# Categorization of Asphalt Overlays on Broken and Seated Pavements

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Breaking and seating (B/S) concrete pavements before the construction of an asphalt concrete overlay is a method adopted by several states to minimize the problem of reflection cracking in composite pavements. Breaking the slabs into smaller pieces decreases their effective length and reduces the thermal movements that are the root cause of the development of reflection cracking. The B/S treatment has a significant effect on the structural response and behavior of the concrete slab. After B/S, slab structural models such as the Westergaard model or finite element models are not applicable. The two most important factors that affect the performance of such pavements are (i) the extent of breaking and (ii) the sizes and patterns of the broken slabs. Traditionally, pavements with asphalt concrete overlays on broken and seated concrete slabs are categorized as flexible pavements, and an equivalent modulus characterizing the B/S layer is used for mechanistic modeling. To investigate the validity of this practice, a comparative analysis of a large quantity of Dynaflect deflection data on flexible, composite, and B/S pavements in Ohio is presented. The original pavement in all composite and B/S sections studied was jointed reinforced concrete. Based on maximum deflection, spreadability, and the $W_1/W_5$ ratio, the observed performance of asphalt overlays on B/S pavements with 0.152- to 0.762-m fragments closely resembles those of composite pavements rather than those of flexible pavements.

The proper categorization of pavements is an essential step toward developing techniques for their design and evaluation. Historically, pavements are divided into two broad categories, namely, flexible and rigid. The characteristics of the materials used in the construction of these pavements have a major influence on their categorization. Accordingly, several design and evaluation procedures have been developed for new as well as in-service flexible and rigid pavements. When an in-service flexible pavement receives a rehabilitation treatment in the form of an asphalt concrete (AC) overlay, the pavement is still classified as a flexible pavement. When a rigid pavement is in need of rehabilitation, a widely used action is, again, to provide an AC overlay. Such pavements have come to be known as composite pavements.

The performance of composite pavements is largely governed by the underlying concrete layer. Thermal movements of the concrete slabs at the joints and at working cracks exert excessive strains in the AC layer that result in the development of reflection cracking (Figure 1). The cracks form at the bottom of the asphalt layer, above a joint or a crack, and propagate vertically to the surface. Such cracks cause early deterioration of the overlay, increase life-cycle costs, and reduce the useful life of the pavement.

Some of the methods proposed for the control of reflection cracking in AC overlays include (a) providing a thick overlay; (b) changing the viscosity of the asphalt; (c) using admixtures in the AC mix; (d) treating the existing, cracked pavement before overlay by means of breaking, stabilizing, and crack sealing; (e) using stress-relieving interlayers (e.g., asphalt rubber, fabrics, and membranes); and (f) sawing and sealing the joints in the overlay directly above the joint in the concrete (*1*). A recent comprehensive survey by the National Asphalt Pavement Association (*2*) showed the widespread use of the cracking and the breaking and seating (B/S) procedure for rehabilitating portland cement concrete (PCC) pavements.

Rehabilitation of a composite pavement by (B/S) PCC slabs involves milling the existing AC layer, breaking the PCC slabs, and seating the slab fragments with a heavy roller. In doing so composite pavements are transformed into B/S pavements, and with the addition of AC overlays, they are categorized as flexible pavements. However, the operation of breaking induces many variables in the pavement, as shown in Figure 2.

The two most important factors that affect the performance of such pavements are (a) the extent of breaking and (b) the size and pattern of the broken slabs. Slabs have been broken into sizes ranging from 0.152 to 0.762 m. A considerable discrepancy in establishing the crack pattern has been noticed among states. Cracking is normally achieved in both the transverse and the longitudinal directions. Some states require cracking in only a transverse pattern. Also, certain agencies do not break the steel reinforcement. Other factors such as the moisture condition of the subgrade soil also have a significant effect on the extent of breaking achieved.

No specific studies have been carried out to ascertain the effects of these variables on the performance of asphalt overlays. There is a need to establish the effect of the extent of breaking and the cracked slab size in classifying AC overlays on B/S PCC pavements.

