# EVALUATION OF EXPERIMENTAL FLEXIBLE PAVEMENTS

Interim Report No. 1
Construction of Altavista Bypass Experimental Pavement

by

K. H. McGhee
Highway Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway Research Council
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## SUMMARY

Deflection tests conducted during the construction and shortly after the completion of a large experimental pavement project are reported. Four different pavement designs, as follows, are compared:

1. 6-inch cement stabilized subgrade
   6-inch crushed stone base
   $7\frac{1}{2}$-inch bituminous concrete

2. 6-inch cement stabilized subgrade
   $9\frac{1}{2}$-inch bituminous concrete

3. 4-inch cement stabilized crushed stone subbase
   6-inch crushed stone base
   $7\frac{1}{2}$-inch bituminous concrete

4. 6-inch cement stabilized subgrade
   4-inch cement stabilized crushed stone base
   $5\frac{1}{2}$-inch bituminous concrete

The results of these early tests support the following conclusions:

1. Pavements having equivalent design parameters are not necessarily equivalent in either early structural strength or in construction costs.

2. Very early deflection tests are not good indicators of the ultimate strength characteristics of pavements having cement stabilized layers.

3. Highly resilient soils must be stabilized to achieve a good working platform and to assure the early development of design strength.

4. Design No. 4, above, develops the design structural strength more rapidly and at a lower cost than the other three designs.

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## INTRODUCTION

For a number of years the Virginia Highway Research Council and the Federal Highway Administration cooperated in comprehensive performance studies of typical highway pavements of all types located in all sections of Virginia. The study, which at one time included nearly two hundred projects, resulted either directly or indirectly in an almost total revision in the Virginia approach to flexible pavement design. As a result of this study highway engineers in Virginia are much more cognizant of soil resiliency, the benefits of cement or lime stabilization, and of the value of thick bituminous concrete layers.[1,2,3,4] In addition, Vaswani has utilized the results of the above mentioned study and those of the AASHO road test in developing a strength coefficient design method for use in Virginia.[5]

The comprehensive studies were phased out at the end of calendar 1971, because most of the projects had reached the age where further study would not be profitable. On the other hand, recent innovations in pavement design are receiving attention so that occasionally new construction projects have features quite different from anything in the past. Examples are full-depth asphalt pavements (up to 16 inches of bituminous concrete base) and pavement systems in which the layers have been switched from their usual positions. Clearly, the evaluation of such projects is crucial to the determination of whether or not the experimental features should be adopted for routine pavement designs.

## PURPOSE AND SCOPE

The present report deals with the construction and preliminary evaluation of four experimental pavement systems designed by the layer coefficient method and found by that method to be structurally equivalent. This work is being done in cooperation with the Materials and Construction Divisions of the Highway Department. The experimental sections are located on the four-lane divided bypass of Altavista, Virginia (U. S. Route 29). While this project is only one of seven included in the overall study, it is reported separately here because of several distinguishing features and because the construction of the four experimental sections has been completed very recently. Construction began in the fall of 1971 and the pavement was opened to traffic in late 1973.

The primary objective of the Altavista project is to evaluate the relative merits of four typical pavement sections designed by the coefficient method. Included are: (1) An evaluation of the original relative structural strengths of the four pavement designs as determined by deflection tests during and immediately after construction, and (2) an evaluation of the relative performance of the four designs as determined by long-term deflection and roughness tests along with visual observations.

A secondary objective is to evaluate the comparative construction costs of the four pavement designs in an effort to show that structurally equivalent pavements may be of different costs.

The present report deals almost entirely with the evaluation of layer deflection tests conducted on the Altavista project while it was under construction. Other projects included in the overall study are indicated in the working plan.[6]

## PROJECT DESCRIPTION

### Background

The AASHO Road Test Results led to the development of a flexible pavement strength equation:

$$D = a_1 h_1 + a_2 h_2 + \ldots$$

where

| | |
|---|---|
| D | designates the thickness index, or total strength index of the pavement; |
| $a_1$ | is the strength coefficient of the surface layer of thickness $h_1$; |

and

| | |
|---|---|
| $a_2$ | is the strength coefficient of the second layer of thickness $h_2$; etc. |

Vaswani assigned the value 1.0 to asphaltic concrete ($a_1$) and evaluated the coefficients for other materials such that a pavement having a thickness index D can be considered structurally equivalent to an asphaltic layer D inches thick.[5] Some of the resulting coefficients are tabulated in Table 1. For design purposes Vaswani also gives a soil support value based on CBR tests and adjusted by a regional resiliency factor.[5]

Table 1

Thickness Equivalencies of Materials

| | Material | Thickness Equivalency |
|---|---|---|
| (a) | Asphalt Mat (A. C.) | 1.0 |
| (b) | Cement Treated Aggregate (CTA) | |
| | (1) Below A. C. and above aggregate layer or above soil cement | 1.0 |
| | (2) Over subgrade | 0.6 |
| (c) | Untreated Aggregate | 0.35 |
| (d) | Soil Cement | 0.40 |

## Typical Sections

The Altavista Bypass project was originally designed with the standard pavement cross section shown in typical section A (appended). From the coefficients listed in Table 1 the standard design was determined to have a thickness index of 12.0. Typical sections B, C, and D (also appended) have thickness indices of 11.9, 12.0, and 11.9 respectively. A cost analysis showed that the experimental sections were estimated to be less costly than the standard section. The control and experimental sections are located as shown on the typical section sheets. Note that each test section was constructed in the southbound lane and repeated in the northbound lane. Test sections range from 2.2 to 2.8 miles in length with the total length of each type design ranging from 4.4 to 5.0 miles. A plan view of the experimental layout is given in Figure 1. The almost ten-mile long project was built under two contracts both by the same prime contractor utilizing two paving subcontractors.

