DESIGN OF SECONDARY AND SUBDIVISION ROADS IN VIRGINIA BASED ON THICKNESS EQUIVALENCY VALUES

by

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and the University of Virginia)

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SUMMARY

The design of secondary and subdivision roads in Virginia is based on the design charts recommended by the Highway Department. In view of recently gained knowledge of materials and design techniques, the Pavement Research Advisory Committee requested that a new design procedure for these roads be developed.

In the proposed design developed, the soil support value of the subgrade has been evaluated in terms of soil resiliency and CBR values. Soil resiliency values for any part of Virginia are given in the report or could be easily determined. The design is based on average daily traffic with 0 to 5 percent trucks. Provision has been made in the design for increased truck traffic.

The proposed design method is based on the AASHO Road Test Results (1962) now being used in many states, including Virginia.

This design was arrived at after personal interviews with the district materials engineers and the evaluation of the designs recommended by them during the last twelve months. In essence, the same pavement designs could be obtained by using the proposed method or the present design charts. However, this method provides the designer more choices in the uses of materials and thus may lead to economies.

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INTRODUCTION

The procedures for designing secondary[1] and subdivision[2] roads were revised in 1967 and 1968 respectively. Both of these procedures are based on a minimum design CBR value of 10 and recommend a number of possible pavement sections based on the total number of vehicles per day.

The AASHO Road test in Ottawa, Illinois, carried out in 1960-62, has considerably modified pavement design concepts. Based on the results of these tests[3] -- at the request of the Virginia Department of Highways (VDH) -- investigations were carried out at the Virginia Highway Research Council and a new design method was recommended for the design of flexible pavements for interstate, arterial and primary roads.[4,5]

This method, after more than two years of evaluation by the VDH, was accepted for use in Virginia. It incorporates the wealth of Virginia design experience and provides flexibility in designs as material and construction economies may dictate.

Impressed by the flexibility of this new design method, the Pavement Research Advisory Committee requested that an investigation be carried out to develop a similar design method for secondary and subdivision roads in Virginia.

TENTATIVE DESIGN METHOD AND MODIFICATION NEEDED

A tentative method for the design of secondary and subdivision roads[6] was recommended in May 1970. This method correlated the thickness index (D)* and the average daily traffic (ADT) based on the design charts recommended by the VDH.[1]

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* Thickness index is defined later under the section entitled Thickness Equivalency.

This method did not fully consider the designs recommended by the individual district offices. It also did not incorporate the soil support value based on soil resiliency and design CBR values as did the new method for primary, interstate and arterial roads.

The Pavement Research Advisory Committee was of the opinion that the new method should include consideration of the soil support value. The subcommittee for the secondary road design also felt the need to account for the increased truck traffic sometimes obtained in some subdivisions.

Another important feature that could not be overlooked in proposing a new design method was the vast experience of the district materials engineers and county engineers in the design of secondary and subdivision roads and the use of local materials. To incorporate their experience it was thought essential to (1) gain knowledge of with their attitudes and thoughts based on their local experiences, and (2) study the designs they have recommended for construction.

The new design method proposed herein includes all the features and considerations mentioned above.

PRESENT DESIGN TECHNIQUES FOR SECONDARY AND SUBDIVISION ROADS

To determine a method and approach to the design of secondary and subdivision roads each district materials engineer and Fairfax county engineers were contacted.

The main conclusions on the design of secondary roads resulting from discussions and the pavement designs recommended by the districts during the last twelve months are as follows:

1. The types and properties of the soils vary from district to district. The general soil type in each district is given in Appendix I. The type of soil in each of the secondary road designs evaluated in this investigation is given in Appendix II.
2. The proximity of local stone quarries enters into the choice between stone base and stabilization.
3. Two district engineers commented that the use of soil-cement or soil-lime is not preferred in residential areas due to the dust nuisance they create.
4. Cement treated aggregate is used by some district engineers to avoid the nuisance caused by soil-cement or soil-lime and also when time is an important factor. In the Culpeper District, local material is sometimes treated to avoid the difficulty of soil disposal in urban areas.

5. The roads with low traffic volumes mostly have either a 6 inch or 8 inch untreated stone base with a prime and double seal.

6. As the traffic increases, the base and subbase thickness increases. For high volumes of traffic, an asphaltic concrete surface is recommended.

7. Some district materials engineers felt that too much importance was being placed on CBR values for the purpose of design and that the other properties of the soils needed to be considered.

8. For subdivision roads an asphaltic concrete surface is recommended even for low traffic zones.

VARIABLES IN THE PROPOSED DESIGN METHOD

As stated previously the design variables are the following:

1) Soil support value in terms of CBR and resiliency,

2) traffic in terms of vehicles per day, and also the truck count, and

3) the thickness equivalency, a, and the thickness, h, of the layers in the flexible pavement system.

CBR Value

The CBR value is obtained by the VDH test method. The test is unable to detect some of the unsuitable soil properties, for example the resiliency of the piedmont soils, soils with high moisture content, or the weak supporting power of unconfined A-3 soils in the Suffolk District. The laboratory test, which is a confined test, has a number of limitations.

In Virginia this is the only test used for pavement design. In some districts no CBR tests are made for low traffic roads. Estimated design CBR values for each county or part thereof are given in Appendix III. These values were obtained from the design CBR values of about 600 road projects over Virginia and also in consideration with most of the district material engineers.

Resiliency Factors

Soil resiliency has been found to be a major cause of pavement deterioration in the Piedmont province of Virginia. The pertinent factors upon which the soil resiliency depends are as follows:

1) AASHO and textural classification of soils -- see Appendix IV.
2) Amount, size, and orientation of the mica content -- the resiliency increases with an increase in the size and quantity of mica.
3) Moisture content -- the resiliency increases with increases in moisture content. Many areas in the Suffolk District show high resiliency where the groundwater table is high.
4) Soil horizon -- soils from the C-horizon are more resilient than soils from the B-horizon. This is because C-horizon soils are silty while B-horizon soils are clayey. This is a consideration in the Lynchburg District, where the primary roads are mostly in the C-horizon while the secondary roads pass through the B-horizon.

For the purpose of design, six soil resiliency classifications have been made as shown in Appendix IV. It is essential that the resiliency factor of the soil should be obtained from this Appendix based on soil classifications. However, based on studies of soil classification reports, typical resiliency factors of the soils to be expected in each county or part thereof are given in Appendix III for general guidance. These values are obtained from the soil classification data reported on about 300 projects in Virginia. It may be noted that the resiliency factor decreases as the soil resiliency increases. Thus, this factor will give lower soil support values with increases in soil resiliency.

In the determination of resiliency factors, the above items, other than the moisture content, were considered. It is, therefore, recommended that these resiliency factors should be considered valid when the moisture content is at or below the plastic limit. For moisture contents above the plastic limit, the resiliency factor should be decreased. Thus, in some areas of the Suffolk District with a high water table and with moisture contents much above the optiumum and near the liquid limit, the resiliency factor could be decreased to as low as 0.5. This is because the CBR of these soils may be very high and pavement damage is caused mostly by the resiliency of the soil alone.

Soil Support Value

The soil support value has been defined as being equal to the design CBR multiplied by the resiliency factor. The design CBR is two-thirds of the average CBR of the project after rejection of the very low and very high CBR values. Based on data given in Appendix III, the soil support values for each county or part thereof have been calculated and are given in Appendix II and Figure 1. These values are subject to modification by the designer, depending on the CBR values determined in the field and also the change in the resiliency factor due to high moisture contents.

Traffic

No load weight studies (18—kip equivalent, etc.) are carried out for secondary and subdivision roads. The only data available for the design of these roads are the vehicles per day (vpd). The design chart recommended herein is therefore based on vpd.

National traffic data show that on the type of roads under discussion the trucks (vehicles other than cars) form about 0 to 5 percent of the total traffic. On some secondary and subdivision roads the truck traffic is greater than 5 percent and may be 25 percent or even higher. To account for these increased heavy loads, an increase in the thickness index is needed. This has been calculated in Appendix V. Based on these calculations it is recommended that for every 50 trucks over the 0 to 5 percent level the thickness index—as obtained from the secondary road design chart—should be increased by 1. Since this recommendation is based mostly on data collected on the national level, it is suggested that it should be treated as a guideline.

Thickness Equivalency

The thickness equivalency, a, is the index of the strength of the material and could be defined as the ratio of the strength of one inch of material in a pavement layer to that of one inch of untreated aggregate base. Thus, if the ratio of the strength of one inch of asphaltic concrete to that of one inch of untreated aggregate base is 1.67, the thickness equivalency, a, of asphaltic concrete is said to be 1.67. Thus, the strength contributed by a 3-inch layer (i.e., h=3) of asphaltic concrete is equivalent to that contributed by $a \times h = 3 \times 1.67 = 5.01$ inches of untreated aggregate base. The sum total of the strength contributed by the different layers of the pavement is termed the thickness index, D, and is equivalent in strength to an untreated aggregate pavement D inches thick.

Based on the above, the thickness equivalency values of the materials used in secondary and subdivision roads have been determined and are given in Table I.

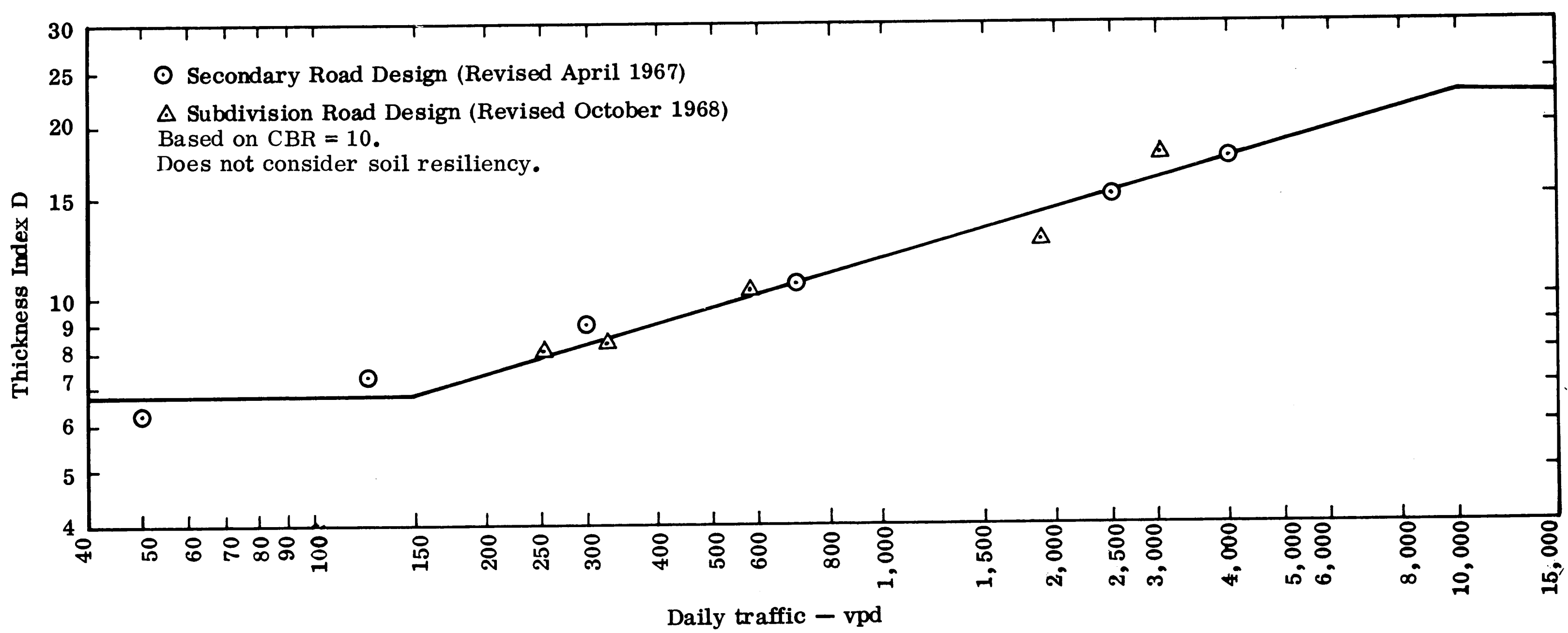

Figure 1. Thickness index evaluation based on traffic only.

TABLE I

THICKNESS EQUIVALENCY VALUES FOR MATERIALS
USED IN SECONDARY AND SUBDIVISION ROADS

Serial No.	Material and Location		Notation	a	Value of a	
					Computed	Recommended
1	Surface —	(a) Asphaltic concrete	A. C.	a_1	1.67	1.67
		(b) Prime and double seal	D. S.	a_D	0.84	0.84
		(c) Prime and single seal	S. S.	a_{ε}	—	0.40
2	Asphaltic concrete — full depth		A. C.	a_1	—	1.50
3	Base —	(a) Untreated aggregate (VDH Specifications)	Agg.	a_2	1.00	1.00
		(b) Cement treated aggregate	CTA	a_{21}	1.33	1.33
		(c) Select material (VDH Specifications)	Sel. mat.	a_3	—	
		i) in Piedmont area		a_3	—	0.00
		ii) in Valley and Ridge and Coastal Plain		a_3	0.83	0.83
		(d) Soil cement	S. C.	a_4	1.00	1.00
		(e) Soil lime	S. L.	a_4	0.92	0.92
		(f) Cement treated sel. mat. C.	Sel. mat. C	a_{41}	1.17	1.17
4	Subbase — When the overlying layers are greater than 4 inches thick	(a) Untreated aggregate (VDH Specifications)	Agg.	a_2	—	0.60
		(b) Cement treated agg.	CTA	a_{21}	—	0.80
		(c) Select material	Sel. mat.	a_3		
		i) in Piedmont area		a_3	—	0.00
		ii) in Valley and Ridge and Coastal Plain		a_3	0.23	0.50
		(d) Soil cement	S. C.	a_4	1.00	0.60
		(e) Soil lime	S. L.	a_4	0.92	0.54
		(f) Cement treated sel. mat.	Sel. mat. C	a_{41}	1.17	0.70

Note: The Serial Number signifies the position of the layer within the pavement system, and the thickness equivalency values are based on the positions of the layers.