## CONSEQUENCES OF BREAKING

Crack initiation in PCC pavements is generally believed to be caused by the vertical and horizontal movements of the slabs. Horizontal movements may be due to temperature variations that induce

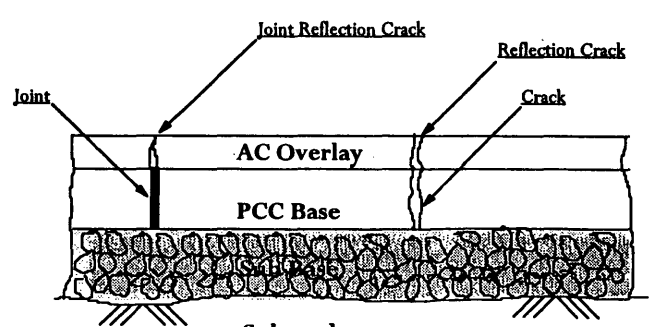


**FIGURE 1 Reflection cracking on composite pavements.**

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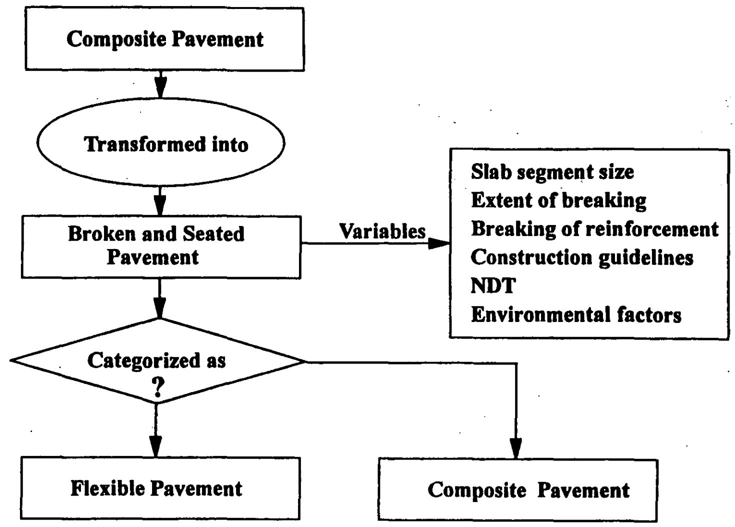


FIGURE 2 Categorization of broken and seated pavements.

contraction and expansion in the slabs. Studies show that such movements are directly proportional to the length of the slab (*3*). This implies that with a shorter length there is a better chance of reducing crack development and in turn reflection cracking. However, breaking PCC slabs into smaller pieces results in a reduction of the flexural strength and an increase in surface deflection and subgrade stress. The optimum size of the cracked pieces for retaining structural integrity and at the same time minimizing thermal movements is yet to be established. The AASHTO (*4*) specifications suggest breaking the slab into nominal pieces of 0.610 to 1.067 m in size.

## OBJECTIVES

The Ohio Department of Transportation (ODOT) has built several lane miles of experimental sections with AC overlays on B/S PCC pavements. These sections along with the road network in the state are routinely monitored by ODOT as part of its maintenance and management program. A vast quantity of Dynaflect deflection data has been recorded for all pavements since 1985. By using this information the present study attempts to accomplish the following objectives:

1. Develop a data base of Dynaflect deflections for various classes of pavements,
2. Analyze the deflection data to examine the structural effectiveness of pavements,
3. Investigate the effect of cracked slab size on the structural effectiveness of AC overlays on B/S pavements,
4. Statistically compare the deflection characteristics of various pavements, and
5. Find the validity of treating B/S pavements as flexible pavements.

## DATA GATHERING

Since 1984 ODOT has used Dynaflect deflection measurements to design AC overlays on all four-lane pavements programmed for rehabilitation. Slight variations in measured deflections on rigid pavements resulted in substantial differences in overlay thicknesses when they were calculated by a two-layer elastic procedure. After observing the deflection data it seemed that a dynamic load larger than 4.448 kN (that is used in Dynaflect equipment) would result in a better design of overlay thicknesses on rigid and composite pavements. Thus, research was initiated to compare the results obtained from Dynaflect and a falling weight deflectometer (FWD). The results presented in an ODOT report by Edwards et al. (*5*) indicated that although differences occurred from pavement to pavement, the deflections obtained with Dynaflect on the average correlated quite well with FWD measurements. Pavement nonlinearity was not significant. Based on the results of the study, it was concluded that ODOT will continue to use Dynaflect deflection measurements to design overlays.