Not to scale

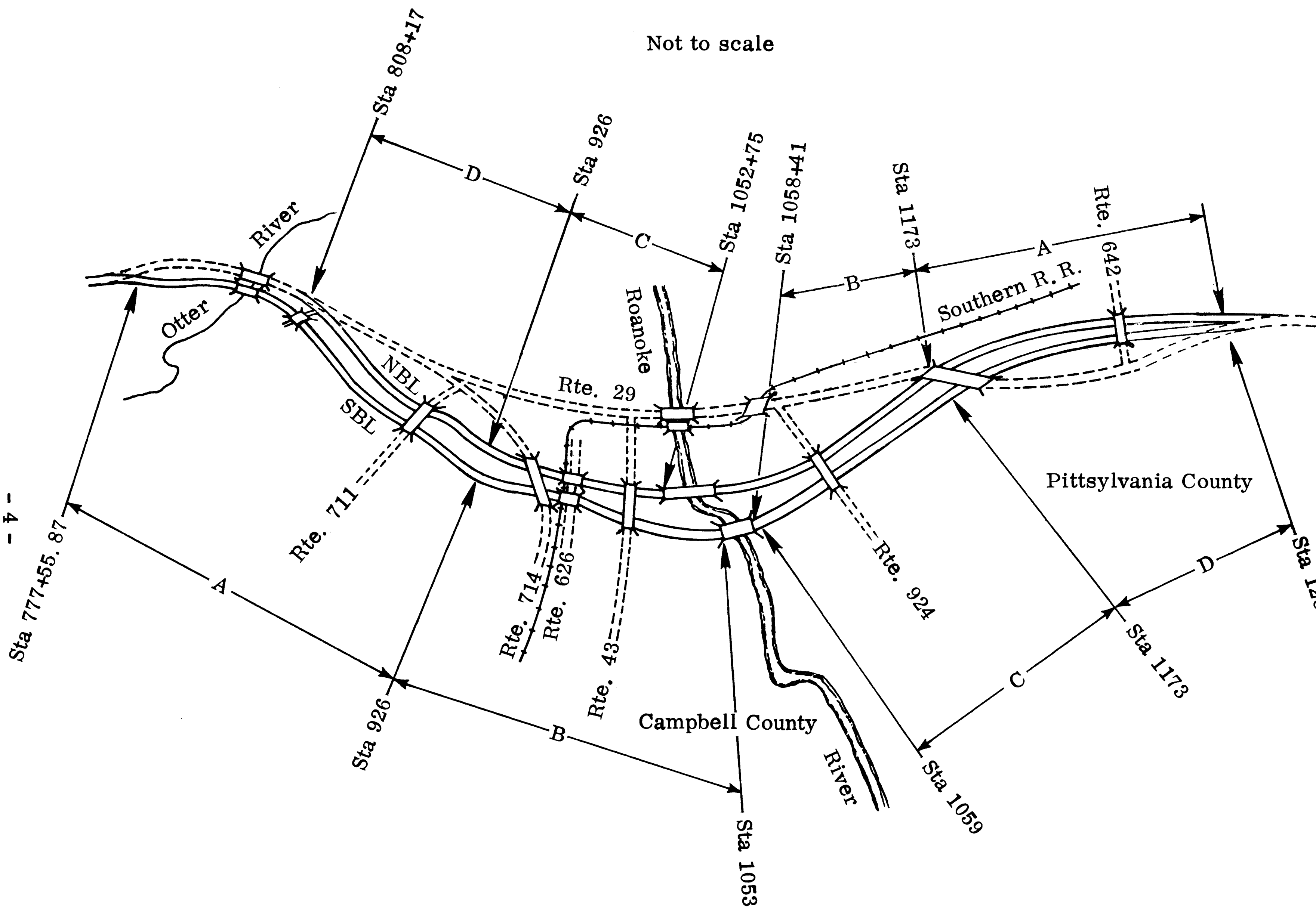



Figure 1. Plan view of Altivista Bypass experimental project.

## Soil Conditions

The nature of the embankment and subgrade soils on the Altavista Project were determined during the preliminary engineering phase of the project. The details of these soil conditions are available in the project records. Briefly, the subgrade soils are predominately micaceous silts from A-2-4(0) through A-5(10) and with California bearing ratio values of from 5 to 16. Since these soils are categorized as highly resilient with poor bearing capacity it has been conventional in Virginia to stabilize the top six inches of the subgrade with portland cement. As has been reported elsewhere, this stabilization has been found to provide both a good working platform for construction equipment and to enhance long-term pavement performance.(4) As indicated above, such stabilization was provided on three of the experimental sections on the present project, while the fourth design specified compacted native subgrade without stabilization.

## Specifications

All experimental sections on the Altavista project were constructed in accordance with the project plans and the Virginia Department of Highways Road and Bridge Specifications dated July 1, 1970.

## Traffic Projection

Since the experimental project is a bypass, existing traffic conditions were nonexistent. However, Location and Design Division studies in 1968 projected an average daily design traffic of 2,730 vehicles in one direction based on traffic studies on connecting roadways. These same studies projected the daily mean 18,000 pound equivalent axle loads in the traffic lanes to be 134.

# EVALUATION PROCEDURES

In general, the evaluation of experimental features begins when substantial portions of the subgrade for a given project have been prepared. At that time, dynaflect deflection tests are conducted on the subgrade. Similar tests follow the placement of subsequent pavement layers, including the final riding surface. Further steps in the evaluation of each project are as follows:

(1) Procurement of final plans and cross sections, materials descriptions, construction costs, and date of acceptance from the contractor.

(2) Establishment of easily identified project limits by the use of roadside markers and written descriptions.

(3) Initial and periodic collection of data reflecting:

a. traffic characteristics,

b. structural capability as indicated by deflection tests,

c. roughness, and

d. visual defects such as cracking, rutting, patching, and settlements.

(4) Compilation of records of major maintenance operations (bituminous concrete overlays, for example) and their costs.

The details of the procedures mentioned in (3) above are given in earlier studies[4,7], where it may be seen that a pavement is considered to have failed when the cracking factor[4] reaches 50. Because of the relative smoothness of its pavements, Virginia has been dissatisfied with performance evaluations based on present servicibility index concepts in which the BPR roughometer was used.[8] Recent efforts with the Portland Cement Association roadmeter appear more promising, so that this device will be used for roughness testing.

## RESULTS AND DISCUSSION

### Layer Deflections

Deflection tests were conducted at regular time intervals from the beginning of subgrade preparation until the project was opened to traffic. The first tests were conducted on the raw subgrade of Section B and the cement stabilized subgrade of Section A on August 8, 1972. Tests were then run on each layer of each section as test locations became available. Final tests on the finished surface of all sections were conducted during the fall of 1973.

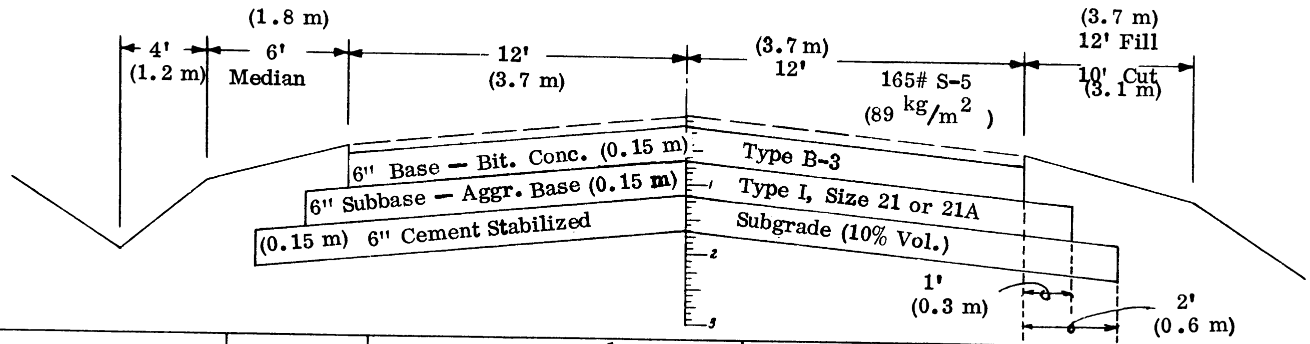
Table 1-A (Appended) summarizes all deflection tests conducted to date. In this table the test results are listed according to location within the project and within the pavement structure. Along with the Benkelman beam deflection at each location, the bending factor and the calculated accumulative thickness index[9] are tabulated for each testing condition. All deflection tests employed the dynaflect with the conversion to Benkelman beam made thorough use of the equation (Benkelman beam = 27.8 dynaflect) determined by Hughes.[10] In addition to Table 1-A the deflection data are summarized in Figures 2, 3, 4, and 5 according to design types A, B, C, and D respectively. In these figures, all deflection tests for a given pavement layer have been averaged. The data shown include the dynaflect deflection, the bending factor, the accumulative thickness index, and the weighted average air temperature at the time of testing. Finally, Figure 6 depicts graphically the reduction in average dynaflect deflection for each design type as each of the pavement layers was constructed. A discussion of the deflection results for each design type follows.

