflection D5 is predominantly governed by the subgrade properties.

Figure 1. FAA’s KUAB Model 240 HWD Equipment.

Flexible pavements were built on three different subgrades with target California Bearing Ratio (CBR) of 4, 8, and 20 respectively. For each subgrade type, there are two flexible test items – one with conventional crushed stone base P-209 and the other with asphalt stabilized base P-401. For the traffic tests, the test plan is to use the same load on all the test sections. Therefore, it is desirable that all the pavements have similar testing life. Total stiffness of a pavement is one of the parameters that may be used to predict the pavement remaining life. The CBR method of pavement design uses deflection as the critical response to design pavement. Figure 2 shows the comparison between peak center deflections D0 for the six flexible test sections.

For flexible pavements with P-209 crushed stone base, test sections LFC and MFC show similar D0s. Test section HFC shows comparatively lower D0. A similar trend is observed for flexible test items with P-401 asphalt stabilized base (similar deflection D0 for LFS and MFS and lower deflection D0 for HFS). Test sections with asphalt stabilized base showed lower deflection D0s compared to the test sections on crushed stone base.

Figure 3 shows the D5 values for the flexible test items LFS, LFC, MFC, MFS, HFS, and HFC. The three subgrades show different strengths. For the low-strength subgrade, the LFC D5 values are 8 to 9 percent higher than the LFS D5 values. MFC D5s are 6.8 to 7.5 percent higher than the MFS D5s, and HFS D5s are 6 to 8 percent higher than the HFC D5s. The load-deflection relationship is fairly linear.

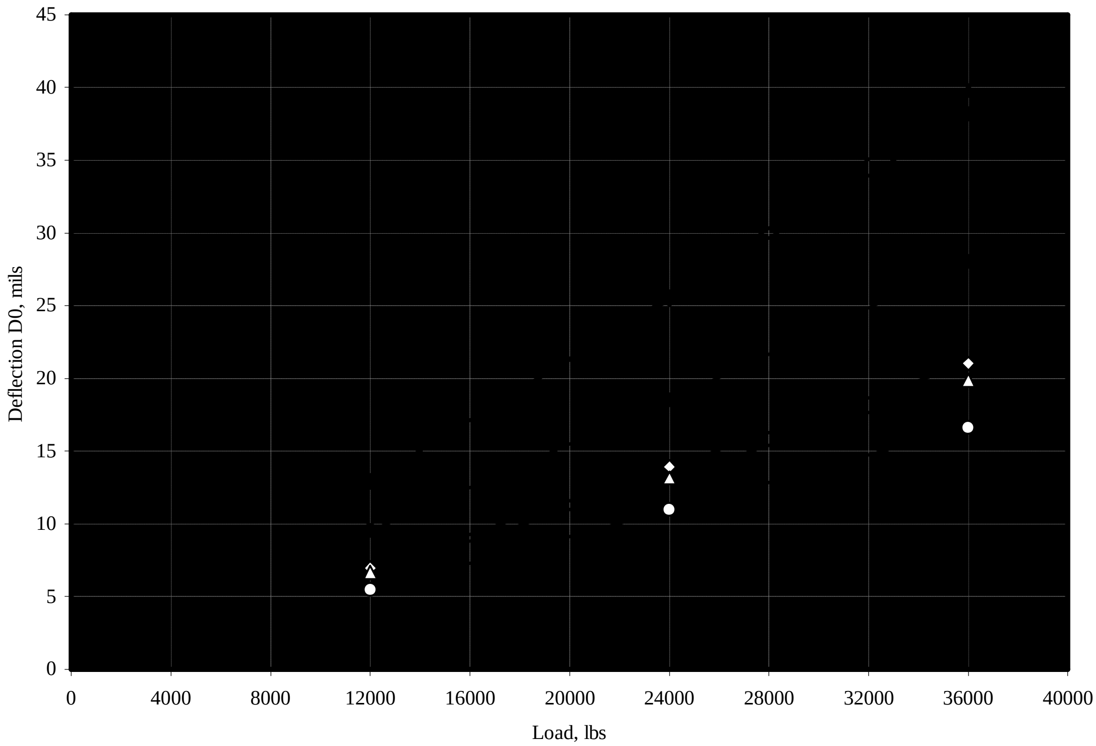

Figure 2. Comparison of Average Deflections D0 for Flexible Pavements.