All available Dynaflect deflection data due to a 4.448-kN load on flexible, rigid [continuously reinforced concrete pavement (CRCP), jointed reinforced concrete pavement (JRCP)], composite, and B/S pavements were retrieved from the ODOT mainframe computer. Table 1 presents the number of pavement sections, number of deflection tests on each section, and other available details for each class of pavement. On each section 30 to 100 Dynaflect measurements were made, depending on the total section length. Other available data included air and pavement surface temperature at the time of deflection measurements and the thickness of the AC surface and PCC layers. For composite pavements data such as the year of construction, jointing arrangement, the use of load transfer devices, and reinforcement details were not available. For some sections, however, the condition of the pavement in terms of the presence of cracks, rutting, or faulting was available at the points where deflection measurements were made. Since this information was not available for all sections, the condition data were not used in the analysis and are not presented here.

Seven in-service composite pavement sections were rehabilitated with AC after removing the existing AC surface layer and then breaking and seating the underlying PCC pavements. These PCC pavements consisted of jointed reinforced concrete slabs on a 0.152-m granular subbase. Breaking was achieved by using either a guillotine or a pile hammer. An attempt was made to get uniform breakage in each section; however, most of the pavements broken with the guillotine hammer had a problem where drops overlapped,

**TABLE 1 Dynaflect Deflection Measurements**

| Pavement Type | # of Pavement Sections | # of Deflection Tests | AC Thickness Range (m) | PCC Thickness (m) | | Pavement Surface Temperature (°C) | $W_1$ (mm) | $W_5$ (mm) | Spreadability (%) | $W_1$/ $W_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Flexible | 108 | 3711 | 0.165 -0. 311 | | Average | 13 | 0.014 | 0.005 | 66.71 | 2.88 |
| | | | | | Deviation | 18 | 0.30 | 0.09 | 8 | 1.11 |
| Composite | 188 | 17956 | 0.076 -0. 216 | 0.228 | Average | 15 | 0.011 | 0.006 | 75.19 | 1.96 |
| | | | | | Deviation | 14 | 0.19 | 0.08 | 7.87 | 0.4 |
| CRCP | 29 | 556 | | 0.228 | Average | 10 | 0.012 | 0.007 | 75.96 | 1.84 |
| | | | | | Deviation | 21 | 0.08 | 0.06 | 3.98 | 0.28 |
| JRCP | 134 | 8258 | | 0.228 | Average | 13 | 0.012 | 0.007 | 75.86 | 1.93 |
| | | | | | Deviation | 19 | 0.17 | 0.11 | 5.65 | 0.35 |
| Break and Seat (0.152 m fragments) | 3 | 54 | 0.076 -0. 216 | 0.228 | Average | 14 | 0.012 | 0.005 | 79.9 | 1.86 |
| | | | | | Deviation | 9 | 0.20 | 0.07 | 4.58 | 0.32 |
| Break and Seat (0.457 m fragments) | 7 | 246 | 0.076 -0. 216 | 0.228 | Average | 10 | 0.011 | 0.005 | 73.44 | 2.36 |
| | | | | | Deviation | 14 | 0.14 | 0.08 | 12.75 | 0.56 |
| Break and Seat (0.762 m fragments) | 3 | 54 | 0.076 -0. 216 | 0:228 | Average | 16 | 0.010 | 0.005 | 82.28 | 1.7 |
| | | | | | Deviation | 11 | 0.10 | 0.08 | 2.5 | 0.16 |

Note: 1m = 39.37 in.
1 mm = 0.039 in.
°F = 1.8 *(°C) + 32

usually in the middle of the lane. This area was cracked much more than the other parts. Breaking resulted in thorough slab cracking, and no additional effort was made to break the reinforcement. All of the data collected were entered into a data base and were sorted by type of pavement. A separate data base was established for each type of pavement.