Control Section A

DEFLECTION SUMMARY

6029-015-103, C501
6029-071-111, C501

TYPE OF PAVEMENT Flexible




| Course | No. Tests | Dynaflect Deflection ($^{1}/1,000$ in.) | | B. F. | Thickness Index | Mean Temp. ($^{o}$F) | |
|---|---|---|---|---|---|---|---|
| Subgrade | 126 | 1.587 | (40 μm) | 45 | — | 79 | (26$^{o}$C) |
| C. S. Subgrade | 283 | 1.423 | (36 μm) | 49 | 4.6 | 78 | (26$^{o}$C) |
| Aggregate Base | 305 | 1.076 | (27 μm) | 53 | 5.7 | 73 | (23$^{o}$C) |
| B-3 | 163 | 0.790 | (20 μm) | 60 | 9.6 | 54 | (12$^{o}$C) |
| S-5 | 82 | 0.389 | (10 μm) | 67 | 15.0 | 71 | (22$^{o}$C) |

**Figure 2. Deflection Summary, Design A.**

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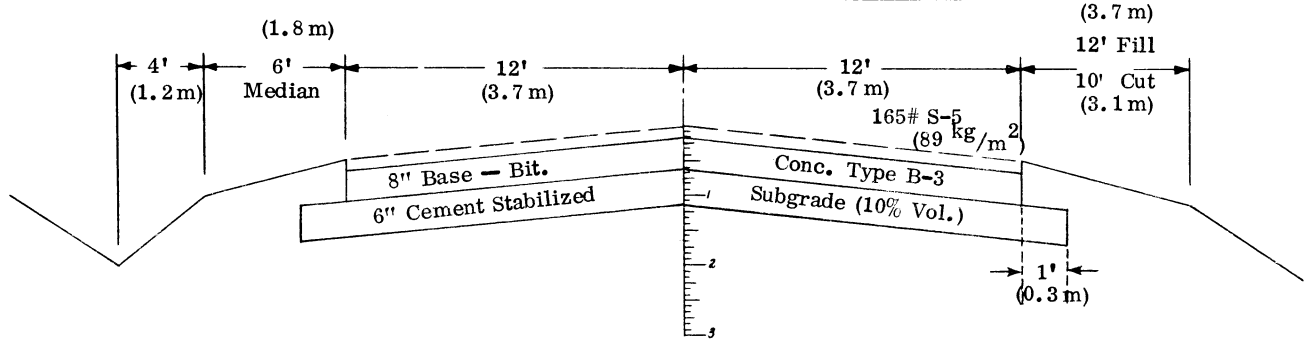
Experimental Section B

DEFLECTION SUMMARY

6029-015-103, C501

6029-071-111, C501

TYPE OF PAVEMENT Flexible




| Course | No. Tests | Deflection ($^1/1,000$ in.) | B. F. | Thickness Index | Mean Temp. ($^oF$) |
|---|---|---|---|---|---|
| Subgrade | 78 | 2.092 (53 um) | 42 | — | 78 ($26^oC$) |
| C. S. Subgrade | 261 | 2.089 (53 um) | 48 | 3.7 | 72 ($22^oC$) |
| B-3 | 301 | 0.639 (16 um) | 70 | 12.0 | 61 ($16^oC$) |
| S-5 | 85 | 0.603 (15 um) | 73 | 14.0 | 74 ($23^oC$) |

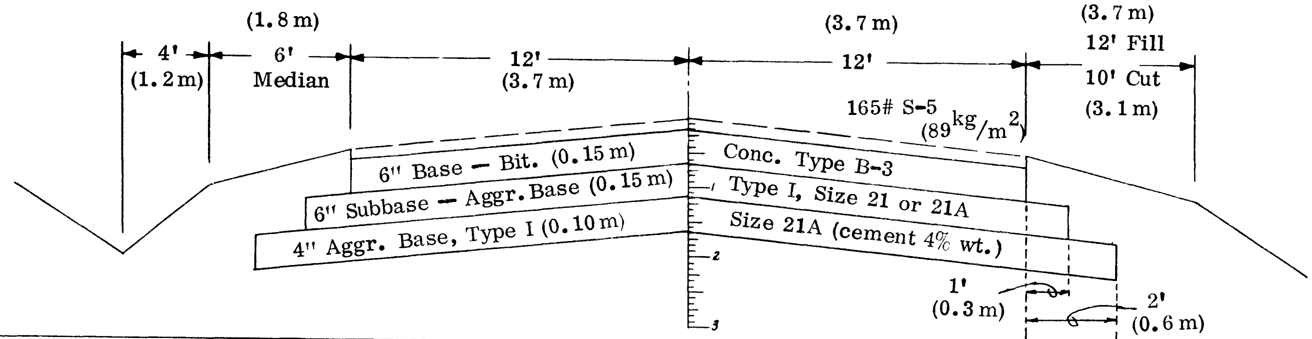
Figure 3. Deflection Summary, Design B.

Experimental Section C

DEFLECTION SUMMARY

6029-015-103, C501
6029-071-111, C501

TYPE OF PAVEMENT Flexible




| Course | No. Tests | Deflection ($^1/_{1,000}$ in.) | B. F. | Thickness Index | Mean Temp. ($^oF$) |
|---|---|---|---|---|---|
| Subgrade | 104 | 2.737 (70 µm) | 38 | — | 80 (27°C) |
| C. T. Aggregate Base | 168 | 2.533 (64 µm) | 43 | 2.8 | 67 (19°C) |
| Aggregate Base | 95 | 1.691 (43 µm) | 53 | 5.0 | 79 (26°C) |
| B-3 | 296 | 0.894 (23 µm) | 59 | 7.4 | 73 (23°C) |
| S-5 | 90 | 0.750 (19 µm) | 64 | 9.5 | 89 (32°C) |

Figure 4. Deflection Summary, Design C.

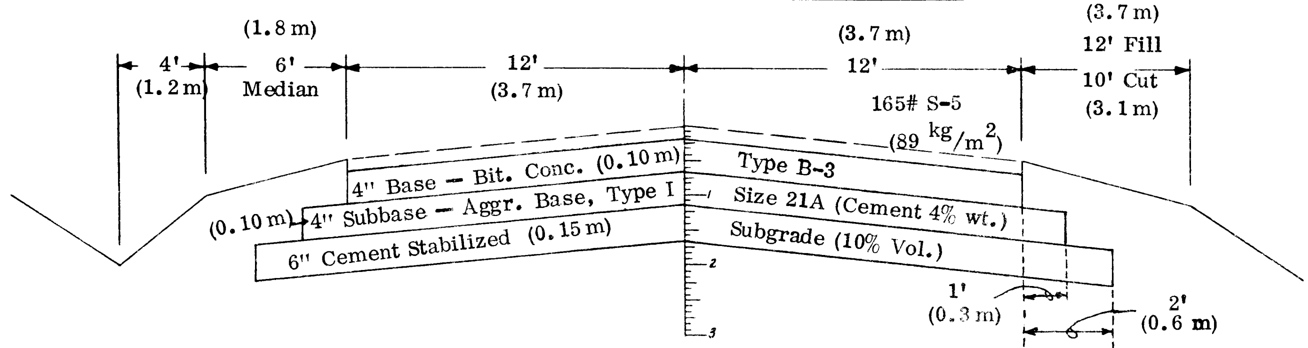
Experimental Section D

DEFLECTION SUMMARY

6029-015-103, C501

TYPE OF PAVEMENT Flexible

6029-071-111, C501




| Course | No. Tests | Deflection ($^1/1,000$ in.) | B. F. | Thickness Index | Mean Temp. (°F) |
|---|---|---|---|---|---|
| Subgrade | 104 | 1.768 (45 µm) | 45 | — | 78 (26°C) |
| C. S. Subgrade | 253 | 1.267 (32 µm) | 49 | 4.7 | 65 (18°C) |
| C. T. Agg. Base | 17 | 0.856 (22 µm) | 62 | 8.1 | 88 (31°C) |
| B-3 | 317 | 0.560 (14 µm) | 63 | 11.0 | 62 (17°C) |
| S-5 | 68 | 0.378 (10 µm) | 72 | 17.0 | 87 (31°C) |

Figure 5. Deflection Summary, Design D.