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It has been found that as the thickness of untreated material increases the thickness equivalency value contributed by the lower portion of the layer decreases. No provision for this finding was made in this investigation. Based on the evaluation it is recommended that the thickness of untreated stone in the base should not exceed 8 inches and the stone thickness in the base and subbase combined, in excess of 12 inches, should not be considered as contributing significantly to the structural strength of the pavement. In such cases an alternate design such as stabilization should be considered. Further, if the untreated material is provided over a treated material the thickness of the untreated material greater than 6 inches — because of its valiency property — may reduce the structural strength of the pavement.

Values of the thickness index, D, were calculated for flexible pavement designs for secondary and subdivision roads as revised by the VDH in 1967 and 1968 respectively. Appendix VI gives the traffic classification, the design equation, and the value of the thickness index and the average value of the thickness index for each traffic classification of secondary and subdivision roads. Figure 2 shows the correlation of the thickness index with vpd.

PROPOSED DESIGN METHOD

The proposed design method, as stated previously, is based on the soil support value, traffic, and the thickness index.

A nomogram has been developed based on the correlationship obtained between these three variables. This nomogram is shown in Figure 3.

To determine the validity of this nomogram the thickness index values for a number of projects were calculated and correlated with the thickness index values obtained from the nomogram for the same designs. These projects have been divided into four groups as follows:

1) Group 1. The VDH present design charts for secondary and subdivision roads.

2) Group 2. Ninety-five designs of secondary roads as recommended by all the districts in Virginia during the last 12 months.

3) Group 3. Evaluation and correlation of the design as recommended by each district separately, based on the experience of the engineers in each district.

4) Group 4. Design sections recommended by Fairfax County, based on the VDH present design charts.

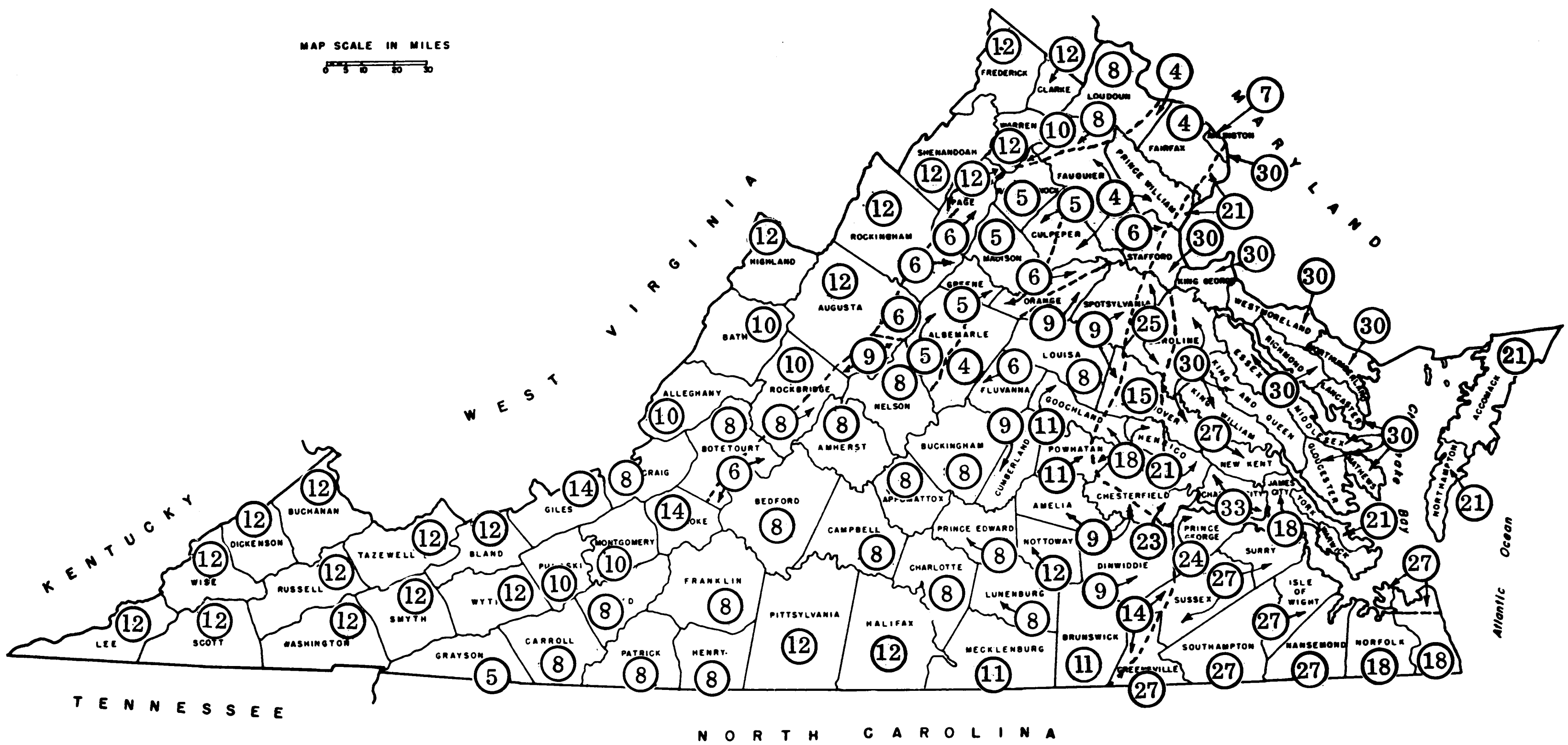

Figure 2. Soil support values for secondary and subdivision roads.

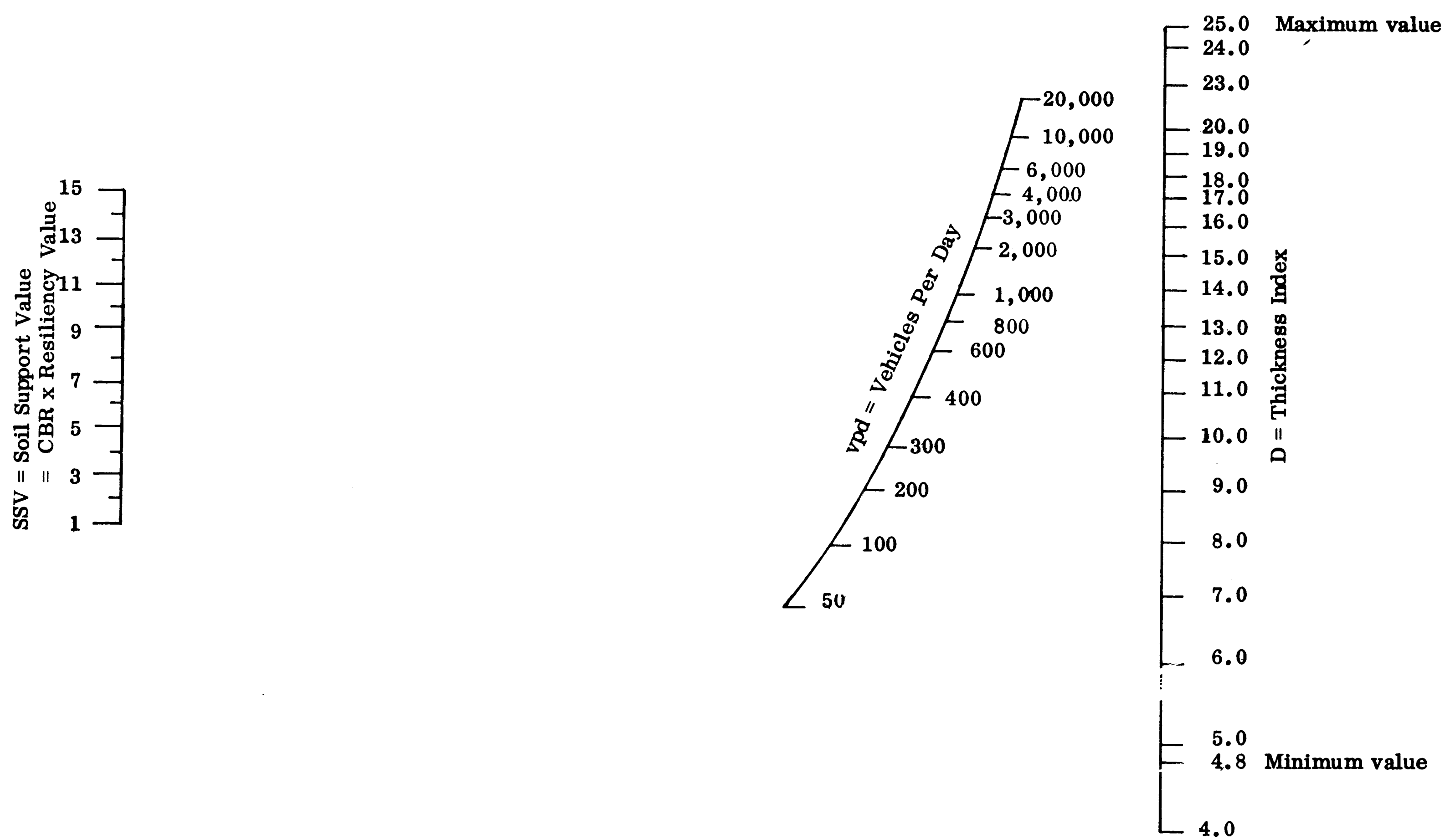

Figure 3. Nomograph correlating the soil support value, and the thickness index (based on AASHO Equation) for secondary and subdivision roads.

The correlation of designs in each group are discussed below:

Correlation in Group 1: The thickness index, D, of each design recommended by the VDH for secondary and subdivision roads was calculated, assuming a CBR value of 10. The calculations and the values for each design are given in Appendix VI. The average D value calculated for each traffic category -- as shown in Appendix VI -- was correlated with the D value obtained from the nomogram, assuming a soil support value of 5.

In this group two linear regression analyses--each with eleven data points--were tried. The first gave a relation of $y = 0.87\ x = 0.4$ with a correlation coefficient, R, of 0.96 and a standard error of estimate, E_S of 1.3. The second made to go through the origin, gave a relation of $y = 0.9\ x$, with $R=0.96$ and $E_S = 1.2$. The graph of the second relationship is shown in Figure 4.

The R value of 0.96 in both cases shows an excellent correlation and hence shows that the nomogram does represent the recommended design. Figure 4 clearly shows that the D values calculated for the designs recommended by the VDH are almost the same as obtained from the nomogram.

Correlation in Group 2: The details of the 95 designs recommended by the districts are given in Appendix II. This appendix gives (1) the calculated thickness index, D, for each design; (2) the CBR value as determined in the field or the estimated CBR value; (3) the resiliency factor; (4) the soil support value, SSV, calculated on the basis of the data supplied or on the basis of the estimated value; (5) the traffic data in vpd supplied for each project, and (6) the value obtained from the nomogram based on the SSV and vpd.

In this group two linear regression analyses -- each with 95 data points -- were tried. The first gave a relationship of $y = 0.82x=1.83$, with $R = 0.9$ and $E_S = 1.8$. The second, passing through the origin, gave a relationship of $y = 0.92x$, with $R = 0.88$ and $E_S = 1.9$. The graph of the second relationship is shown in Figure 5.

The slope of 0.97 in the second relationship is approximately equal to 1.0, which indicates that the D value calculated from the design would be almost the same as that obtained from the nomogram. The R value of 0.88 shows an excellent correlation. Thus, it appears that the nomogram could closely predict the designs. recommended by the various districts in Virginia.

Correlation in Group 3: To verify the extent to which the nomogram could predict the designs recommended by each district materials engineer, or the district engineer, the D values of the recommended designs of each district were correlated with the D values obtained from the nomogram. The correlations and the correlation values obtained for each district are shown in Figures 6 through 13.