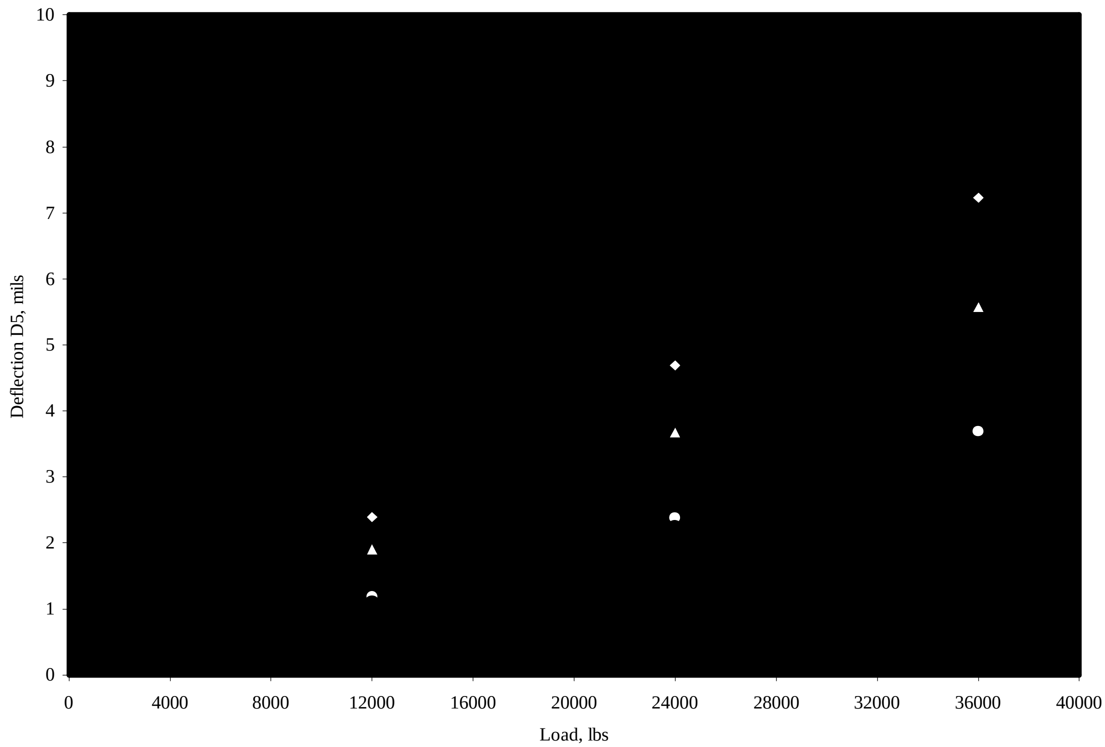

Figure 3. Comparison of Average Deflections D5 for Flexible Pavements.

STATIC TESTS ON FLEXIBLE PAVEMENTS AT THE NAPTF

Each flexible pavement test item consists of five MDDs. Each wheel path (15-foot offset from centerline) has two MDDs. These MDDs are designated as NW-MDD, NE-MDD, SW-MDD, and SE-MDD. One MDD is located in the centerline of pavement test item (CL-MDD aligned with the west side MDDs). Figure 4 shows the locations of the MDDs within a test item. The MDDs were used to measure deflections of pavement layers at multiple vertical locations referenced to a stable point. Each MDD contains seven potentiometer displacement transducers (DT). The DTs are positioned in the head assembly of the MDD at the pavement surface. The head assembly is positioned above a lined bore-hole. At the bottom of the bore-hole, an expandable hydraulic anchor is placed as the stable reference point. Six snap-ring anchors are placed at various depths in the lined bore-hole. The DTs are connected to the anchors with carbon-graphite fiberglass composite rods.