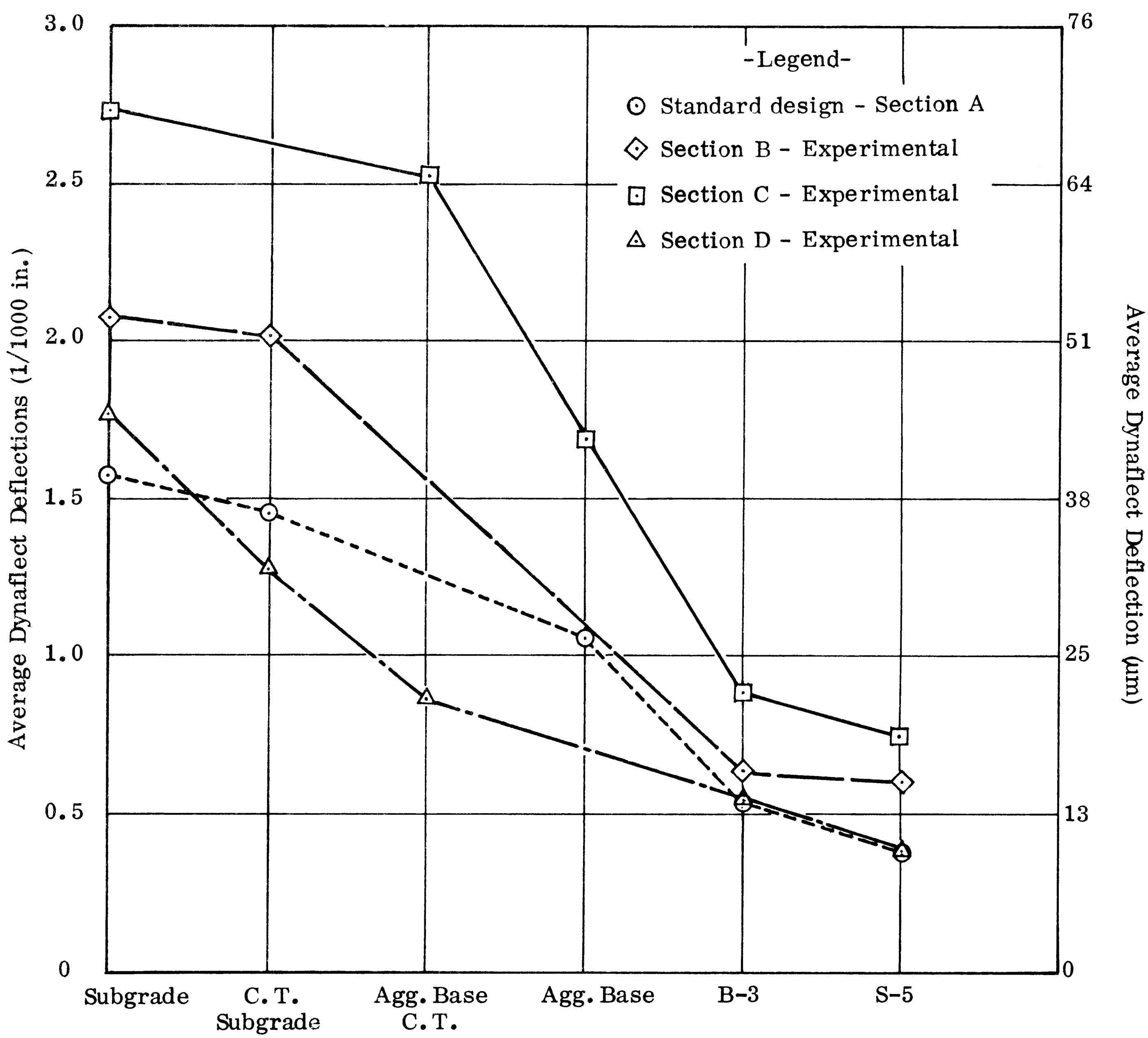



Figure 6. Deflection of pavement layers.

Design A

Design A, shown in Figure 2, is of the general type often considered as the standard for many areas of the state and for that reason was chosen as the standard of comparison for the present study.

The dynaflect deflection tests conducted on this section generally followed the expected pattern, i.e., deflections were reduced as each succeeding pavement layer was constructed. The results of these layer tests, however, were not as enlightening as had been hoped before construction of the experimental pavement began. While it had been expected that deflection tests on each layer as the pavement was built would give an immediate indication of how much each layer contributed to the total pavement strength, the tests showed that such an early indication was not practical. It is evident from the test results that time is an important factor in the development of the pavement's ultimate strength. While this is no doubt primarily due to the hydration and strength development time required for the cement treated subgrade, it is likely that variations in moisture content and increased consolidation of pavement layers as construction proceeds also are factors.

Some type of interplay between these variables is evidenced in Figure 7, an example of typical deflection test results shown for each 1,000-ft. interval throughout the northbound subsection of Design A. A study of this figure and the testing dates shown in Table 1-A (Design A, Pittsylvania County) gives some indication of the time factor. Note, for example, that cement stabilization of the subgrade seemed to have little effect on deflection when the stabilization was about one week old. The addition of the 6-inch crushed stone layer did seem to significantly reduce deflections. However, at least part of this reduction was no doubt due to increasing strength of the stabilized subgrade with increased age. Another significant decrease in deflections occurred with the addition of the 6-inch bituminous concrete base layer. Again the decrease in deflections may be due partly to a strength increase by the cement stabilized subgrade. Possibly the most striking thing about the Design A deflection tests is the apparently inordinate reduction in deflections caused by the addition of the $1\frac{1}{2}$-inch bituminous concrete surface (see tests dated October 29, 1973, as contrasted with those on B-3 in July and August 1973). The indication in Table 1-A, Figure 2, and Figure 7 is that the thin surface course has contributed as much or more to the pavement strength than the 6-inch layer of bituminous concrete base. Since this is clearly an unreasonable finding, one can only conclude that the total pavement structure is continuing to gain strength with time due to some of the variables discussed previously. Again, it is important to note that the cement stabilized subgrade, the crushed stone base, and the bituminous concrete base were all constructed and tested within a period of about eight weeks while the surface deflection tests were not conducted until approximately ten weeks after the completion of the base course testing.

The total pavement strength developed by Design A by the time construction was completed appears to be at least as high as required by design parameters. This is evidenced by the thickness index of 15.0 determined from deflection tests compared to a design index of 12.0. It should be noted here that the thickness index computed from deflection tests is only an approximation of the true index because the computations involve certain assumptions concerning the strength characteristics of the various materials used in the pavement structure.