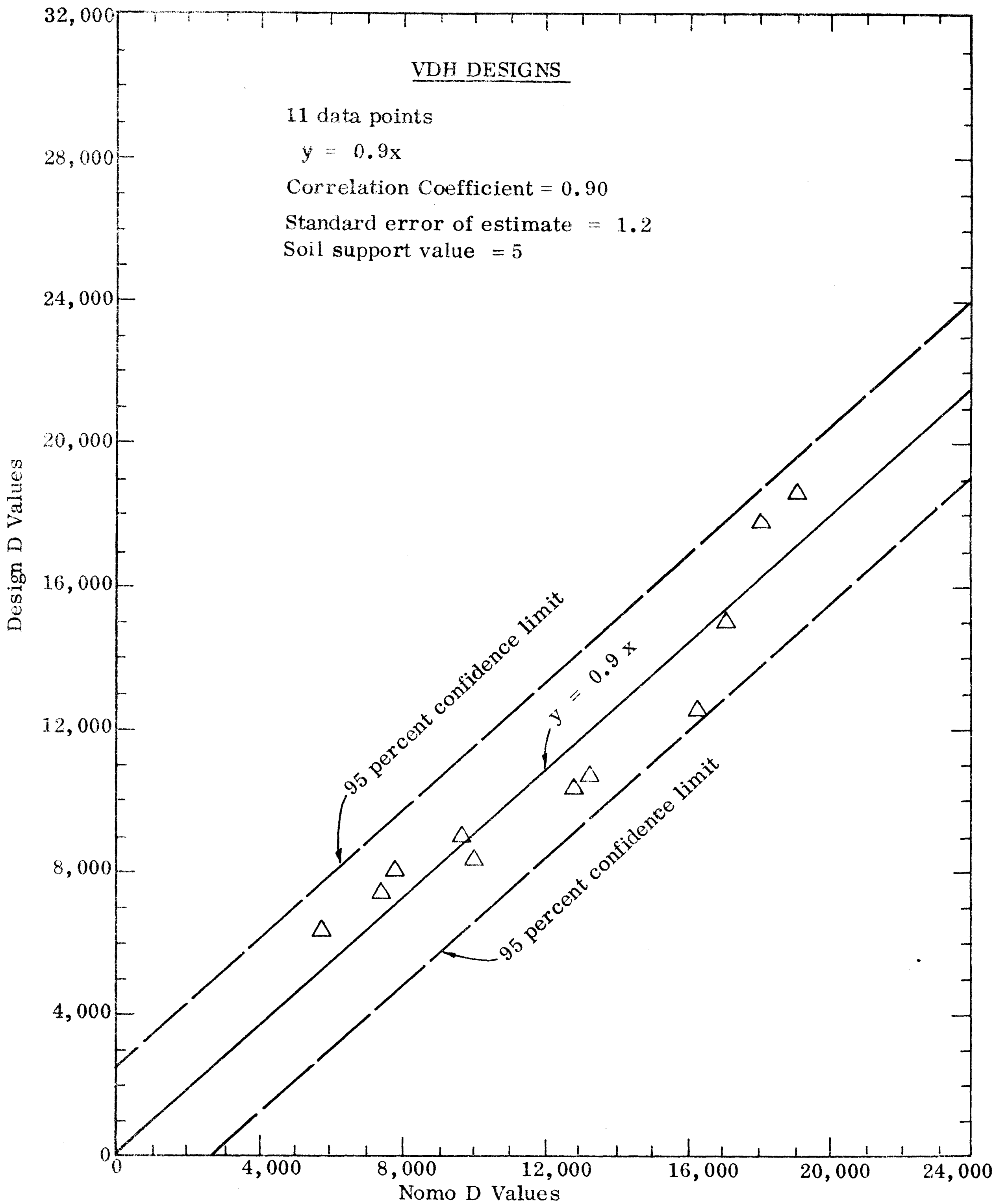

Figure 4. Correlation of the design D values and the nomogram D values for secondary and subdivision roads.

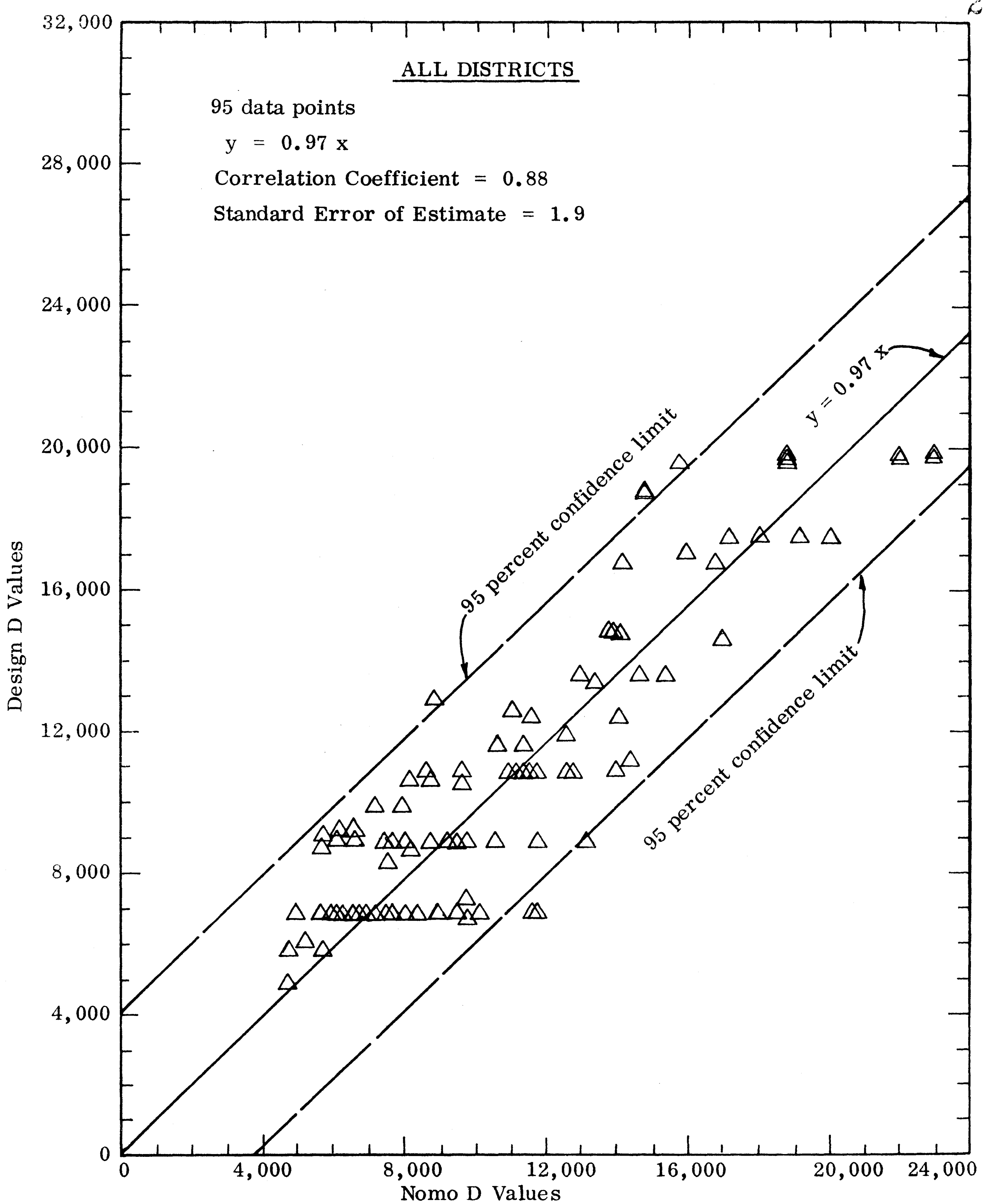

Figure 5. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the districts.

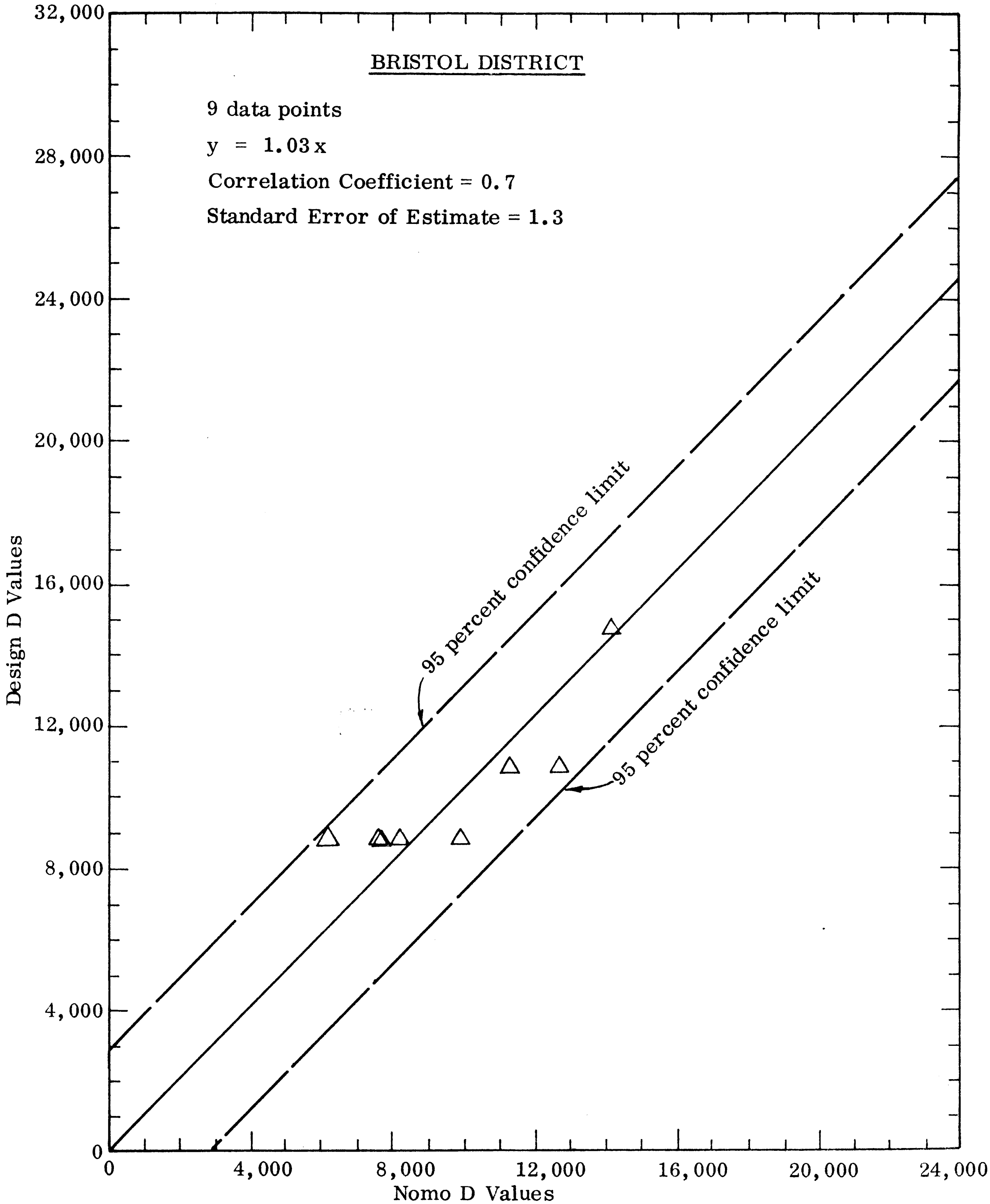

Figure 6. Correlation of the design D values and the nomogram D values for the secondary road design recommended by the Bristol District.

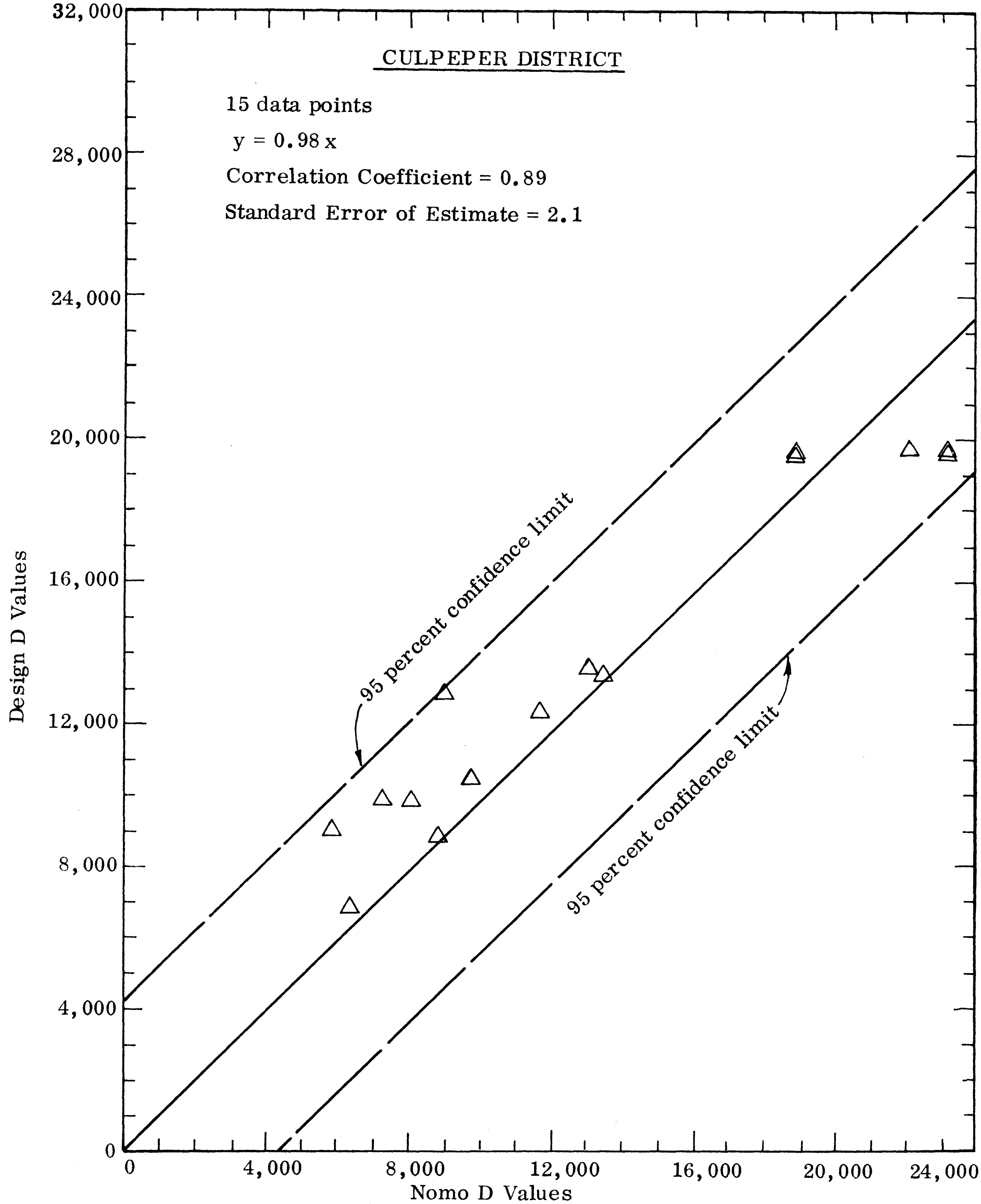

Figure 7. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Culpeper District.