## DATA PROCESSING

The thickness of the PCC layer in composite and B/S pavements was constant and was equal to 0.229 m (Table 1). However, the thickness of the AC layer and the surface temperature at the time of deflection measurements varied with each project. Although subgrade soil characteristics varied, no laboratory data on soil properties were available for analysis. The broken and seated pavements received thick overlays, either 0.165 or 0.216 m. Initially, an attempt was made to normalize deflection values to a standard temperature by using a model developed at the University of Toledo (*6*). This model requires data on site-specific conditions such as solar radiation, wind, air temperature, cloud cover, and other factors to calculate the temperature profile within an AC layer at a given time. Since such data were not available for all sections, the analysis was simplified by normalizing deflections to a standard temperature of 21°C by the Asphalt Institute method (*7*). This method relies only on surface temperature, which was measured at the time of the Dynaflect tests.

The Dynaflect data from each group of pavements were analyzed for three structural parameters, namely $W_1$, $W_1/W_5$ ratio, and spreadability. The results are provided in Table 1. The numbers of flexible and composite pavement sections were significantly higher than the numbers of B/S sections (Table 1). The scatter of the average maximum deflections ($W_1$), the $W_1/W_5$ ratios, and spreadability are plotted (see Figures 4, 5, and 6). For a better visualization of the data section averages were plotted for composite and flexible pavements and individual points were plotted for B/S pavements. This was necessary because only a few sections were available for B/S pavements.

## SIGNIFICANCE OF $W_1/W_5$ RATIO

The measurement of the deflection basin on the pavement surface is used to evaluate its structural capacity. Figure 3 shows the stress distribution in a typical pavement structure subjected to a load (*4*). The stress due to the load gets distributed over a wide area through the upper layers of the pavement before reaching the subgrade level. The deflection values measured at or beyond $a_{3e}$ are indicative of subgrade characteristics. The measured surface deflection at this radial offset value must logically be influenced by the subgrade layer. It is generally believed that the deflection value $W_5$ obtained from Dynaflect measurements indicates subgrade soil properties. A ratio of $W_1$ and $W_5$ can be a good indicator of the load-spreading characteristics of pavement layers, which is a function of pavement type. If two pavements have nearly equal $W_5$ measurements, the values of the maximum deflections ($W_1$) would indicate the relative strengths of the two pavements, with the weaker pavement exhibiting a higher maximum deflection. The ratio of $W_1/W_5$ for the weaker pavement would be higher than that for the other pavement. This means that with a higher $W_1/W_5$ ratio the load-spreading ability of the pavement is lower. By this rationale rigid and composite pavements would exhibit lower $W_1/W_5$ values than flexible pavements.

The primary use of $W_5$ is in the calculation of the subgrade modulus, which is in turn used for stress computations. In the present study an attempt was made to investigate the possible relation between pavement type and $W_1$ and $W_5$ values. Table 1 presents the average $W_1$, $W_5$, and $W_1/W_5$ values for various classes of pavements obtained from the Dynaflect measurements. Flexible pavements