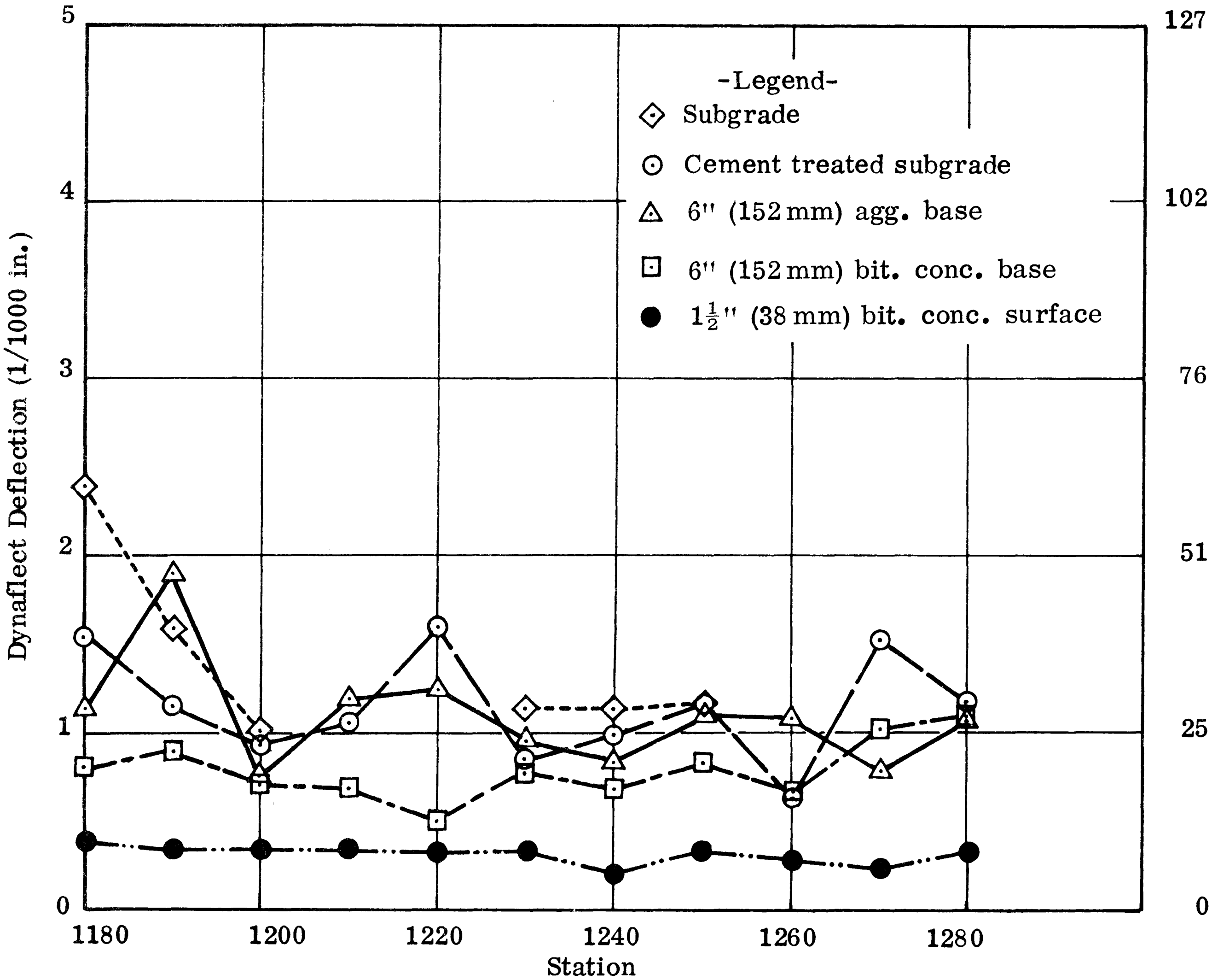



Figure 7. Layer deflections at 1,000 ft. (308 m) intervals. Typical results (Design A — NBL).

## Design B

Design B, sometimes referred to as a modified full-depth asphalt pavement because, except for the cement stabilized subgrade, the pavement is comprised entirely of bituminous concrete, shows strength development under construction very much as would be expected. As can be seen in Table 1-A and in Figures 3 and 6 the majority of the strength development can be attributed to the 8-inch bituminous concrete base course. Furthermore, since from four weeks to ten months had elapsed between tests on the cement stabilized subgrade and those on the bituminous concrete base, it is reasonable to assume that the stabilized subgrade had developed most of its strength before the bituminous concrete was applied and tested.

In this case, as with Design A, the thickness index data show that the completed pavement has a structural strength at least equivalent to design requirements. Again, the measured thickness index of 14.0 compares favorably with the design value of 11.9.

## Design C

Experimental Design C is the only one of the four constructed with an unstabilized subgrade soil. For this reason, a poorer working platform was provided for the contractor's equipment. This factor, together with extremely wet construction seasons and very poor soil conditions, resulted in some construction difficulties. These problems were evidenced (1) in the need to apply lime as a drying agent to certain saturated portions of the subgrade soil, (2) in the distortion of the prepared subgrade soils under construction traffic, and (3) primarily in the very early failure of one segment (stations 1117 to 1130 approximately) of the 4-inch thick cement treated crushed stone subbase under construction traffic. This subbase failure was corrected by the provision of 4% cement by weight to the previously unstabilized layer of crushed stone base. Because of this change in the pavement character the altered segment of roadway will be excepted in future studies where the performances of the four designs are compared. Nevertheless, the researchers plan to observe the behavior of this exception for an indefinite period.

As indicated above, the subgrade soils in the C sections were very poor. This is also shown in the deflection results given in Table 1-A and in Figures 4 and 6. Note that subgrade deflections and deflections on all subsequent layers were higher for Design C than for the other three designs. Even though the two subsections of Design C were located some distance apart and in opposite lanes, by chance they were located in two of the worst soil areas on the experimental project. Soil problems identified in some portions of Design C were saturation in the Campbell County subsection and the presence of a highly resilient blue micaceous silt in the Pittsylvania County subsection.

The gain in pavement strength with the addition of pavement layers had some of the characteristics seen for Design A. Note that again in Design C it appears, at first glance, that the $1\frac{1}{2}$-inch surface course has contributed almost as much to pavement strength as the 6-inch bituminous concrete base. However, a study of the testing dates in Table A-1 shows that the crushed stone and the bituminous concrete base layers were applied shortly after cement treatment of the 4-inch subbase layer. Tests on the surface course were conducted several months later in most cases. Hence, it is likely that much of the increase in thickness index apparently due to the surface course (Figure 4) was really due to strength gained by the cement treated subbase.

Apparently due to the soil problems and construction difficulties discussed above, Design C has a completed thickness index averaging 9.5, which does not compare well with the design index of 12.0. This design will deserve close observation and testing to determine whether there are later significant improvements in pavement strength or whether premature failures occur.

Design D

Design D, which contains two cement stabilized layers, produced the strongest finished product of the four designs included. The deflection data shown in Table 1-A and Figures 5 and 6 are self-explanatory and it suffices to point out that the final deflections are the lowest and the final thickness index the highest of those measured for the four designs. Clearly, the final thickness index of 17.0 compares very favorably with the design index of 11.9.

The gain in pavement strength with time as noted for Designs A and C is again evident for Design D in that the surface course applied some months after the other pavement layers seemed to inordinately increase pavement strengths.

It is important to note here that while this particular design may perform extremely well, there will be reflection cracks from the cement treated crushed stone underlying the relatively thin bituminous concrete course. Furthermore, as has been reported earlier from a study of a similar pavement,[7] the extreme rigidity of this design coupled with the tendency of the cement treated stone to crack both transversely and longitudinally can result in behavior very much like that of a concrete pavement. Thus, if water becomes trapped under the stabilized stone a pumping action can occur to the detriment of pavement performance. The performance of this particular section will be watched closely for any evidence of this phenomenon.

## Cost Comparison

Direct cost comparisons of the standard and the three experimental pavement sections are readily available from the appended Typical Sections A through D where contract bid prices have been used to compute actual construction costs. Note that sections A and C were the most costly and happened to cost the same. Section D, with two cement stabilized layers but relatively thin asphaltic concrete, was the least costly by some $16,000 per mile. It should be kept in mind that the bid prices given were effective in late 1971 and in no way reflect current construction costs. It is conservatively estimated that the Altavista pavement costs would be doubled if the contracts were let in mid-1974. Furthermore, the relative costs of the four experimental sections may have changed because all highway materials have not increased in cost at the same rate.

A closer analysis of actual construction costs is provided in Table 2, where more details are given. As can be seen in the table, pavement construction costs are roughly related to the total thickness of pavement provided. In fact, when viewed in terms of cost per inch of pavement depth the standard design (Design A) is the most economical pavement, while the thick bituminous concrete pavement (Design B) is the most expensive.

Table 2

Construction Cost Summary

| Section | Cost per mile | Total Thickness (in.) | Cost per mile per in. | Thickness Index* | Cost per mile/T.I.** |
|---|---|---|---|---|---|
| A | $99,106 | 19.5 | $5,082. | 15.0 | $ 6,607. |
| B | 89,126 | 15.5 | 5,750. | 14.0 | 6,366. |
| C | 99,106 | 17.5 | 5,662. | 9.5 | 10,432. |
| D | 83,213 | 15.5 | 5,369. | 17.0 | 4,895. |

*Measured thickness index, from deflection tests.

**Cost per mile per unit measured thickness index.

However, in keeping with current design concepts wherein the pavement thickness index is the major structural parameter, it is more realistic to consider the costs per unit of thickness index. When viewed in this manner, the very rigid, highly stabilized Design D is the least expensive, while Design C, in which the subgrade was unstabilized, is the most costly.

While it is too early to draw firm conclusions, the deflection tests suggest, at this time, that the least expensive two designs (B and D) may provide better performance than the two more costly designs (A and C).