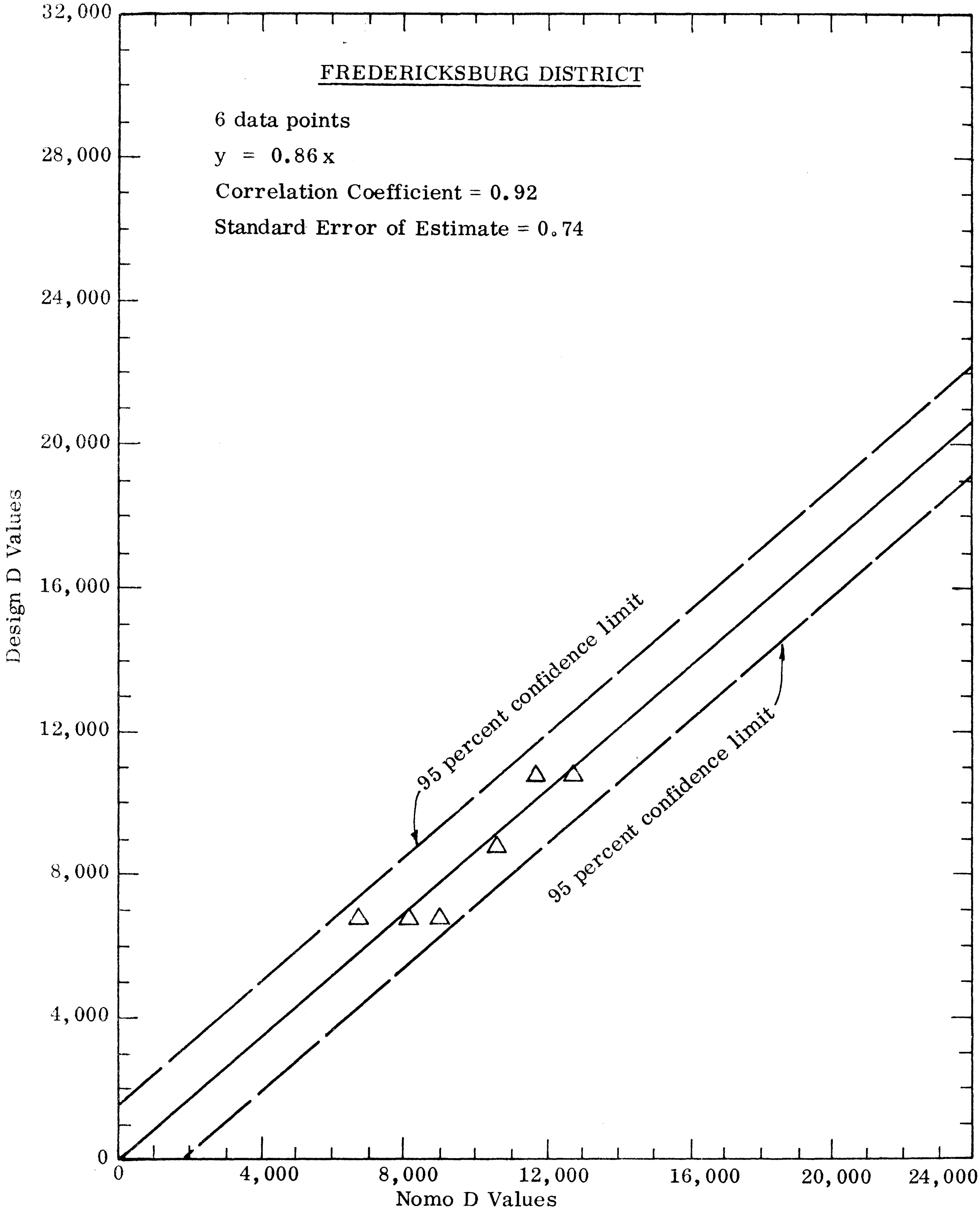

Figure 8. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Fredericksburg district.

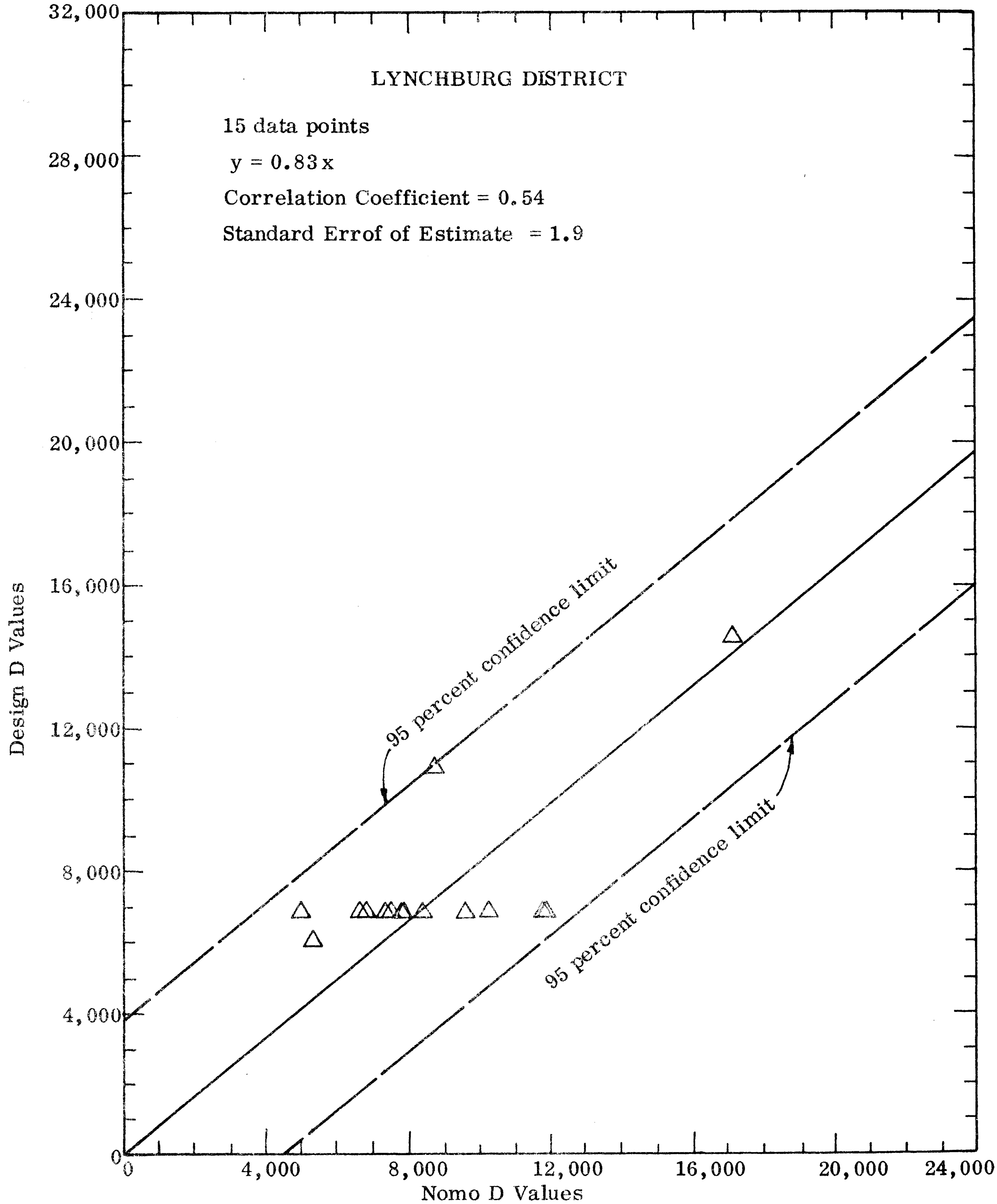

Figure 9. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Lynchburg district.

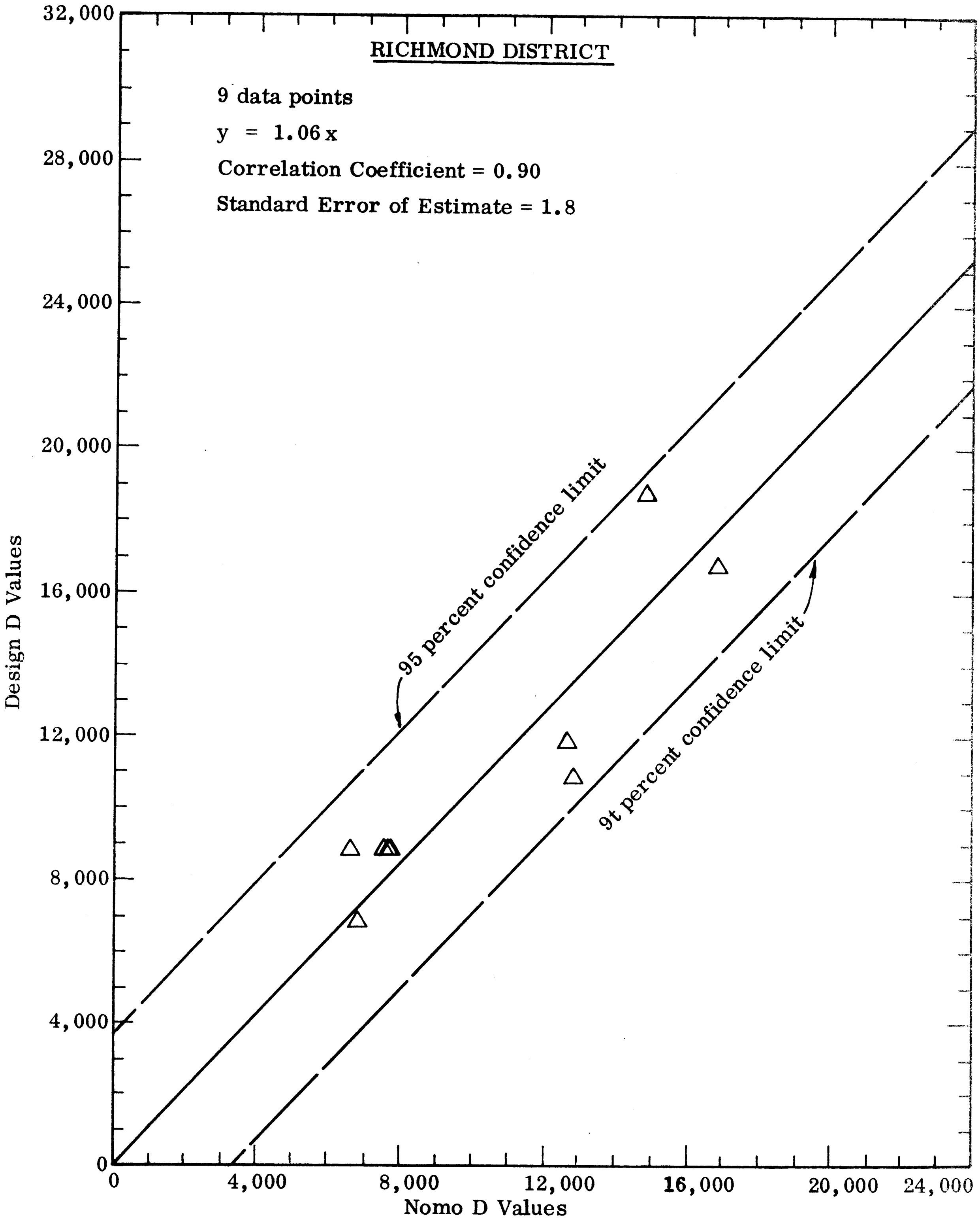

Figure 10. Correlation of the design D values and the nomogram D values for secondary road designs recommended by the Richmond district.