Static tests were performed on 03/03/00 over the CL-MDDs on the six flexible pavement test items to study the load-deflection behavior of pavement component layers. The pavement structures were loaded by a six-wheel gear configuration at 12,000-, 24,000-, 36,000-, 48000-, and 60,000-lb wheel loads. One of the middle wheels was placed on top of the MDD (Figure 4). Load was applied for a duration of 2 minutes. After 2 minutes, the load was removed, but the MDD data collection was continued for an additional 2 minutes. Figure 5 shows a typical DT response time history from the static tests. The DT sensor, that measures the total pavement deflection, was not working in test item LFS. Therefore, the results from static tests are shown only for test items LFC, MFC, MFS, HFS, and HFC.

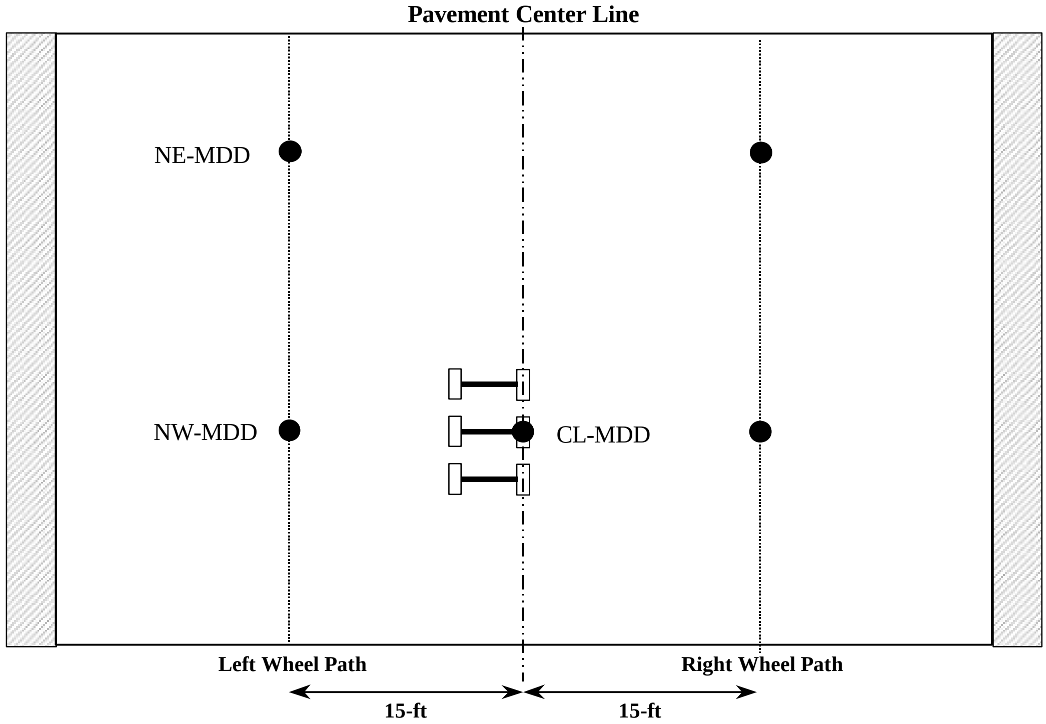

Figure 4. MDD Locations in a Test Pavement and Gear Configuration for Static Tests.

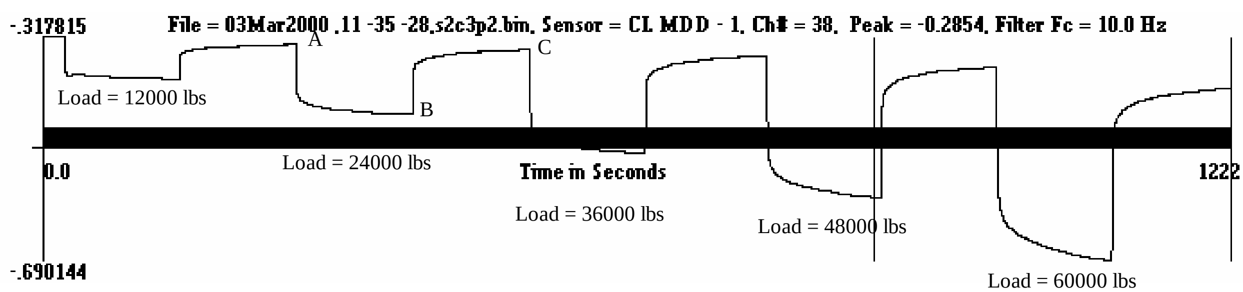

Figure 5. A Typical MDD Time History Plot for Static Test (Test Item LFC).