## CONCLUSIONS

The following conclusions are based on tests conducted during construction and shortly after completion of the Altavista project. Because pavement characteristics may change under the first few months' exposure to traffic and changing climatic conditions, no definite indications of ultimate pavement performance are offered in this initial report.

1. Pavements having equivalent design thickness indices are not necessarily equivalent in early structural strength.

2. Pavements having equivalent design thickness indices are not necessarily equivalent in construction costs.

3. Very early deflection tests are not good indicators of the ultimate strength characteristics of pavements having cement stabilized layers.

4. Highly resilient soils, especially micaceous silts, must be stabilized to achieve a good working platform for pavement construction and to assure the early development of the design structural strength.

5. A design utilizing a cement stabilized subgrade overlain with a cement stabilized stone base and bituminous concrete develops the design structural strength more rapidly and at a lower cost than any of the other three designs.

## ACKNOWLEDGEMENTS

The research reported was conducted under the sponsorship of the Virginia Department of Highways and the Federal Highway Administration. The study is financed from HPR funds and is under the general supervision of Jack H. Dillard, head of the Virginia Highway Research Council.

The interest and cooperation of J. P. Bassett, pavement design engineer; F. L. Burroughs, construction engineer; and numerous district, residency, and project personnel have made the experimental project possible. The author gratefully acknowledges this assistance.

Finally, the diligence displayed by G. V. Leake, highway materials technician, in conducting the deflection tests and in keeping detailed records of construction progress is most appreciated.

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APPENDIX

Table 1- A

DETAILS OF DEFLECTION TEST RESULTS

Design A

| | Campbell County | | | | | Pittsylvania County | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Course | Dates | Stations | Def'l. (1) (1/1000) | (2) B. F. | (3) T. I. | Dates | Stations | Def'l. (1/1000) | B. F. | T. I. |
| Subgrade | Aug. 10, 72 | 892-926 | 41 | 38 | — | Jun. 13, 73 | 1226-1290 | 44 | 45 | — |
| Subgrade | | | | | | Jun. 28, 73 | 1173-1202 | 49 | 54 | — |
| C. S.Subg. | Aug. 8, 72 | 837-874 | 39 | 45 | 3.8 | Jun. 26, 73 | 1228-1271 | 40 | 47 | 4.0 |
| C. S.Subg. | Aug. 9, 72 | 778-800 | 48 | 45 | 3.5 | Jun. 22, 73 | 1274-1290 | 36 | 58 | 6.3 |
| C. S.Subg. | Aug. 10, 72 | 886-891 | 31 | 49 | 4.8 | Jul. 9, 73 | 1173-1226 | 43 | 47 | 3.8 |
| Agg. Base | Aug. 18, 72 | 778-800 | 32 | 41 | 3.5 | Jul. 3, 73 | 1285-1290 | 24 | 60 | 7.7 |
| Agg. Base | Aug. 18, 72 | 837-867 | 27 | 50 | 5.5 | Jul. 9, 73 | 1256-1285 | 25 | 57 | 6.8 |
| Agg. Base | | | | | | Jul. 11, 73 | 1187-1255 | 32 | 52 | 5.5 |
| Agg. Base | | | | | | Jul. 17, 73 | 1173-1187 | 33 | 56 | 5.9 |
| B-3 | Nov. 6, 72 | 819-870 | 14 | 63 | 11 | Jul. 17, 73 | 1262-1290 | 17 | 58 | 8.5 |
| B-3 | Nov. 6, 72 | 892-926 | 12 | 54 | 9.0 | Jul. 31, 73 | 1183-1262 | 20 | 58 | 8.0 |
| B-3 | Nov. 15, 72 | 871-892 | 12 | 56 | 9.5 | Aug. 14, 73 | 1173-1202 | 22 | 59 | 7.9 |
| B-3 | May 15, 73 | 819-869 | 17 | 63 | 9.5 | | | | | |
| S-5 | Aug. 30, 73 | 820-926 | 13 | 65 | 12 | Oct. 29, 73 | 1173-1287 | 9 | 69 | 17 |

Design B

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Subgrade | Aug. 8, 72 | 1016-1046 | 52 | 42 | — | Jun. 28, 73 | 1153-1172 | 82 | 43 | 2.8 |
| C. S. Subg. | Aug. 12, 72 | 1033-1053 | 39 | 48 | 4.5 | Jul. 9, 73 | 1154-1173 | 96 | 43 | 2.7 |
| C. S. Subg. | Aug. 17, 72 | 978-1013 | 40 | 49 | 4.5 | Jul. 11, 73 | 1097-1153 | 61 | 47 | 3.5 |
| C. S. Subg. | | | | | | Jul. 17, 73 | 1059-1096 | 65 | 49 | 3.8 |
| B-3 | Nov. 6, 72 | 927-971 | 17 | 69 | 13 | Aug. 14, 73 | 1125-1173 | 29 | 60 | 7.2 |
| B-3 | Nov. 28, 72 | 890-1048 | 10 | 76 | 17 | Aug. 28, 73 | 1059-1124 | 26 | 67 | 9.0 |
| B-3 | May 17, 73 | 920-1036 | 15 | 72 | 14 | | | | | |
| S-5 | Jul. 11, 73 | 939-1052 | 22 | 68 | 10 | Oct. 29, 73 | 1059-1172 | 13 | 79 | 17 |
| S-5 | Aug. 30, 73 | 928-939 | 15 | 73 | 15 | | | | | |

Design C

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Subgrade | | | | | | Jun. 26, 73 | 1109-1093 | 104 | 39 | — |
| Subgrade | Aug. 18, 72 | 998-1002 | 72 | 38 | — | Jun. 13, 73 | 1164-1173 | 74 | 43 | — |
| Subgrade | | | | | | Jun. 20, 73 | 1108-1163 | 63 | 40 | — |
| C. T. Ag. B. | | | | | | Jul. 31, 73 | 1062-1095 | 62 | 51 | 4.2 |
| C. T. Ag. B. | | | | | | Aug. 2, 73 | 1095-1144 | 44 | 39 | 2.8 |
| Agg. Base | Aug. 10, 72 | 927-936 | 27 | 52 | 6.0 | Aug. 7, 73 | 1073-1102 | 57 | 57 | 5.0 |
| Agg. Base | | | | | | Aug. 9, 73 | 1101-1115 | 44 | 45 | 3.7 |
| B-3 | Jul. 19, 72 | 1022-1041 | 33 | 52 | 5.5 | Aug. 28, 73 | 1060-1109 | 31 | 64 | 7.9 |
| B-3 | Aug. 14, 72 | 1041-1052 | 23 | 56 | 6.5 | Aug. 30, 73 | 1138-1174 | 30 | 60 | 7.1 |
| B-3 | Nov. 15, 72 | 926-936 | 13 | 63 | 11 | | | | | |
| B-3 | Nov. 28, 72 | 985-1006 | 19 | 62 | 9.0 | | | | | |
| B-3 | May 17, 73 | 980-1050 | 20 | 59 | 8.5 | | | | | |
| B-3 | May 30, 73 | 926-952 | 24 | 57 | 7.0 | | | | | |

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Design C (Continued)

| | Campbell County | | | | | Pittsylvania County | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Course | Dates | Stations | Def'l. (1) (1/1000) | (2) B. F. | (3) T. I. | Dates | Stations | (1/1000) | B. F. | T. I. |
| S-5 | Jul. 11, 73 | 946-1050 | 27 | 63 | 8.5 | Nov. 8, 73 | 1059-1173 | 16 | 66 | 11 |
| S-5 | Aug. 28, 73 | 939-950 | 15 | 65 | 11 | | | | | |