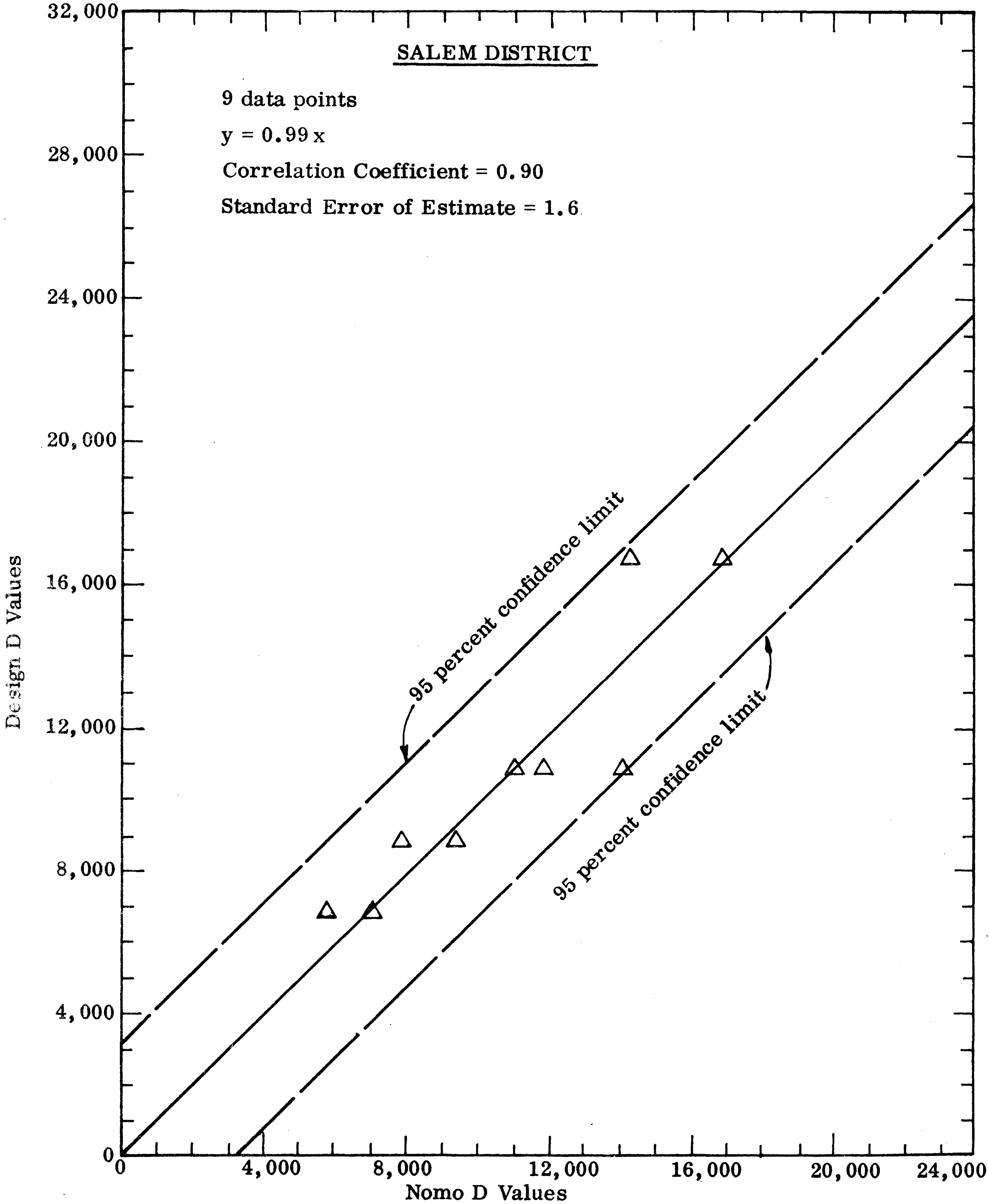

Figure 11. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Salem district.

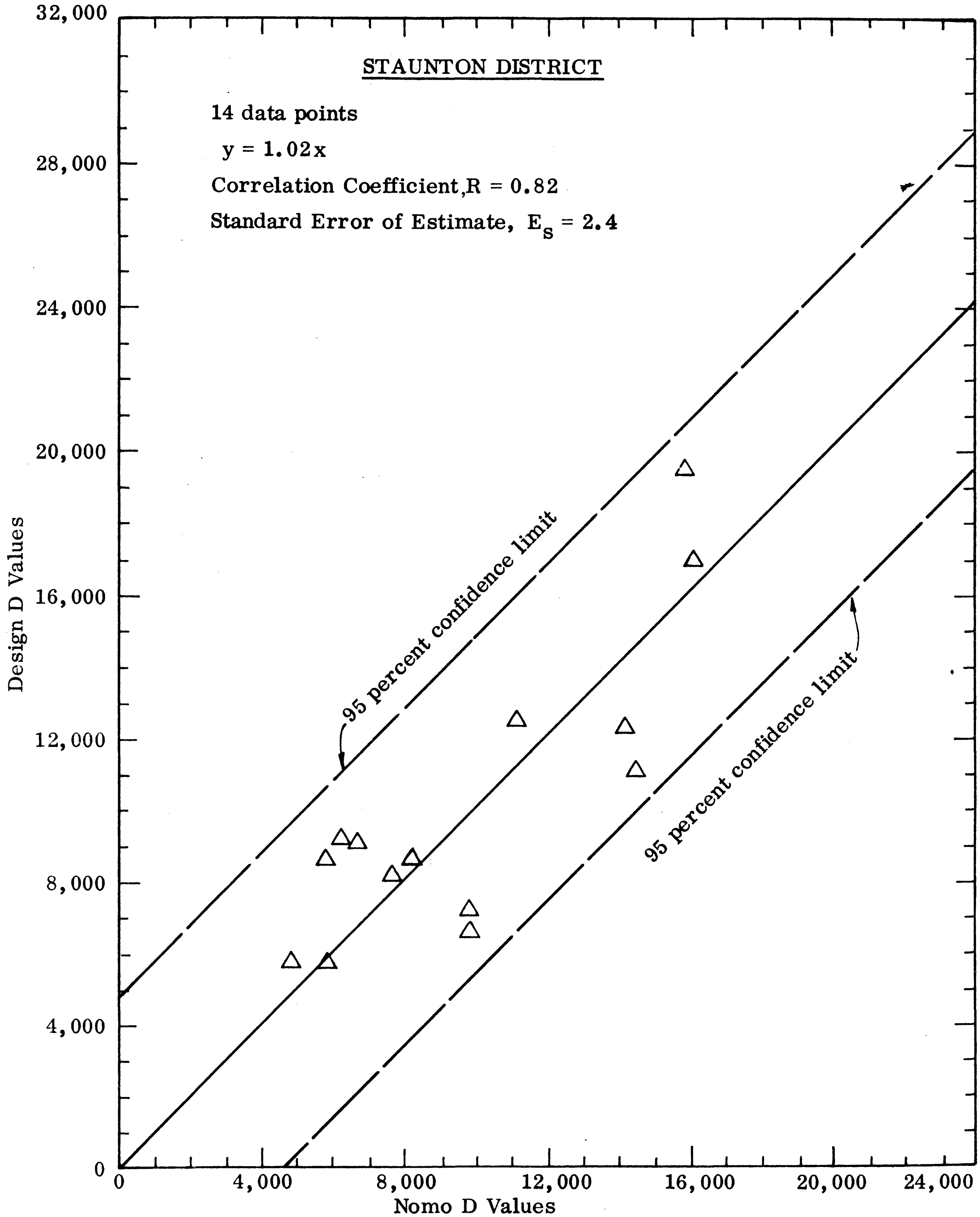

Figure 12. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Staunton district.

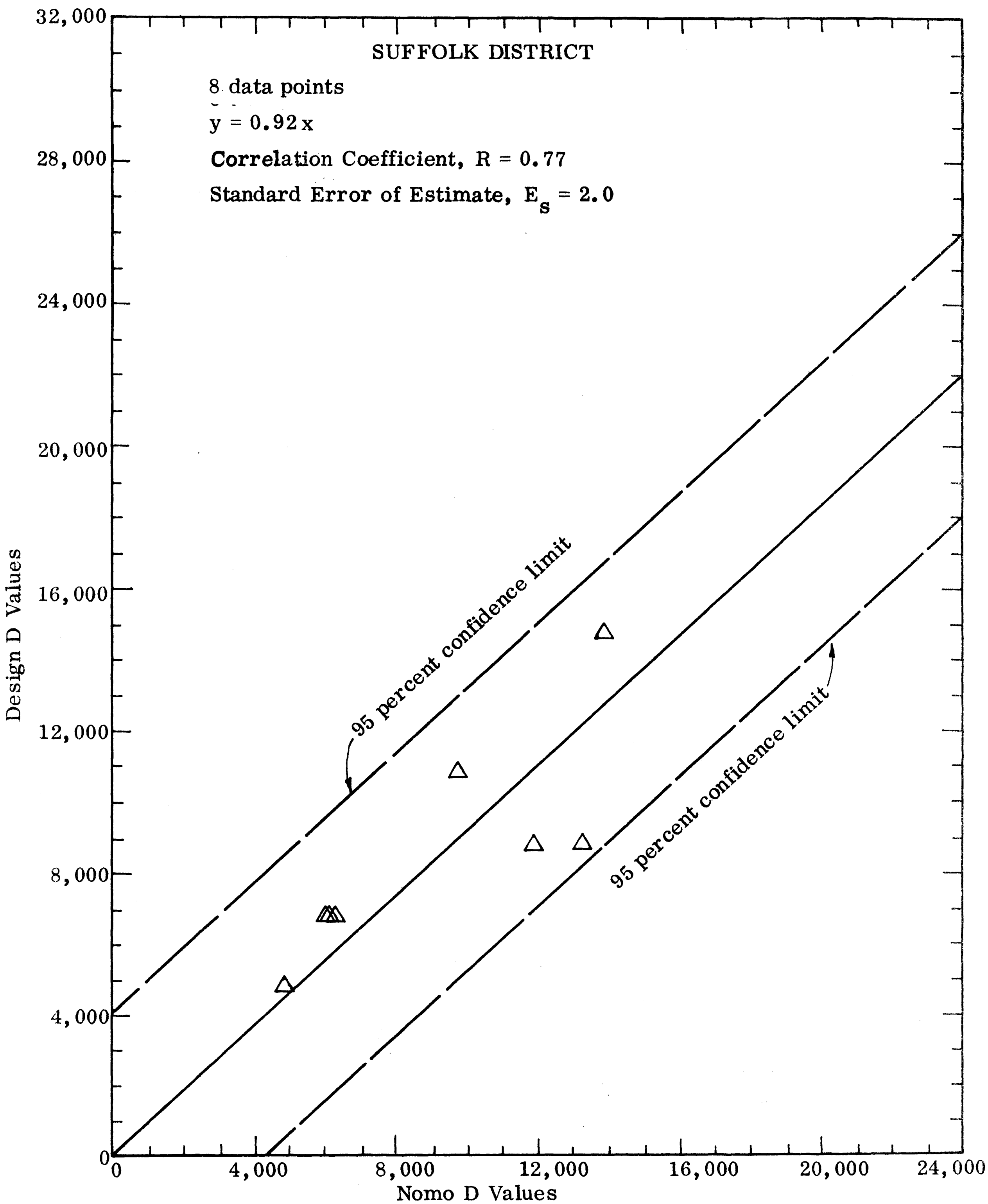

Figure 13. Correlation of the design D values and the nomogram D values for the secondary road designs recommended by the Suffolk district.

In all these figures equation y =Ax has been used to determine the variation between the actual and the predicted values. All the graphs show that the slope of the curve is almost 1.0, which means that the predicted value are almost the same as the design values. The correlation coefficient, R, varies from a minimum of 0.7 for the Bristol District to a maximum of 0.95 for the Fredericksburg District, except for the Lynchburg District, which is discussed below. The values of the standard error of estimate are also acceptable.

In the case of the Lynchburg District, out of 15 designs 13 have a design value of 6.8. The range of D values for the correlation in this district was therefore almost nonexistent except for two points among the 15. It is therefore very difficult, based on the present data, to judge whether the nomogram could predict the design technique used in the Lynchburg District.

In the case of the Suffolk District, the correlation could be improved if the soil resiliency value is further corrected for the increase in the subgrade moisture due to the high water table. The resiliency factors adopted in this investigation are based on soil classification only. The need for reducing these values for moisture content above the plastic limit has been specified in the discussion. Since no Atteburg limits and subsoil moisture date were available, the resiliency factor could not be modified. Figure 13 shows that the design values are generally higher than the nomogram values.

<u>Correlation in Group 4</u>: Fairfax County has recommended standard typical street sections--designated as Rev. 7-10-70--based on traffic categories. These typical sections are based on the VDH present design charts for subdivision roads. The thickness index of each section--assuming a CBR equal to 10--was calculated for each traffic category. The nomogram value for each traffic category was determined for SSV's values of 30 and 10. These SSV values were taken because the resiliency factors for the soil were a minimum of 1 and a maximum of 3, which give SSV = CBR x Resi. factor = 10 x 3 = 30 or 10 x 1 = 10.

The linear correlation of y = Ax for the eight data points so calculated is shown in Figure 14. The slope of 0.99 obtained by regression analysis and as shown in this figure indicates that the nomogram will closely predict the design required based on the soil support value for the subdivision roads. The value of R = 0.86 is also very good. The value of $E_s = 1.4$ for D values ranging from 8.2 to 18.1 are highly acceptable. The nomogram could therefore be adopted for the design of subdivision roads in Fairfax County.

Local governments adopting the VDH design standards as revised in 1968 could also adopt this nomogram for the design of their subdivision roads. It is however, recommended that for subdivision roads the D value obtained from the nomogram after being corrected for the increased number of trucks, may be increased by 1.0 if a thin asphaltic concrete treatment is proposed.