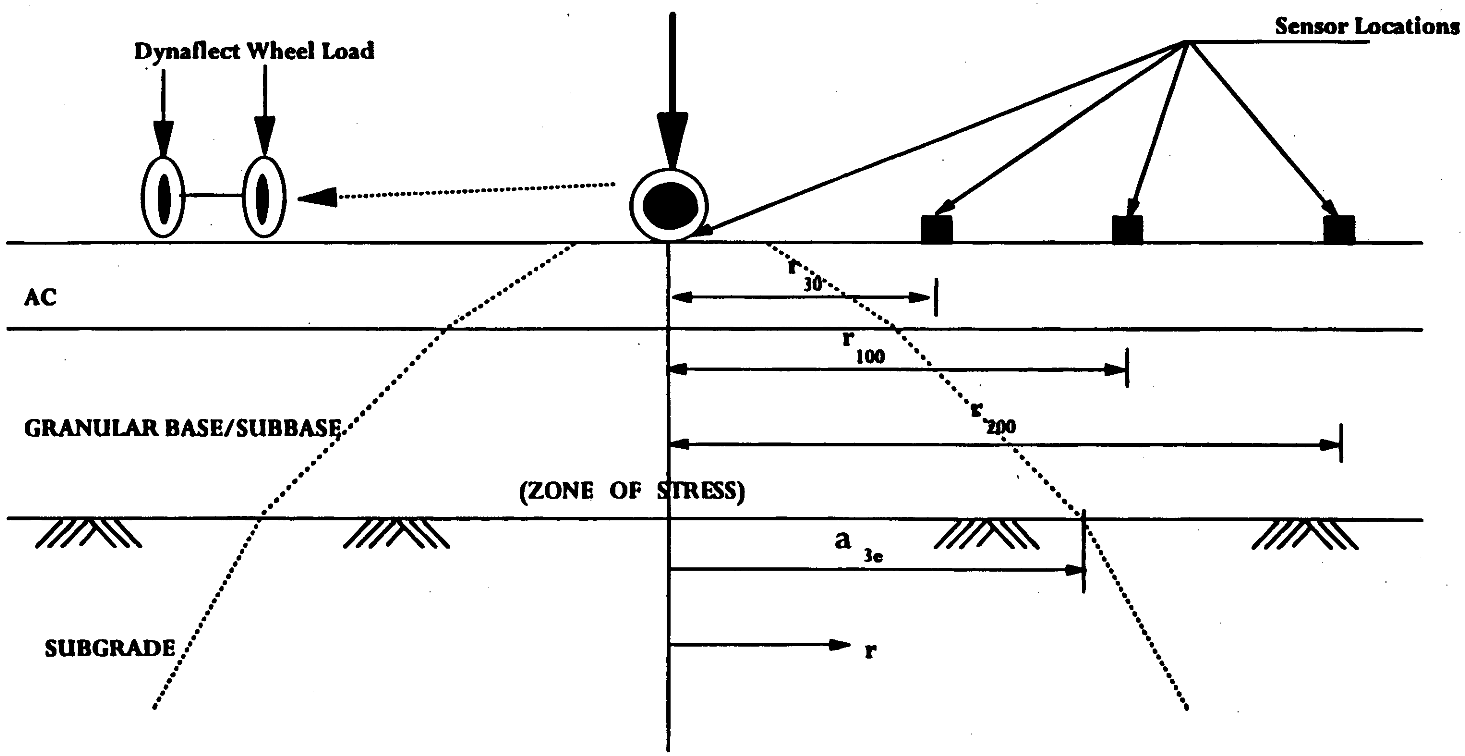


FIGURE 3 Stress zone within pavement structure.

have an average $W_1/W_5$ ratio of 2.88. For rigid pavements (CRCP and JRCP) this average is 1.89, and for composite pavements it is 1.96. Thus, it can be concluded that the $W_1/W_5$ ratio is a good indicator of pavement type. In addition to other parameters, this paper attempts to use this ratio to categorize the B/S pavements.

## COMPARING STRUCTURAL CHARACTERISTICS OF PAVEMENTS

### Structural Parameters

In an area of the pavement containing no joints or cracks, the structural condition of a pavement, when using Dynaflect measurements, is determined from $W_1$, $W_5$, and spreadability values. $W_1$ is the reading of the sensor closest to the load that measures maximum deflection and, thereby, determines the overall pavement integrity. $W_5$ is the sensor farthest from the load and is indicative of subgrade strength. Spreadability is a measure of the volume of the deflection bowl and indicates the load-spreading characteristics of the pavement layers. Spreadability is calculated by the following equation:

$$\text{Percent Spreadability} = \frac{\Sigma (W_1 + W_2 + W_3 + W_4 + W_5)}{5W_1} \times 100$$

Backcalculated moduli or structural numbers, or both, could also be used to characterize the behaviors of these pavements. Such an approach was not possible in the present study because of the lack of information on the subbase.