Design D

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Subgrade | | | | | — | Jun. 13, 73 | 1174-1185 | 49 | 47 | — |
| Subgrade | | | | | — | Jun. 15, 73 | 1226-1270 | 55 | 41 | — |
| Subgrade | | | | | — | Jun. 20, 73 | 1186-1204 | 30 | 56 | — |
| C. S. Subg. | Aug. 8, 72 | 858-881 | 28 | 46 | 4.5 | Nov. 13, 72 | 1264-1291 | 30 | 56 | 6.2 |
| C. S. Subg. | Aug. 9, 72 | 887-910 | 34 | 47 | 4.5 | Jun. 28, 73 | 1232-1284 | 37 | 49 | 4.7 |
| C. S. Subg. | Aug. 10, 72 | 911-926 | 30 | 47 | 4.5 | Jul. 3, 73 | 1174-1251 | 39 | 53 | 5.3 |
| C. T. Ag. B | | | | | — | Aug. 1, 73 | 1227-1232 | 20 | 55 | 7.0 |
| C. T. Ag. B | | | | | — | Aug. 7, 73 | 1199-1227 | 30 | 66 | 8.2 |
| C. T. Ag. B | | | | | — | Aug. 9, 73 | 1180-1199 | 20 | 60 | 8.5 |
| B-3 | Nov. 15, 72 | 842-926 | 10 | 67 | 15 | Nov. 13, 72 | 1264-1291 | 16 | 68 | 12 |
| B-3 | May 30, 73 | 829-925 | 14 | 65 | 12 | Aug. 1, 73 | 1231-1285 | 18 | 60 | 9.0 |
| B-3 | | | | | | Aug. 16, 73 | 1174-1230 | 21 | 60 | 8.2 |
| S-5 | Aug. 30, 73 | 829-925 | 11 | 72 | 16 | Nov. 8, 73 | 1177-1280 | 11 | 72 | 17 |

---

1. Average Benkelman beam deflection (1/1000 in.) Note: 1/1000 in. = 25.4 μm.
2. Average bending factor.
3. Average thickness index.

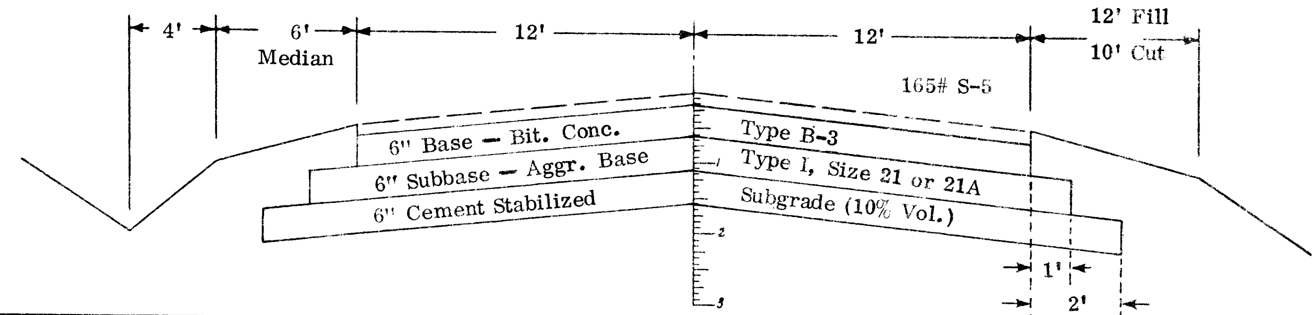
Control Section A

PAVEMENT COST SHEET

(PRIMARY AND SECONDARY PROJECTS)

TYPE OF PAVEMENT Flexible

6029-015-103, C501
6029-071-111, C501




| ELEMENT | THICKNESS | WIDTH | END AREA □' | UNITS/LIN. FT. | COST/UNIT | COST/LIN. FT. |
|---|---|---|---|---|---|---|
| Surface - 165# S-5 | 1½" | 24' | 3.00 | 0.220 Ton | 9.74 Ton | 2.14 |
| Base - 690# B-3 | 6" | 24' | 12.00 | 0.921 Ton | 8.77 Ton | 8.08 |
| Prime - RC-70/MC-70 | 0.4 Gal. | 24' | — | 1.07 Gal. | 0.28 Gal. | 0.30 |
| Subbase - Aggr. Base, I | 6" | 26' | 13.00 | 0.481 C.Y. | 8.25 C.Y. | 3.97 |
| Cover Mat'l. - Fine Aggr. | 15# | 28' | — | 0.024 Ton | 8.25 Ton | 0.20 |
| Cure - RC-250 or AE-2 | 0.2 Gal. | 28' | — | 0.62 Gal. | 0.28 Gal. | 0.17 |
| Cement - 10% Vol. | 6" | 28' | 14.00 | 0.35 Bbl. | 7.35 Bbl. | 2.57 |
| Processing | 6" | 28' | 14.00 | 3.11 S.Y. | 0.43 S.Y. | 1.34 |
| | | | | 24 Foot Lane | Construction Cost | 18.77 |
| | | | | | | |
| | | | | 24 Foot Lane | Cost Per Mile | $99,106 |
| | | | | 7.4 metre lane | Cost Per km | $61,595 |
| | STATIONS | | LENGTH | | | |
| | From | To | (mi.) | (km) | | |
| NBL | 1172+69.42 | 1287+00 | 2.165 | 3.483 | | |
| SBL | 777+55.87 | 926+06.81 | 2.813 | 4.526 | | |
| | | | 4.978 | 8.010 | | |
| | | | | | | |

Figure A-1. Typical Section A.

2605

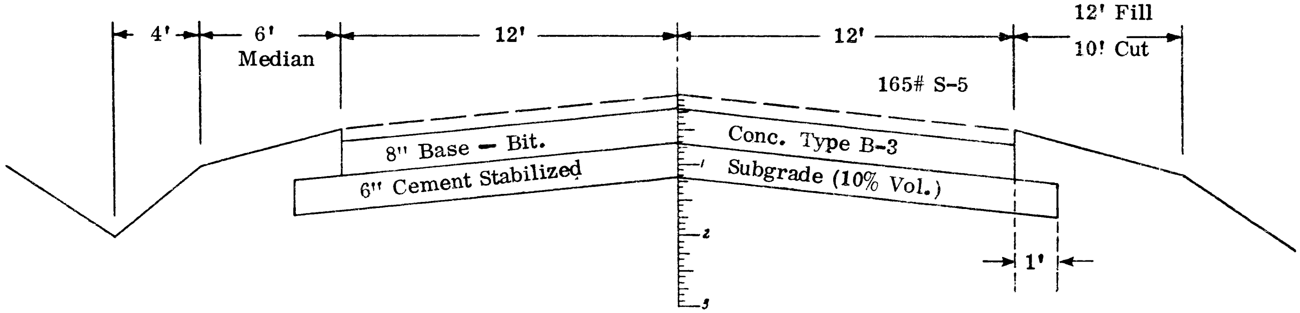
PAVEMENT COST SHEET

Experimental Section B

(PRIMARY AND SECONDARY PROJECTS)

TYPE OF PAVEMENT Flexible

6029-015-103, C501
6029-071-111, C501




| ELEMENT | THICKNESS | WIDTH | END AREA □' | UNITS/LIN. FT. | COST/UNIT | COST/LIN. FT. |
|---|---|---|---|---|---|---|
| Surface - 165# S-5 | $1\frac{1}{2}$" | 24' | 3.00 | 0.220 Ton | 9.74 Ton | 2.14 |
| Base - 920# B-3 | 8" | 24' | 16.00 | 1.228 Ton | 8.77 Ton | 10.77 |
| Cover Mat'l. - Fine Aggr. | 15# | 26' | — | 0.022 Ton | 8.25 Ton | 0.18 |
| Cure - RC-250 or AE-2 | 0.2 Gal. | 26' | — | 0.58 Gal. | 0.28 Gal. | 0.16 |
| Cement - 10% Vol. | 6" | 26' | 13.00 | 0.325 Bbl. | 7.35 Bbl. | 2.39 |
| Processing | 6" | 26' | 13.00 | 2.89 S.Y. | 0.43 S.Y. | 1.24 |
| | | | | 24 Foot Lane | Construction Cost | 16.88 |
| | | | | | | |
| | | | | 24 Foot Lane | Cost Per Mile | $89,126 |
| | | | | 7.4 metre lane | Cost Per km | $55,392 |
| | STATIONS | | LENGTH | | | |
| | From | To | (mi.) | (km) | | |
| NBL | 1058+41 | 1172+69.42 | 2.164 | 3.482 | | |
| SBL | 926+06.81 | 1053+85 | 2.420 | 3.894 | | |
| | | | 4.584 | 7.376 | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Figure A-2. Typical Section B.