For a given load (say 24,000-lb load in Figure 5), the total deflection (AB) is composed of recovered deflection (BC) and unrecovered deflection (AC). In this study, the recovered deflections were used for analysis purpose.

Figure 6 shows the recovered surface deflections for the flexible test items (except LFS) at different load levels. Test item LFC shows highest deflection values. The static recovered deflections for test item MFS are 4 to10 percent higher than the deflections for test item MFC. Test items HFS and HFC showed similar surface deflections.

Figure 7 shows the recovered subgrade deflections for the flexible test items (except LFS) at different load levels. The subgrade deflections are highest for test item LFC. The recovered subgrade deflections for test item MFS are 27 to 61 percent higher than the deflections for test item item

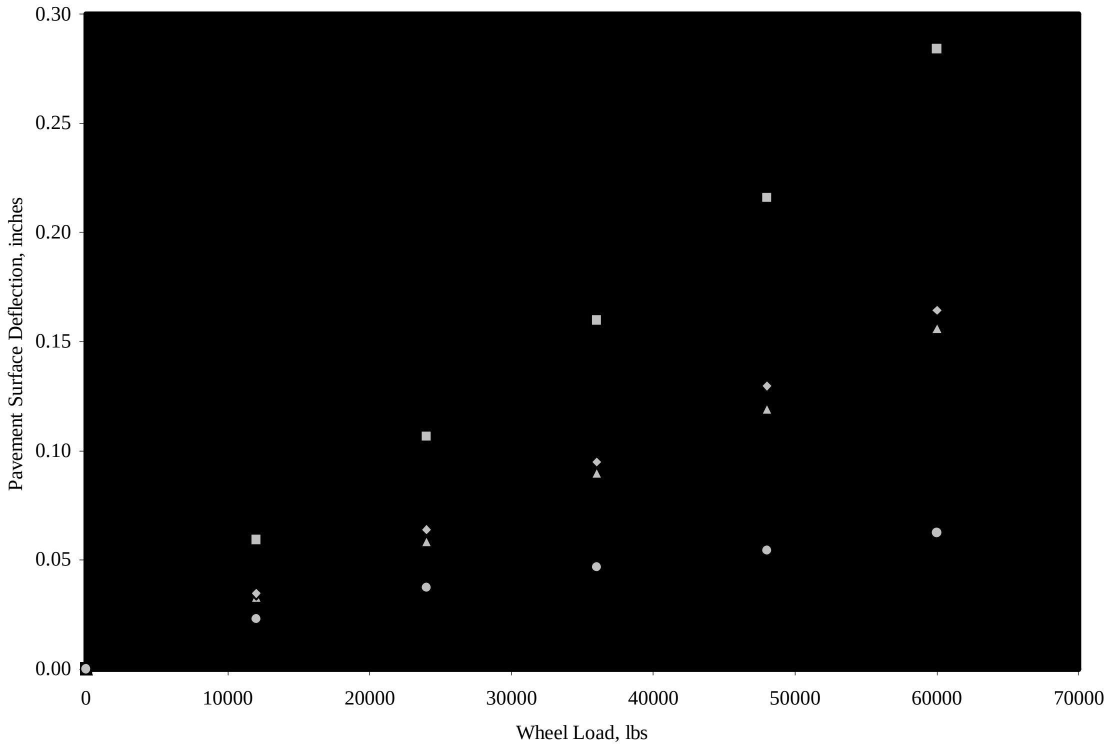

Figure 6. Recovered Surface Deflections for Flexible Test Items from Static Load Tests.