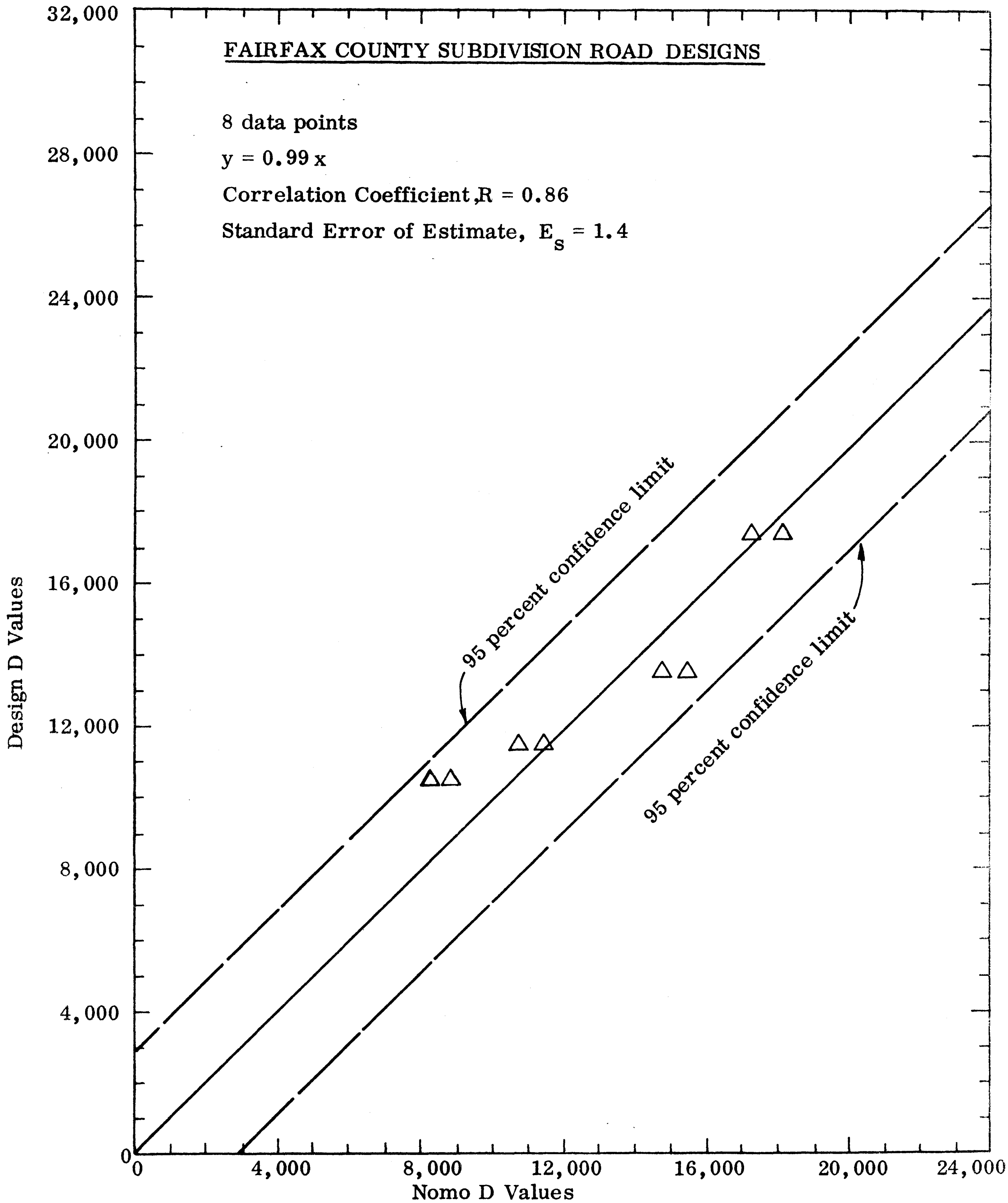

Figure 14. Correlation of the design D values and the nomogram D values for the subdivision road designs for Fairfax County.

From the above discussions it is evident that the nomogram in Figure 3, recommended for predicting the thickness index of the pavements, could be used for the design of secondary and subdivision roads.

ADVANTAGES OF THE PROPOSED METHOD OVER THE PRESENT DESIGN CHARTS

The proposed method has the following advantages over the design charts.

Flexibility in Choice of Design

The proposed method based on thickness equivalency values provides more flexibility in the choice of materials and the thickness of the materials in each layer. The present design charts of the VDH recommend a few designs under each traffic category. The proposed method not only satisfies and covers all these designs--as shown above-- but gives additional choices in the selection of new ideas, use of new or local materials, or improvement of the local materials.

The two best examples of new ideas or improved local materials are; (1) the full depth asphaltic concrete course, and (2) the use of cement treated aggregate in the base course. A few additional designs covering these two aspects--but not given in the present design charts--are shown in Appendix VII. All these designs have thickness indices equivalent to those obtained in the present design charts.

This type of flexibility in the choice of designs will provide economic and material usage advantages.

Better Understanding of the Materials

With the thickness equivalency values as given in Table 1, a designer would have a better concept of the relative strength of materials.

Simplicity

The proposed method is simple and easy to apply by field personnel not involved in design technicalities.

Progressiveness

As the knowledge of the materials grows and different types of materials are used in pavement design, this method could encompass those materials.

Accepted by Other States and Virginia

There is nothing new about this method. It was a result of the AASHO Road Test Results (1962). It has been accepted in a number of other states and is used in Virginia for the design of primary, arterial, and interstate roads.

CONCLUSIONS

1. A method of design based on the soil support values and average daily traffic for secondary and subdivision roads has been proposed.

2. In essence, the same pavement design can be obtained by using both the proposed method and the present design charts.

3. The proposed method provides additional flexibility in the choice of designs with accompanying, economic and materials usage advantages.

4. The proposed method could be easily improved as new materials and new ideas are obtained.

ACKNOWLEDGEMENTS

This is to gratefully acknowledge the time and help given by all District Materials Engineers in discussing their experiences in pavement design and also in supplying some of the pertinent data. J. P. Bassett and K. H. McGhee, who were the members, of the subcommittee contributed in continually imparting the information needed and joining in the frequent discussion of the development of this method. Thanks are also extended for the encouragement of Jack H. Dillard and others at the Research Council.

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APPENDICES

APPENDIX I

Comments on the Soils Used in the Construction of Secondary Roads

Bristol District — All counties except Grayson have heavy clay or shaley and sandstone clays. In some places coal is mixed with the soil. Grayson has more resilient soils (silt and mica content) than other counties in the district.

Culpeper District — In the coastal plains one encounters granular sandy soils; in the central portion, micaceous silts; in the narrow neck from the north, there is a triassic shaley clay; and on the northwestern border, heavy clay.

Fredericksburg District — The soils east of Rte. 1 are sandy, while on the west they are silty and hence more resilient.

Lynchburg District — Secondary road subgrades many times include the B-horizon in addition to the C-horizon. The B-horizon soil is clayey or clays and silts mixed. In the C-horizon the subgrade is silty, decomposed stone, sandy silt, and soils mixed with stone and sometimes micaceous silt too.

The primary and interstate roads in the Lynchburg District pass through the C-horizon, which is more micaceous and resilient than in the case of secondary roads. The soil resilience values for secondary roads are therefore higher than for interstate and primary roads.

Richmond District — The soils on the eastern side are sands, the central belt soil consists of mixtures of sand, silt and clay, and the soils become more silty in the southern and western parts.

Staunton District — The soil is clay except for the silts on the southeastern border of the district. The silt sometimes contain mica.

Suffolk District — The soils in this coastal plain are mostly sand but in many places they are clayey and include organic material. The sandy soils have high soil support values, except for the A-3 soil (i.e., one graded soil, dead sand), which unless confined or stabilized has a very poor supporting strength. The laboratory CBR values for A-3 soils are very high.

The groundwater level in this region is high and the soils are more resilient due to their moisture content rather than to their textural classification.

APPENDIX II

SOIL TYPE, CBR, RESILIENCY FACTOR, SSV, TRAFFIC, DESIGN SECTION AND THICKNESS INDEX OF SECONDARY ROADS PROJECTS IN 1970-71

S No	Project	Soil Type	Design CBR Eval.	Design CBR Est.	R. F.*	S S V	Traffic vpd	Design	Thickness Index Design	Thickness Index Nomo.
Bristol District								**		
1	0613-010-[illegible]-C501	Sand or shaley clay	--	6	2.0	12	108	D. S. +8"Agg.	8.8	6.1
2	0650-036-[illegible]-C501	Plastic clay A-5(2)	--	6	2.0	12	216	D. S. +8"Agg	8.8	7.5
3	0731-095-[illegible]-C501	Clay shales or shaley clays	--	6	2.0	12	225	D. S. +8"Agg.	8.8	7.6
4	0609-092-[illegible]-C501	Shales and shaley or sandy shaley clay	8	--	2.0	16	255	D. S. +8"Agg.	8.8	7.6
5	0615-095-[illegible]-C501	Clay	--	6	2.0	12	268	D. S. +8"Agg.	8.8	8.1
6	0692-095-[illegible]-C501	Sandy shaley clay	8	--	2.0	16	450	D. S. +8"Agg.	8.8	9.8
7	0700-095-[illegible]-C501	Soft shale with some rock & hard shale	7-40	9	2.0	18	610	D. S. +10"Agg.	10.8	11.2
8	0613-095-159-C501	Sandy or shaley clay	7	--	2.0	14	830	D. S. +10"Agg.	10.8	12.6
9	0624-013-117-C501	Sandy and/or shaley clay	9-25	10	2.0	20	1665	4"A. C. +8"Agg.	14.7	14.1
Culpeper District										
1	0630-056-135-C501	Micaceous silt and silty clays	--	5	1.0	5	55	3"Agg. +6"S. C.	9.0	5.8
2	0635-054-125-C501	Micaceous sandy silts with clays	--	5	1.5	7.5	85	D. S +6"Agg.	6.8	6.3
3	0802-023-133-C501	Micaceous silt with some clay	--	4.0	1.0	4.0	105	D. S. +3"Agg. + 6"S. C.	9.8	7.2
4	0616-030-153-C501	Shaley silts, blackjack clay and silty clay	3-25	4	1.0	4.0	210	D. S. +6"Agg. + 6"S. C.	12.8	8.9
5	0615-032-122-C501	Silty clays	6	--	1.5	9	210	D. S. +3"Agg. + 6"S. C.	9.8	8.0
6	0640-002-134-C501	Micaceous silt and silty clay	--	5	1.0	5.0	201-400	D. S. +4"Agg. + 6"S. L.	10.4	9.7
7	0621-053-161-C502	Sandy silts with clays and weathered shale	10	--	2.0	20	344	D. S. +8"Agg.	8.8	8.8
8	0692-023-131-C501	Micaceous silts with some clay	--	4	1.0	4.0	425	D. S. +6"Agg. + 6"S. L.	12.3	11.6
9	0643-076-176-C501	Micaceous silt	--	6	1.0	6.0	610	1.5"A. C. +5" Agg. +6"S. C.	13.5	13.0
10	0659-054-142-C501	Silty clays	5.0	--	1.0	5.0	720	2"A. C. +4"Agg. + 6"S. C.	13.3	13.4
11	0674-076-155-C501	Shale, silt and blackjack clay	8.2	--	1.0	8.2	+4000	4.5"A. C. +6"Agg. +6"S. C.	19.5	18.8
12	0633-029-155-C501	Silt and clay and sand and gravel	17-62	--	2.5	30	7220	7"A. C. +6"CTA	19.7	18.8
13	0716-029-175-C501	Micaceous silty clay and silt	6 & 38	4	1.0	4.0	10500	7.5"A. C. +6" Sel. Mat. C.	19.8	23.0
14	0693-029-174	Micaceous silts and silts	3-5	7	1.0	7	10540	7"A. C. +6"CTA	19.7	22.0
15	0644-029-197-C501-C502 0789-029-198	Sand and gravel	21-78	7	3.0	21	17190-35850	7"A. C. +6"CTA	19.7	23.0

APPENDIX II (contd.)