### Evaluation Based on Maximum Deflection

From Table 1 the average maximum deflection values for B/S pavements with 0.152-, 0.457-, and 0.762-m fragments and composite pavements were nearly equal, with a range of between 0.010 and 0.012 mm. The average maximum deflection on flexible pavements was higher and was equal to 0.014 mm.

The scatter of maximum deflections is plotted in Figure 4. Flexible pavements and B/S pavements with 0.152-m fragments have a wide scatter. Composite pavements also have a wide scatter, but most of the points lie in a narrow band between 0.005 and 0.018 mm. B/S pavements with 0.457- and 0.762-m fragments have less scatter, with most of the points lying in a band between 0.005 and 0.015 mm, which indicates a behavior similar to that of composite pavements.

Based on maximum deflection measurements, the structural responses of all B/S pavements closely resemble those of composite pavements.

### Evaluation Based on Spreadability

Spreadability is a direct function of the load distribution characteristics of the materials used in the pavement layers. Materials with higher moduli of elasticity distribute the load over a wider area. The spreadability of concrete pavements is higher than that of flexible pavements (*5*) owing to the better load dispersion characteristics of concrete. Composite pavements with a concrete base should have spreadability values greater than those of flexible pavements but nearly equal to those of concrete pavements. As seen in Table 1, the average spreadability of composite pavements is 75.19 percent compared with 66.71 percent for flexible pavements. The spreadability values for all B/S pavements in general were higher than those for both flexible and composite pavements: 79.90 percent for 0.152-m fragments, 73.44 percent for 0.457-m fragments, and 82.28 percent for 0.762-m fragments. Again, the B/S sections behaved the same irrespective of the size of the fragments.

As seen in Figure 5, the spreadability values for flexible pavements exhibit a wide scatter, whereas most of the points for composite and B/S pavements fall within a range of 70 to 85 percent.

Therefore, on the basis of spreadability values, it is observed that the behavior of B/S pavements is similar to that of composite pavements.

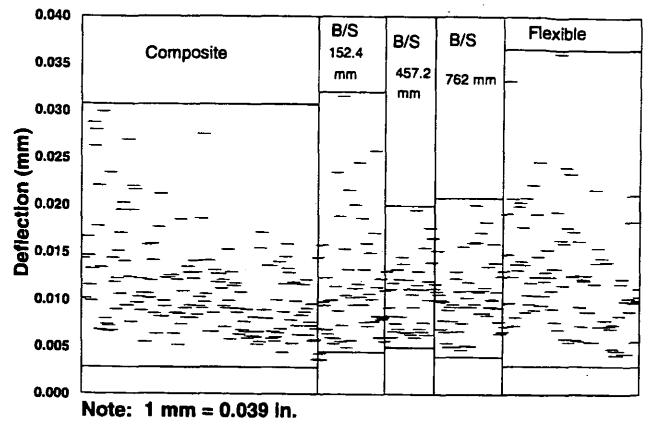


**FIGURE 4 Scatter of maximum deflections (Dynaflect deflection measurements).**

### Evaluation Based on the $W_1/W_5$ Ratio

The $W_1/W_5$ values for all types of pavements studied are presented in Table 1. As stated earlier $W_1/W_5$ values for flexible pavements are about 2.9 and those for rigid and composite pavements are about 2.0.

Figure 6 shows the scatter of $W_1/W_5$ values for different types of pavements. Most of the values for composite and all B/S pavements lie within a narrow range of 1.3 to 2.2, whereas the values for flexible pavements exhibit a wide scatter.