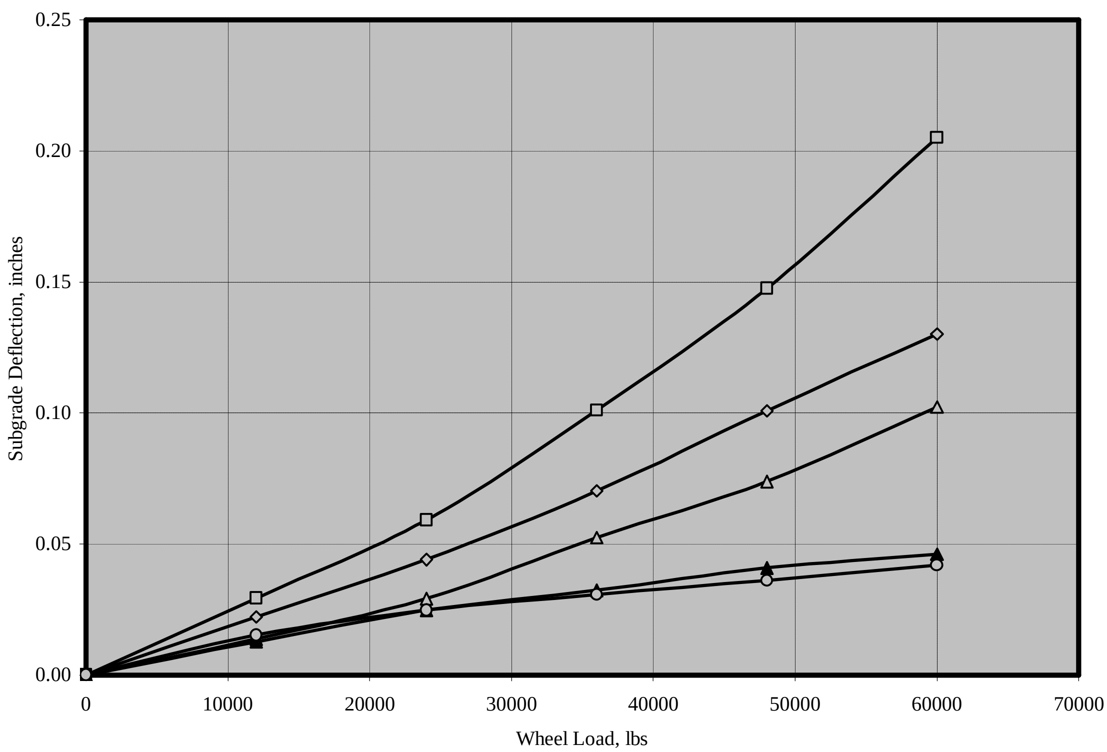

Figure 7. Recovered Subgrade Deflections for Flexible Test Items from Static Load Tests.

MFC. The difference between the MFS and MFC subgrade deflections reduces with increase in the load level. Test items HFS and HFC showed similar subgrade deflections.

Figure 8 shows the subgrade contribution to the total pavement deflection (surface deflection) for the flexible test items.

The stress-softening behavior of fine-grained subgrade (silty-clay used in LFC and DuPont clay used in MFC and MFS) and stress-hardening behavior of sandy subgrade (used in HFS and HFC) is clearly observed.

PAVEMENT SURFACE DEFLECTION AS A PREDICTOR OF LIFE

If pavement surface deflections are considered as a predictor of pavement life, the deflections from FWD tests in Figure 2 predict that the test items with conventional base should fail before the pavements with stabilized base. For a given load level, test items LFC and MFC should show similar pavement life. Test items LFS and MFS should also show similar pavement life to each other but at a significantly higher level than for LFC and MFC.

The study of pavement surface deflections from static load tests shows in (Figure 6) that test item LFC should fail first with MFC and MFS showing similar pavement life to each other but at a significantly higher level than for LFC. Test items HFS and HFC should also show similar pavement life. MFC has completely changed its relationship to LFC and MFS compared to the HWD surface deflections shown in Figure 2.