Experimental Section C

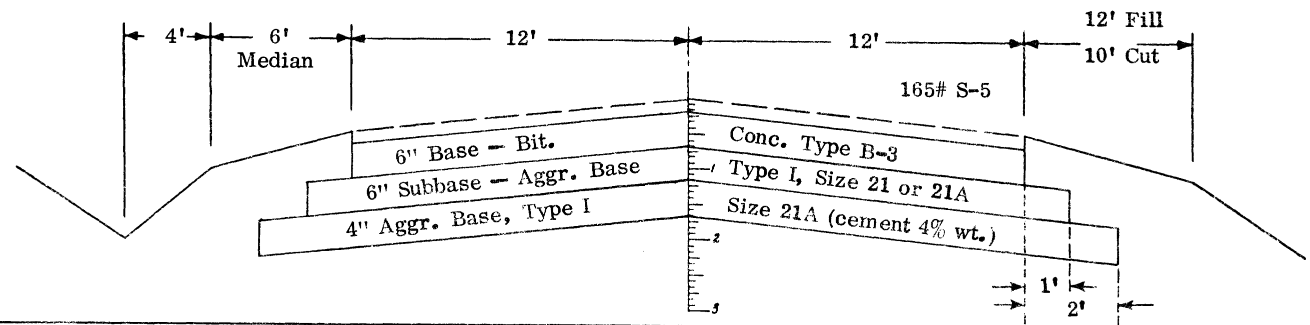
PAVEMENT COST SHEET

(PRIMARY AND SECONDARY PROJECTS)

TYPE OF PAVEMENT Flexible

6029-015-103, C501

6029-071-111, C501




| ELEMENT | THICKNESS | WIDTH | END AREA □' | UNITS/LIN. FT. | COST/UNIT | COST/LIN. FT. |
|---|---|---|---|---|---|---|
| Surface - 165# S-5 | $1\frac{1}{2}$" | 24' | 3.00 | 0.220 Ton | 9.74 Ton | 2.14 |
| Base - 690# B-3 | 6" | 24' | 12.00 | 0.921 Ton | 8.77 Ton | 8.08 |
| Prime RC-70 or MC-70 | 0.4 Gal. | 24' | — | 1.07 Gal. | 0.28 | 0.30 |
| Subbase-Aggr. Base, I | 6" | 26' | 13.00 | 0.481 C.Y. | 8.25 C.Y. | 3.97 |
| Cover Mat'l. - Fine Aggr. | 15# | 28' | — | 0.024 Ton | 8.25 Ton | 0.20 |
| Cure - RC-250 or AE-2 | 0.2 Gal. | 28' | — | 0.62 Gal. | 0.28 Gal. | 0.17 |
| Cement - 4% Wt. | 4" | 28' | 9.33 | 0.144 Bbl. | 7.35 Bbl. | 1.06 |
| Aggr. Base - Type I | 4" | 28' | 9.33 | 0.346 C.Y. | 8.25 C.Y. | 2.85 |
| | | | | 24 Foot Lane | Construction Cost | 18.77 |
| | | | | | | |
| | | | | 24 Foot Lane | Cost Per Mile | $99,106 |
| | | | | 7.4 metre lane | Cost per km | $61,595 |
| | STATIONS | | LENGTH | | | |
| | From | To | (mi.) | (km) | | |
| NBL | 926 + 27.71 | 1052 + 75 | 2.395 | 3.854 | | |
| SBL | 1059 + 53 | 1173 + 02.74 | 2.149 | 3.458 | | |
| | | | 4.544 | 7.311 | | |
| | | | | | | |

Figure A-3. Typical Section C.

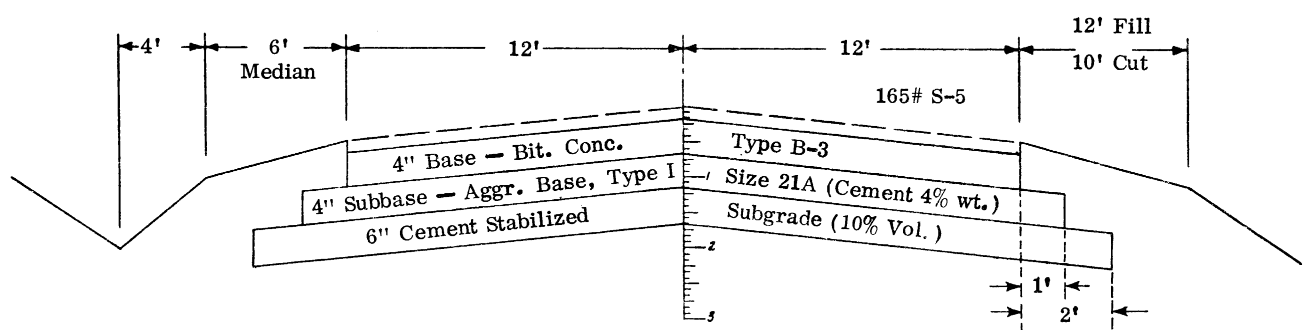
Experimental Section D

PAVEMENT COST SHEET

(PRIMARY AND SECONDARY PROJECTS)

TYPE OF PAVEMENT Flexible

6029-015-103, C501
6029-071-111, C501




| ELEMENT | THICKNESS | WIDTH | END AREA □' | UNITS/LIN. FT. | COST/UNIT | COST/LIN. FT. |
|---|---|---|---|---|---|---|
| Surface — 165# S-5 | 1½" | 24' | 3.00 | 0.220 Ton | 9.74 Ton | 2.14 |
| Base — 460# B-3 | 4" | 24' | 8.00 | 0.614 Ton | 8.77 Ton | 5.38 |
| Cover Mat'l. - Fine Aggr. | 15# | 26' | — | 0.022 Ton | 8.25 Ton | 0.18 |
| Cure - RC-250 or AE-2 | 0.2 Gal. | 26' | — | 0.58 Gal. | 0.28 Gal. | 0.16 |
| Cement - 4% Wt. | 4" | 26' | 8.67 | 0.134 Bbl. | 7.35 Bbl. | 0.98 |
| Subbase - Aggr. Base, I | 4" | 26' | 8.67 | 0.321 C.Y. | 8.25 C.Y. | 2.64 |
| Cover Mat'l. - Fine Aggr. | 15" | 28' | — | 0.024 Ton | 8.25 Ton | 0.20 |
| Cure - RC-250 or AE-2 | 0.2 Gal. | 28' | — | 0.62 Gal. | 0.28 Gal. | 0.17 |
| Cement - 10% Vol. | 6" | 28' | 14.00 | 0.35 Bbl. | 7.35 Bbl. | 2.57 |
| Processing | 6" | 28' | 14.00 | 3.11 S.Y. | 0.43 S.Y. | 1.34 |
| | | | | 24 Foot Lane | Construction Cost | 15.76 |
| | | | | | | |
| | | | | 24 Foot Lane | Cost Per Mile | $83,213 |
| | | | | 7.4 metre lane | Cost Per km | $51,717 |
| | STATIONS | | LENGTH | | | |
| | From | To | (mi.) | (km) | | |
| NBL | 808 + 17 | 926 + 27.71 | 2.237 | 3.599 | | |
| SBL | 1173 + 02.74 | 1287 + 00 | 2.159 | 3.474 | | |
| | | | 4.396 | 7.073 | | |

Figure A-4. Typical Section D.

2607