S No.	Project	Soil Type	Design CBR Eval.	Design CBR Est.	R.F.*	SSV	Traffic vpd	Design	Thickness Index Design	Thickness Index Nomo.
Fredericksburg District										
1	0601-088-135-C501	A-4(7) to A-7-5(15)	14	--	1.5	21	180	D.S. +6"Agg.	6.8	6.7
2	0642-066-123-C501	A-2-4 (0)	35	--	3.0	105	310	D.S. +6"S.C.	6.8	8.1
3	628-089-129-C501	A-4 (1) to A-4 (4)	23	--	3.0	69	372	D.S. +6"Agg.	6.8	9.0
4	0609-066-120-C502	A-2-4(0) to A-4 (8)	31	--	3.0	33	540	D.S. +6"Sel. Mat C+4" Sel. Mat.	8.8	10.6
5	0606-088-137-C501	A-4 (1) to A-7-6 (9)	12	--	3.0	36	660	D.S. +6"Sel. Mat. C+4"Sel. Mat. or D.S. +10"Agg.	10.5 or 10.8	11.6
6	0614-086-111-C501	A-4 (1) to A-6 (3)	36	--	3.0	108	920	D.S. +10" Agg.	10.8	12.7
Lynchburg District										
1	0680-062-147-C501	Silt and gravel (C-horizon)	--	5	1.5	7.5	39	D.S. +6"Agg.	6.8	5.0
2	0655-062-139-C501	Clayey silt (B-horizon) or silt and decomposed stone (C-horizon)	--	5	1.5	7.5	57	6" agg.	6.0	5.3
3	0675-019-128-C501	Clay (B-horizon) or silt (C-horizon)	--	5	1.5	7.5	104	D.S. +6"Agg.	6.8	6.6
4	0649-014-130-C501	Silty clay (B-horizon) or sandy silt (C-horizon)	--	5	1.5	7.5	107	D.S. +6"Agg.	6.8	6.6
5	0617-062-125-C501	Silty disintegrated stone or sandy silt or clayey silt	--	5	1.5	7.5	118	D.S. +6"Agg.	6.8	6.8
6	0634-062-142-C501	Silty clay (B-horizon) or disintegrated granite(C-horizon)	--	5	1.5	7.5	149	D.S. +6"Agg.	6.8	7.4
7	0602-014-120-C501 0602-062-149-C501	Silt	--	5	1.5	7.5	160	D.S. +6"Agg.	6.8	7.3
8	0666-005-137-C501 0666-062-146-C501	Sandy soil and river jack and their mixture	--	5	1.5	7.5	179	D.S. +6"Agg.	6.8	7.5
9	0600-024-111-C501	Clay (B-horizon) or silt (C-horizon)	--	6	1.5	9	206	D.S. +6"Agg.	6.8	7.7
10	0635-062-122-C501	Sandy silt or silt and decomposed stone (all C-horizon)	--	5	1.5	7.5	231	D.S. +6"Agg.	6.8	8.4
11	0675-015-145-C501	Clay and clayey silt (B-horizon) or micaceous silt (C-horizon)	--	5	1.5	7.5	325	D.S. +6"Agg.	6.8	9.5
12	0869-071-173-C501	Clay (B-horizon) or sandy silt (C-horizon)	--	8	1.5	12.0	328	D.S. +4"Agg. + 6"S.C.	10.8	8.7
13	0664-062-155-C501	Silt and cobbles (B-horizon) or sand silt and cobbles (C-horizon)	--	5	1.5	7.5	376	D.S. +6"Agg.	6.8	10.2
14	0640-071-174-C501	Clay (B-horizon) or silty schist (C-horizon)	--	8	1.5	12.0	613	D.S. +6"Agg.	6.8	11.8
15	0640-071-174-C502	Clay (B-horizon) or silty schist (C-horizon)	--	8	1.5	12.0	613	D.S. +6"Agg.	6.8	11.7
16	0622-005-130-C501	Clay (B-horizon) or decomposed schists and micaceous silt (C-horizon)	--	5	1.5	7.5	2716	1.5"A.C.+6" Agg. +6"S.C.	14.5	17.0

APPENDIX II (contd.)

S No.	Project	Soil Type	Design CBR Eval.	Design CBR Est.	R. F.*	SSV	Traffic vpd	Design	Thickness Index Design	Thickness Index Nomo.
Richmond District										
1	0603-020-155-C501	Sandy micaceous clays (A-5 and A-6)	4.1	--	1.5	6.2	89	D. S. +8"Agg.	8.8	6.6
2	0627-055-117-C501 0627-067-116-C501	Micaceous silts and silty sandy clays and disintegrated granite (A-2 to A-7)	5	--	1.0	5.0	95	D. S +6"Agg.	6.8	6.8
3	0662-055-136-C501	Silty micaceous clays (A-4 to A-7)	5	--	1.0	5.0	150	D. S. +8"Agg.	8.8	7.7
4	0628-072-116-C501	Silty sandy clays (A-4 to A-6)	8	--	2.5	20	250	D. S. +8"Agg.	8.8	7.5
5	0627-026-148-C502	Micaceous, silty sand clays and gravel (A-4 to A-7)	10	--	1.5	15	260	D. S. +8"Agg.	8.8	7.5
6	0723-067-121-C501-C502	Sandy micaceous clay (A-3 to A-7)	5	--	1.0	5.0	560	D. S. +10"Agg. or D. S. +5" Agg. +6"S. C.	10.8 or 11.8	12.6
7	0712-012-132-C501	Silty micaceous clays (A-4 to A-6)	7	--	1.0	7.0	605	D. S. +10"Agg.	10.8	12.8
8	0616-074-103-C501	Silty sandy clays (A-6)	5	--	3.0	15	2050	4"A. C. +6"Agg. +6"S. C.	18.7	14.8
9	0647-020-105-C501	Silty sandy clays (A-4 to A-6)	10	--	2.5	25	3590	4"A. C. +4"Agg +6"S. C. or 4"A. C +10"Agg.	16.7	16.8
Salem District										
1	0607-011-122-C501	Shaley clay	--	4	1.5	6	69	D. S. +6"Agg.	6.8	5.7
2	0719-031-131-C501	Micaceous silt	--	8	1.0	8	135	D. S. +6"Agg.	6.8	7.0
3	0666-011-135-C501	Clay	--	4	1.5	6	172	D. S. +6"Agg.	8.8	7.8
4	0700-070-143-C501	Micaceous silt	7	--	1.0	7	300	D. S. +8"Agg.	8.8	9.3
5	0969-033-133-C501	Silt	--	8	1.0	8	421	D. S. +10"Agg.	10.8	11.0
6	0631-070-142-C501	Silt	--	8	1.0	8	565	D. S. +10"Agg.	10.8	11.8
7	0619-009-153-C501	Clay over decomposed granite	--	5.0	1.5	7.5	900	D. S. +10"Agg.	10.8	14.0
8	0601-080-146-C501	Clay	--	7	2.0	14.0	1493	4"A. C. +10"Agg.	16.7	14.2
9	0609-044-176-C501	Micaceous silt	--	8	1.0	8	1000-4000	4"A. C. +10"Agg.	16.7	16.8
Staunton District										
1	0710-081-144-C501	Clays with some sandy silts (A-4-5, A-6 and A-7)	4.0	--	2.0	8.0	75	D. S. +6"Agg. + 8"sel. mat.	8.9	5.7
2	0603-081-138-C501	Sandy clays (A-1-a to A-4-2)	12	--	2.5	30	75	D. S. +4"Agg. +4" sel. mat.	5.7	4.8
3	0631-081-133-C501	Sandy and clayey loams (A-2-4 and A-6)	5.0	--	2.0	10.0	80	D. S. +4"Agg. + 4" Sel. Mat.	5.7	5.8
4	0614-008-114-C501	Silty and clay gravels and clays (A-2-4, A-6 and A-7)	5.0	--	2.0	10	100	D. S. +4"Agg. + 8"Sel. Mat.	6.9	6.2
5	0663-081-139-C501	Clay and sandy clay (A-7-5)	--	5	2.0	10.0	120	D. S. +6"Agg. + 10"Sel. Mat.	9.1	6.6
6	0876-007-163-C501	Clay (A-7-6 or A-6)	6.0	--	2.0	12	210	D. S. +6"Agg. + 6" Sel. Mat.	8.2	7.6
7	0716-081-143-C501-C502	Silty or clayey (A-4 (5) or A-7-6 (20)	5.3	--	2.0	10.6	253	D. S. +6"Agg. + 8" Sel. Mat	8.6	8.2

APPENDIX II (contd.)

S No.	Project	Soil Type	Design CBR Eval.	Design CBR Est.	R.F.*	SSV	Traffic vpd	Design	Thickness Index Design	Thickness Index Nomo.
Staunton District (contd.)										
8	0635-007-157-C501	A-7-6 clay with gravely particles (A-7-6)	5.2	--	2.0	10.4	382	D.S. +4"Agg. + 8" Sel. Mat.	6.6	9.8
9	0632-007-164-C501	Sands, sandy clays and gravels (A-2, A-6 and A-7)	11	--	2.5	25	450	D.S. +5"Agg. + 6"Sel. Mat.	7.2	9.8
10.	0677-081-134-C501	Silty and sandy clays (A-4(0) and A-7-5)	7.2	--	2.0	14.0	578	D.S. +8"Agg. + 16"Sel. Mat	12.5	11.1
11	0661-034-140-C501	Clay (A-6 (7) and A-7-5)	2.5	--	2.0	5.0	1550	4"A.C. +10"Agg. +12"Sel. Mat.	19.5	15.8
12	1101-003-119-C501	Sandy loam and gravel and sandy clays (A-4 (2) and A-7-6)	10	--	2.5	25	1600	D.S. +5" B-3+ 8"Sel. Mat. or 6.5" A.C. +6" Sel. Mat. Type II	11.0 or 12.3	14.1
13	0627-034-139-C501	Shaley and silty clays (A-4, A-6, and A-7)	2.8	--	2.0	5.6	1660	4"A.C. +8"Agg. + 10"Sel. Mat.	17.0	16.0
14	0664-007-165-C501	Silty, sandy clays and gravels (A-2-4 or A-6)	11	--	2.5	27.5	1664	4"A.C. +5"Agg. + 6" Sel. Mat	11.1	14.4
Suffolk District										
1	0616-040-132-C501	Sand and sandy clay (A-2-4, A-6 and A-7-6)	8	--	3	24	35	D.S. +4"Agg.	4.8	4.8
2	0633-040-134-C501	Clay sand (A-2-4 (0) and A-7-6 (7))	14.4	--	3	43	130	D.S. +6"Agg.	6.8	6.1
3	0626-091-129-C501	Clay, sand and their mixture (A-2-4, A-4 and A-7-6)	20	--	3	60	140	D.S. +5"Agg. or D.S. +6"S.C.	6.8	6.0
4	0602-091-130-C501	Clay, sand and their mixture (A-2-4 to A-6)	16	--	3	48	160	D.S. +6"Agg. or D.S. +6"S.C.	6.8	6.2
5	0653-091-134-C501	Clay, sand and sand clay (A-2-4 to A-7-6 but no A-3)	18	--	3	54	415	D.S +4"Agg. + 6"S.C.	10.8	9.7
6	0695-001-153-C501	A-2-4 and A-4	16-42	--	3	57	765	D.S. +6"CTA	8.8	11.8
7	0730-040-133-C501	Clay and sand mixture (A-6 and A-2-6)	22	--	3	66	1034	D.S. +8"gravel	8.8	13.2
8	0619-040-131-C501	Sand and sandy clay (A-4-A-6 and A-7-6)	17	--	3	51	1358	D.S. +8"Agg. + 6"S.C.	14.8	13.8

* R. F. = Resiliency Factor

** D.S = Double seal

APPENDIX III

CLASSIFICATION BASED ON RESILIENCY AND CBR VALUES OF SOILS

Code	County or Town	Res. Factor	Design CBR	Soil Support Value =(Res. Factor x CBR
00	Arlington - W. of Rte. 95	1.0	7	7
	E. of Rte. 95	3.0	10	30
01	Accomack	3.0	7	21
02	Albemarle - E. of Rte. 29	1.0	4	4
	W. of Rte. 29	1.0	5	5
03	Alleghany	2.0	5	10
04	Amelia	1.5	6	9
05	Amherst	1.5	5	8
06	Appomattox	1.5	5	8
07	Augusta	2	6	12
08	Bath	2.0	5	10
09	Bedford	1.5	5	8
10	Bland	2.0	6	12
11	Botetourt - a bulge in the eastern rock, half way up to Eagle rock.	1.5	4	6
	rest of county.	2.0	4	8
12	Brunswick	1.5	7	11
13	Buchanan	2.0	6	12
14	Buckingham	1.5	5	8
15	Campbell	1.5	5	8
16	Caroline - W. of Rte. 2	2.5	10	25
	E. of Rte. 2	3.0	10	30
17	Carroll	1.0	8	8
18	Charles City	3.0	11	33

APPENDIX III (contd.)

19	Charlotte	1.5	5	8
131	Chesapeake	3.0	6	18
20	Chesterfield - S. W. Mosley and Colonial Heights	1.5	6	9
	rest of county	2.5	9	23
21	Clarke	2.0	6	12
22	Craig	2.0	4	8
23	Culpeper - E. of Rtes. 229 and 15S	1.0	4	4
	W. of Rtes. 229 and 15S	1.0	5	5
24	Cumberland	1.5	6	9
25	Dickenson	2.0	6	12
26	Dinwiddie	1.5	6	9
28	Essex	3.0	10	30
29	Fairfax - E. of Rte. 95	3.0	7	21
	W. of Rte. 95	1.0	4	4
30	Fauquier - No. of Rte. 211	2.0	4	8
	S. of Rte. 211	1.0	4	4
31	Floyd	1	8	8
32	Fluvanna	1.5	4	6
33	Franklin	1.0	8	8
34	Frederick	2.0	6	12
35	Giles	2.0	7	14
36	Gloucester	3.0	10	30
37	Goochland - W. Rte. 522	1.5	7	11
	E. Rte. 522	2.5	7	18
38	Grayson	1.0	5	5
39	Greene	1.0	5	5
40	Greensville - E. Rte. 95	3.0	9	27
	W. Rte. 95	1.5	9	14

APPENDIX III (contd.)