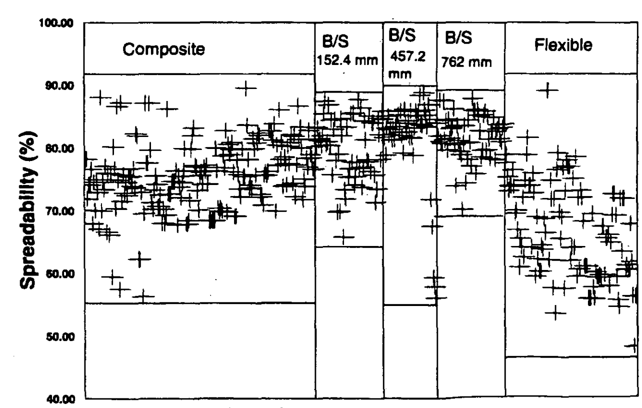


**FIGURE 5 Scatter of spreadability (Dynaflect deflection measurements).**

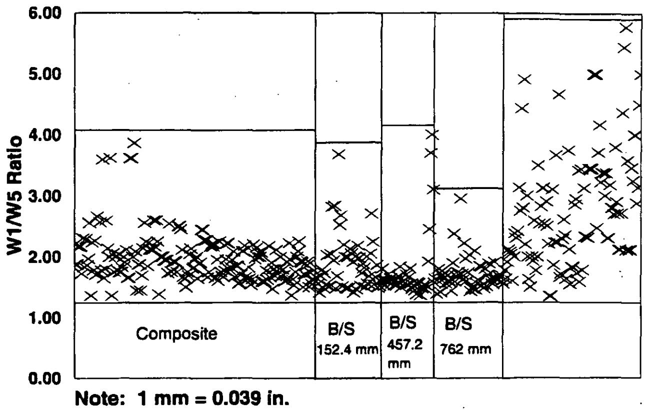


**FIGURE 6 Scatter of $W_1/W_5$ ratio (Dynaflect deflection measurements).**

It can thus be seen that on the basis of the computed $W_1/W_5$ values all B/S sections can better be identified as composite pavements.

## STATISTICAL ANALYSIS

Based on the structural response parameters, B/S pavements behave in a manner similar to composite pavements, irrespective of the size of the cracked slab. A statistical analysis was performed to check the validity of this conclusion.

When comparing two measurements it is desirable to know if the mean values for the two groups are different. If the mean values of measurements are significantly different, then the variable under question is said to have a pronounced effect on the measurement. In the present study the means of the maximum deflections, spreadability, and $W_1/W_5$ ratios for each section were compared. The results of the statistical analyses are presented in Table 2. The null hypothesis ($H_0$) tested was the difference in means equal to 0 at a level of significance of $\alpha$ equal to 0.05.

The differences in the mean values of the average maximum deflection, spreadability, and the $W_1/W_5$ ratio for composite and all B/S pavement sections were statistically insignificant (Table 2). However, this result may have been influenced by unequal sample sizes. A better comparison may have resulted if the two sample sizes had been equal or approximately equal. Therefore, to minimize the effect of unequal sample sizes on the outcome of hypothesis testing, it was decided to generate smaller samples from the composite pavement data. To ensure that a sample is representative of the population from which it is obtained, statistical procedures recommend the use of random sampling techniques. There are several ways of ensuring the selection of a sample that is at least approximately random. For example, if a population has 500 elements and one wishes to select a random sample of size 10, one can use standard random digit tables to obtain 10 different three-digit numbers less than or equal to 500, which will then serve as the serial numbers of those elements to be included in the sample (*8*).

In the present study all of the data from composite pavements were serially numbered from 1 to 188 for each of the structural parameters investigated. By the random sampling technique, a random sample of size 10 was selected. A hypothesis test as described before was performed with this randomly generated sample in place of the previously used large sample size (sample size of 188). This procedure was repeated 10 times for each structural parameter, which resulted in a total of 90 tests. A summary of the results of these tests is presented in Table 3. Of the 90 tests performed, 87 showed that the differences between the structural responses of composite and B/S pavements are insignificant.