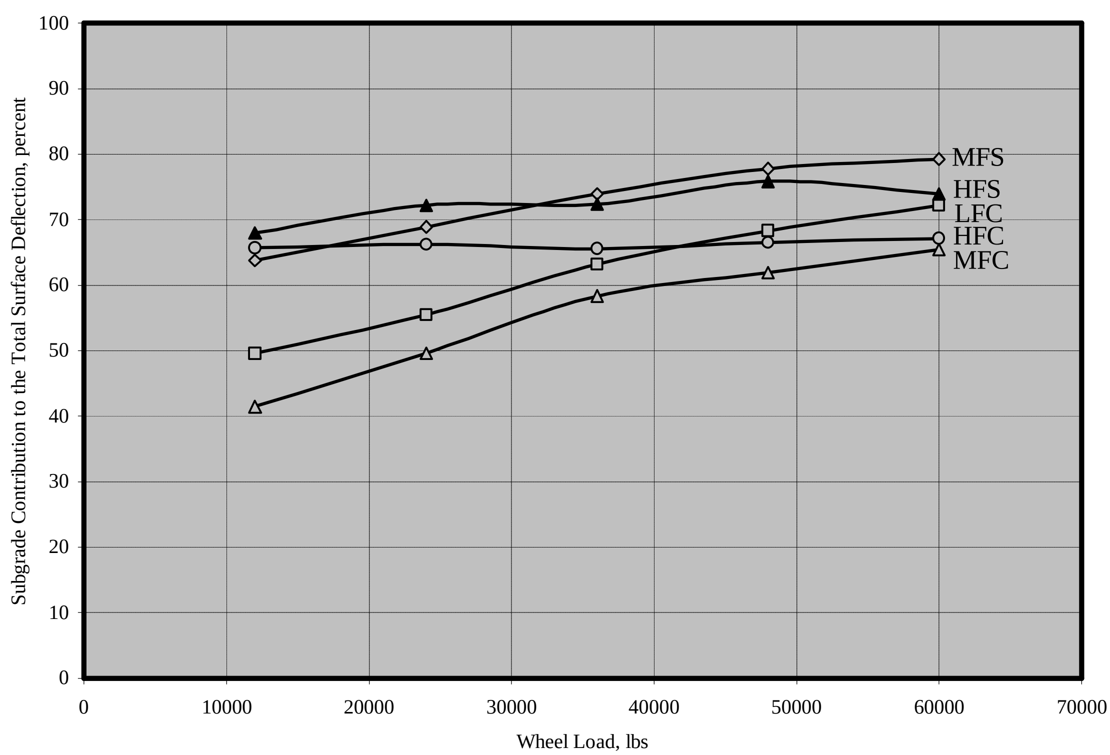

Figure 8. Subgrade Contribution to the Pavement Surface Deflection.

The test items at NAPTF were subjected to traffic tests at 45,000-lb wheel load with a four wheel gear configuration on the south side wheel track and a six wheel gear configuration on the north side wheel track. The speed of the vehicle during traffic tests was 5 mph and the traffic was applied in a predetermined wander pattern. Each wander pattern consisted of 66 passes of the test vehicle. Test item MFC failed after approximately 12,000 passes and MFS at approximately 29,000 passes. Test items LFS and LFC showed no signs of failure after 30,000 passes and were further tested at 65,000-lbs wheel load. Traffic tests on test items HFS and HFC were terminated with no clear evidence of shear failure in the subgrade.

The pavement performance results from traffic tests and study of pavement surface deflections from HWD tests and static load tests show no clear relationship, for the six pavement structures studied, between pavement surface deflection and pavement life, and illustrates the complexity of relating pavement surface deflections to pavement life. Pavement surface deflections are influenced by the loading conditions (load magnitude, number of wheels/axles, and duration of loading for static/HWD/traffic tests), temperature, and moisture conditions in the base/subbase/subgrade. However, the pavement performance is also influenced by the traffic wander, accumulation of permanent deformation, and relationship between the total, permanent, and elastic deformations, in addition to the factors influencing pavement surface deflections.

SUMMARY

The results from HWD tests and static load tests performed on the flexible pavement test items at NAPTF are presented. The comparison of relative surface deflections for different flexible pavement structures from HWD tests and static tests is very different. The load conditions under HWD loading are similar to a "single-wheel" load case with dynamic loading; whereas in the case of static tests a six-wheel gear configuration was used and wheel load interactions become a significant issue. Therefore, any predictions of life based on pavement surface deflections from HWD tests and static load tests would be different. The study showed the complexity of relating pavement surface deflections to pavement life.

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