41	Halifax	1.5	8	12
114	Hampton	3.0	9	27
42	Hanover - E. Rte. 95	3.0	10	30
	W. Rte. 95 & E. Rte. 715	2.5	6	15
	W. Rte. 715	1.5	6	9
43	Henrico W. Rte. 95	2.5	7	18
	E. Rte. 95	3.0	7	21
44	Henry	1.0	8	8
45	Highland	2.0	6	12
46	Isle of Wight	3.0	9	27
47	James City	3.0	6	18
48	King George	3.0	10	30
49	King and Queen	3.0	10	30
50	King William	3.0	10	30
51	Lancaster	3.0	10	30
52	Lee	2.0	6	12
53	Loudoun - W. Rte. 15	2.0	4	8
	E. Rte. 15	1.0	4	4
54	Louisa	1.5	5	7.5
55	Lunenberg	1.5	5	8
56	Madison	1.0	5	5
57	Mathews	3.0	10	30
58	Mecklenburg	1.5	7	11
59	Middlesex	3.0	10	30
60	Montgomery	2.0	5	10
61	Nansemond	3.0	9	27
62	Nelson	1.5	5	8
63	New Kent	3.0	9	27
121	Newport News	3.0	9	27

APPENDIX III (contd.)

122	Norfolk	3.0	9	27
65	Northampton	3.0	7	21
66	Northumberland	3.0	10	30
67	Nottoway	1.5	8	12
68	Orange - N. of 20 & E. 522	1.0	6	6
	N. of 20 & W. 522	1.0	5	5
	S. of 20 & E. 522	1.5	6	9
	S. of 20 & W. 522	1.5	5	8
69	Page - W. Alma	2.0	6	12
	E. Alma	1.0	6	6
70	Patrick	1	8	8
71	Pittsylvania	1.5	8	12
72	Powhatan - W. 522 & 609	1.5	7	11
	E. 522 & 609	2.5	7	18
73	Prince Edward	1.5	5	8
74	Prince George	3.0	8	24
76	Prince William - W. 95	1.0	4	4
	E. 95	3.0	7	21
77	Pulaski	2.0	5	10
78	Rappahannock - N. Flint Hill	2.0	5	10
	S. Flint Hill	1.0	5	5
79	Richmond	3.0	10	30
80	Roanoke	2.0	7	14
81	Rockbridge - W. James Maury and South River	2.0	5	10
	E. James, Maury and South River	1.5	5	8
82	Rockingham - W. 81	2.0	6	12
	E. 81	1.0	6	6
83	Russell	2.0	6	12
84	Scott	2.0	6	12

APPENDIX III (contd.)

85	Shenandoah	2.0	6	12
86	Smyth	2.0	6	12
87	Southampton	3.0	9	27
88	Spotsylvania -W. 95	1.5	6	9
	E. 95	2.5	10	25
89	Stafford W. 95	1.0	6	6
	E. 95	3.0	10	30
90	Surry	3.0	9	27
91	Sussex - E. 95	3.0	9	27
	W. 95	1.5	9	14
92	Tazewell	2.0	6	12
134	Va. Beach - N. 44	3.0	9	27
	S. 44	3.0	6	18
93	Warren	2.0	6	12
95	Washington	2.0	6	12
96	Westmoreland	3.0	10	30
97	Wise	2.0	6	12
98	Wythe	2.0	6	12
99	York	3.0	7	21

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APPENDIX IV

EVALUATION OF SOIL RESILIENCY FACTORS

Soil Type	Zone	Resiliency Factor
Very highly resilient soils — A-5 or A-4 (with G. I. of 5 and up). Both classifications should have large percentage passing #200 sieve and also high mica content. Geologically they are high and low quartz granitoids.	Piedmont	0.5
Highly resilient soils—(a)A-4(with G. I. of 5 and up) having large percentage passing #200 but with low mica content. (b) Sandy silt with high mica content. Geologically they are high and low quartz granitoids.	Piedmont	1.0
Mediumly resilient soils — A-7-5 or micaceous clay. Mostly they are silts without mica content.	Piedmont	1.5
Medium low resilient soils — Clays - A-4-2, A-6, A-7-6 or A-8 (no mica content).	Valley & Ridge	2.0
Low resilient soils — Combination of sand, silt and clays (no mica content).	Northern part of Richmond District	2.5
Very low resilient soils — Sands - A-1, A-2, A-3, or A-4 (with G. I. less than 5). Geologically they are coastal plain sediments (no mica content)	Coastal plains	3.0

APPENDIX V

EVALUATION OF THICKNESS INDEX BASED ON INCREASE IN PERCENT OF TRUCK TRAFFIC

This evaluation has been divided into four steps, percent counts, average truck weight, 18-kip equivalents and additional thickness index due to excess trucks. They are discussed below.

Percent Count by Truck Classification

Virginia W-4 tables of truck weight studies show that the percentage of heavier trucks increases as the road classification improves from the lowest secondary urban to FA primary urban to FA rural urban. The only W-4 table that could be usefully applied for secondary and subdivision roads is the one for FA secondary urban, state jurisdiction system, assuming that single trucks form a very high percentage of total truck traffic on secondary and subdivision roads. The percentage distribution of single units for the years 1965 to 1968 on FA secondary urban as given in Virginia W-4 tables are given below:

Year	Single Unit Truck Classification		
	P&P	2A-4T	2A-6T
1965	59	10	31
1966	49	24	27
1967	53	20	27
1968	55	15	30
Average	54	17	29

Thus it could be assumed that 30 percent of the trucks are 2A-6T and heavier, 20 percent are 2A-4T, and 50 percent are panel and pickup.

Average Truck Weight

Load study data on 100 selected projects with varying intensities of traffic were obtained from the traffic division of the VDH. The 18-kip equivalent on these projects varied uniformly from 1 to above 700.

The average truck weight for each truck classification for each project was determined. The average truck weights for the category 2A-6T varied mostly from 11,000 to 15,000. The average weight of trucks in the 2A-6T category on all these projects was found to be 13,090 lb. = 13,000 lb.say. The average weight of the 2A-4T is about 6,000 lb. and that of the panel and pickup is 4,000 lb.

The average truck weight on secondary and subdivision roads is therefore equal to 0.5 x 4,000 +0.2 x 6,000 +0.3 x 13,000 = 7,100 lb.

Evaluation of 18-kip Equivalent and Additional Thickness Index for Trucks

Shook and Lepps' (7) equation for determining the 18-kip equivalent is as follows:

$$\log EWL_{18} = -10.683 + 3.401 \log S + 1.334 \log W + 1.051 \log N$$

where

EWL_{18} = 18-kip equivalent

S = legal single axle load limit (1,000 lb.) = 18 for Virginia

W = average heavy truck gross weight (lb.) = 7,100 lb. determined above

N = number of heavy trucks

Therefore $\log EWL_{18} = -10.683 + 3.401 \log 18 + 1.334 \log 7,000 + 1.051 \log N.$

$= 1.051 \log N - 1.276$

for 50 trucks $EWL_{18} = 4.58 \doteq 0.5$ say.

The above equation shows that for a 50-truck increase the 18-kip equivalent would increase by about 5. The design chart for primary and interstate roads shows that for a five 18-kip equivalent increase the thickness index of this chart would increase by approximately 0.6. A thickness index of 0.6 on the primary and interstate road design chart is equivalent to 0.6 x 1.67 = 1.0 on the secondary road design chart.

The design chart for secondary and subdivision roads includes 0 to 5 percent trucks. Thus for every 50 additional trucks per day the thickness index as obtained from the chart should be increased by 1.0.

APPENDIX VI

THICKNESS INDEX, D, FOR VDH SECONDARY AND SUBDIVISION ROAD DESIGNS

Traffic Category	vpd	Des. No.	Design Equation	D	Average D
			Secondary Roads		
I	Under 50	1	$D = 6a_2$	6.0	
		2	$D = 3a_2+4a_3$	6.3	= 6.2
	50 - 200	1	$D = D.S. +6a_2$	6.8	
		2	$D = D.S. +6a_4$		
		3	$D = D.S. +3a_2+4a_3$	7.8	
		4	$D = D.S. +3a_2+4a_{42}$	7.5	= 7.3
II	201-400	1	$D = D.S. +8a_2$	8.8	
		2	$D = D.S. +3a_2+6a_4$	9.8	
		3	$D = D.S. +4a_2+6a_3$	9.8	
		4	$D = D.S. +6a_5$	7.8	= 9.0
III	401-1000	1	$D = D.S. +5a_2+6a_4$	11.8	
		2	$D = D.S. +6a_2+6a_{42}$	12.4	
		3	$D = D.S. +6a_5+4a_3$	8.8	
		4	$D = 6a_1+4a_3$	13.3	
		5	$D = D.S. +5a_2+6a_3$	7.2	
		6	$D = D.S. +10a_2$	10.8	= 10.7
IV	1000-4000	1	$D = 4a_1+4a_2+6a_4$	16.7	
		2	$D = 4a_1+5a_2+6a_{41}$	17.2	
		3	$D = 4a_1+5a_2+6a_3$	13.1	
		4	$D = 2a_1+6a_{41}+6a_3$	11.7	
		5	$D = 8a_1+6a_3$	14.7	
		6	$D = 4a_1+10a_2$	16.7	= 15.0

V	Over 4000	1	$D = 5a_1+5a_2+6a_4$	19.4	
		2	$D = 5a_1 6a_2+6a_{42}$	19.9	
		3	$D = 5a_1+6a_2+6a_3$	15.7	
		4	$D = 5a_1+12a_2$	19.4	= 18.6
			<u>Subdivision Roads</u>		
I	up to 250	1	D.S. $+6a_2$	6.8	
		2	D.S. $+6a_4$	7.8	
		3	D.S. $+3a_2+4a_3$	7.8	
		4	D.S. $+3a_2+4a_4$ or	7.8	
			D.S. $+3a_2+4a_{42}$	7.5	
		6	$6a_1$	10.0	8.0
II	251-400	1	D.S. $+8a_2$	8.8	
		2	D.S. $+3a_2+6a_4$	9.8	
		3	D.S. $+4a_2+6a_3$	5.2	
		4	D.S. $+6a_{41}$	7.9	
		6	$6a_1$	10.0	8.3
III	401-750	1	D.S. $+3a_2+6a_4$	9.8	
		2	D.S. $+4a_2+6a_{42}$	10.6	
		3	D.S. $+6a_{41}+4a_3$	8.8	
		4	$5a_1+4a_2$ or	12.4	
			$5a_1+4a_3$	12.4	
		5	D.S. $+5a_2+6a_3$	7.2	
		6	D.S. $+10a_2$	10.8	10.3

APPENDIX VI (contd.)

IV	751-3000	1	$2a_1+4a_2+6a_4$	13.3	
		2	$2a_1+5a_2+6a_{42}$	13.9	
		3	$2a_1+5a_2+6a_3$	9.7	
		4	$2a_1+6a_4+4a_3$	11.3	
		5	$6.5a_1+6a_3$	12.2	
		6	$4a_1+8a_2$	14.7	12.5
V	+3000	1	$4.5a_1+5a_2+6a_4$	18.5	
		2	$4.5a_1+6a_2+6a_{42}$	19.0	
		3	$4.5a_1+6a_2+6a_3$	14.9	
		4	$4.5a_1+12a_2$	19.5	
		6	$8a_1+6a_3$	17.1	17.8

APPENDIX VII

EXAMPLES OF USE OF THE PROPOSED DESIGN METHOD FOR SECONDARY AND SUBDIVISION ROADS

Traffic Category	Traffic vpd	Average D Reqd.*	Design Choices	Design D
Secondary Roads				
Ia	Under 50	6.2	1) 6" S.C.	= 6.0
			2) 6" S.L. +D.S.	= 5.4+0.8=6.2
Ib	50-200	7.3	1) 4" CTA+1.5"A.C.	= 5.2+2.5=7.7
			2) 5" CTA+D.S.	= 6.7+0.8=7.5
II	201-400	9.0	1) 6" A.C.	= 9.0
			2) 6" CTA+D.S.	= 8.0+0.8=8.8
III	1000-4000	15.0	1) 10"A.C.	= 15.0
			2) 6" CTA+4"Agg+2"A.C.	= 8.0+4.0+2.5=14.5
IV	Over 4000	18.6	1) 12"A.C.	= 18.0
			2) 6"CTA+4"Agg. +4"A.C.	= 8.0+4.0+6.7=19.7
Subdivision Roads				
I and II	up to 250 and 250 to 400	8 and 8.3	1) 6" A. C.	= 9.0
			2) 4"CTA+2"A.C.	= 5.3+3.3=8.6
			3) 6"CTA+D.S.	= 8.0+0.8=8.8
			4) 6"S.L. +1.5"AL	= 5.5+2.5=8.0
			5) 4"CTA+3"Agg. +D.S.	= 5.3+3.0+0.8= 9.1
III	401-750	10.3	1) 7"A.C.	= 10.5
			2) 6"CTA +2"A.C.	= 8.0+3.3=11.3
IV	751-3000	12.5	1) 8" A.C.	= 12.0
			2) 4" CTA+4"Agg. +2"A.C.	= 5.3+4.0+3.3=12.6
			3) 4"CTA+4.5"A.C.	= 5.3+7.5=12.8
			4) 6"S.C. +4.5"A.C.	= 6.0+7.5 = 13.5
V	+3000	17.8	1) 12"A.C.	= 18.0
			2) 6"CTA+4"Agg. +4"A.C.	= 8.0+4.0+6.7=18.7
			3) 6"CTA+6"A.C.	= 8.0+10.0= 18.0

Note: Notations used in design choices are same as given in Table I.

* This value is the same as calculated for the present design charts recommended by the VDH (see Appendix VI last column).