**TABLE 2 Statistical Analysis of Pavement Structural Parameters**

| Structural Parameters | Pavements compared | Sample Size | Average | Significant difference between averages | Level of Significance (Probability of error) |
|---|---|---|---|---|---|
| Maximum Deflection (mm) | Composite Vs.<br>B/S (0.152 m fragments) | 188<br>3 | 0.011<br>0.012 | No | 0.85 |
| | Composite Vs.<br>B/S (0.457 m fragments) | 188<br>7 | 0.012<br>0.009 | No | 0.21 |
| | Composite Vs.<br>B/S (0.762 m fragments) | 188<br>3 | 0.011<br>0.010 | No | 0.77 |
| Spreadability (%) | Composite Vs.<br>B/S (0.152 m fragments) | 188<br>3 | 75.19<br>79.90 | No | 0.30 |
| | Composite Vs.<br>B/S (0.457 m fragments) | 188<br>7 | 75.19<br>73.55 | No | 0.37 |
| | Composite Vs.<br>B/S (0.762 m fragments) | 188<br>3 | 75.19<br>82.28 | No | 0.12 |
| $W_1 / W_5$ | Composite Vs.<br>B/S (0.152 m fragments) | 188<br>3 | 1.96<br>1.86 | No | 0.67 |
| | Composite Vs.<br>B/S (0.457 m fragments) | 188<br>7 | 1.96<br>2.05 | No | 0.61 |
| | Composite Vs.<br>B/S (0.762 m fragments) | 188<br>3 | 1.96<br>1.70 | No | 0.25 |

Note: 1 m = 39.37 in.
1 mm = 0.039 in.

TABLE 3 Statistical Analysis of Pavement Structural Parameters Using Random Samples from Composite Pavements

| Structural Parameters | Pavements compared | Sample Size | # of Tests performed | Significant difference between averages | | Range of Level of Significance (Probability of error) for each test. |
|---|---|---|---|---|---|---|
| | | | | # of 'Yes' | # of 'No' | |
| Maximum Deflection (mm) | CompositeVs. B/S (0.152 m fragments) | 10 (random) 3 | 10 | 0 | 10 | 0.173 - 0.934 |
| | CompositeVs. B/S (0.457 m fragments) | 10 (random) 7 | 10 | 0 | 10 | 0.066 - 0.873 |
| | CompositeVs. B/S (0.762 m fragments) | 10 (random) 3 | 10 | 0 | 10 | 0.328 - 0.946 |
| Spreadability (%) | CompositeVs. B/S (0.152 m fragments) | 10 (random) 3 | 10 | 0 | 10 | 0.036 - 0.906 |
| | CompositeVs. B/S (0.457 m fragments) | 10 (random) 7 | 10 | 0 | 10 | 0.202 - 0.994 |
| | CompositeVs. B/S (0.762 m fragments) | 10 (random) 3 | 10 | 3 | 7 | 0.008 - 0.339 |
| $W_1 / W_5$ | CompositeVs. B/S (0.152 m fragments) | 10 (random) 3 | 10 | 0 | 10 | 0.426 - 0.995 |
| | CompositeVs. B/S (0.457 m fragments) | 10 (random) 7 | 10 | 0 | 10 | 0.415 - 0.977 |
| | CompositeVs. B/S (0.762 m fragments) | 10 (random) 3 | 10 | 0 | 10 | 0.065 - 0.605 |

Note: 1m = 39.37 in.
1 mm = 0.039 in.

This analysis further reinforces the previous conclusions that all B/S pavements behave as composite pavements.

## SUMMARY AND CONCLUSIONS

1. Based on maximum deflection, spreadability, and $W_1/W_5$ ratios, the performances of asphalt overlays on B/S pavements with 0.152-, 0.457-, and 0.762-m fragments closely resemble those of composite pavements. The original pavement in all composite and B/S sections studied was jointed reinforced concrete. This finding will help engineers identify the appropriate theories to use in the design of the maintenance and rehabilitation needs of such pavements.
2. The ratio $W_1/W_5$ is a good indicator of pavement type. A value of 2.88 represents flexible pavements and a value of 2.00 and below represents composite and rigid pavements types.
3. The findings of the present study may be improved upon by selecting a large number of B/S sections and grouping all of the pavement sections on the basis of AC layer thicknesses, the ages of the pavements, environmental characteristics, and soil characteristics before comparing them.
4. To better understand the performances of B/S pavements and to compare their behaviors with those of other pavements a study has been initiated by ODOT in which test pavements have been constructed to investigate the effects of several variables. The validity of the current findings would be verified by such a study, and the results will be presented when they become available.

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