ANALYSIS OF SPRING BREAK-UP DATA IN VIRGINIA

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SYNOPSIS

The paper presents an analysis of road performance data collected at the time of the spring break-up on more than 1000 miles of primary and nearly 5000 miles of secondary roads in the Culpeper District. The purpose of the survey was to secure detailed information on road performance and to determine the extent and, insofar as possible, the causes of the major break-up. Results of such a survey are useful in conjunction with the planning of maintenance and construction programs

A uniform system of rating the numerous road sections was devised. Five ratings, depending upon the degree of distress, were employed. The survey was started about the middle of February, 1948 and all field work was completed near the first of April. Thus, all ratings were obtained at a time when subgrade support was at a minimum.

The performance ratings both for the primary and for the secondary roads were summarized by counties. The secondary roads were further divided into hard and non-hard surface types. A map of each county was prepared showing the ratings for each road section.

Despite the fact that primary highways carry approximately 80 percent of the traffic, their performance was considerably better than that of secondary roads. For example, about 43 percent of the primary roads were giving good performance (ratings 1 and 2) as compared to only 20 percent of the secondary roads. Likewise, only 29 percent of the primary highways were rated as poor (ratings 4 and 5), while 47 percent of the secondary roads were in this category.

For the purpose of analysis the Culpeper District was divided into five general soil areas according to parent materials. It was found that the roads in the Coastal Plain Sediments soil area were giving the best performance, while those in the Triassic "Red Beds" soil area were rated the poorest in the District.

The studies revealed that in all five soil areas macadam bases performed much better than selected soil, gravel, stone or stabilized bases. The order of ratings for bituminous surfaces from the best to poorest performance was as follows: plant mix, heavy bituminous mixes and light bituminous mixes.

An analysis of the 30-year weather records (1917-1947) brought to light certain pertinent facts. It was found that pavement break-ups are most severe for those years with low temperatures preceded by subgrade and base saturation (high precipitation). The past winter was second only to the 1935-36 one as regards to climatic conditions favorable to a severe break-up.

In order to design, construct and maintain better roads, highway engineers are making use of research to evaluate the various factors responsible for the behavior of pavements. Road condition surveys, if made at a time when differences in performance are most apparent, can be useful for this purpose. A comprehensive and thorough study at the time of the spring break-up will not only serve the purpose of locating the areas where distress is most prevalent, but also may serve to indicate the best solution to some of the problems.

Good pavement performance is dependent upon a number of factors. Often these factors are so interrelated that it becomes almost a hopeless task to isolate and evaluate each factor individually for some particular section of road. A study of a large number of pavements may bring to light certain facts not otherwise obtainable. Among the important variables are climate, traffic, design and the soil area in which the pavement is located. All highway engineers have observed that the spring break-up is much more severe some years than others. What are the climatic factors which contribute to a major spring break-up? What pavement designs are giving "year-around" good performance for the traffic conditions to which they are subjected? In what areas are the roads distressed the most at the time of the "break-up"?

To answer these questions the Department collected detailed information on weather data, and road performance this past spring to determine insofar as possible the extent and causes of the major break-ups. The survey was extensive since it included the 38,000 mi. in the secondary system and the 9,000 mi. of primary highways. It was started about the middle of February and all field work was completed near the first of April. The survey consisted of an inspection, logging and description of failure types (surface and base) and a performance rating of each individual road section. Pictures were taken to illustrate both poor and good performance and to record actual conditions.

In addition to the field survey, an analysis was made of the 30 yr. weather data throughout the State. For this analysis the reports from 16 US Weather Bureau stations (two per district) were used.

It may be pertinent at this time to note that the field parties were alerted to pay particular attention to road damage being caused by excessive loads. During the time of the break-up load limit restrictions were placed on many highways. Most interstate routes retained their designated 40,000-lb. gross load limit; however, many other primary roads were restricted to 24,000-lb. gross load and practically all secondary routes were posted for 16,000 lb.

Results of the state-wide road condition survey have been summarized by counties and districts; however, because of their bulk they are not included in this report. More detailed analysis of the data was desired to study the factors affecting pavement performance. Thus, the paper presents an analysis of the survey results for the Culpeper District - one of the eight in the State.

DESCRIPTION OF THE CULPEPER DISTRICT

The Culpeper District with an area of 5021 sq. mi. is located in the north central part of the State. It is bounded by Maryland on the north, by the crest of the Blue Ridge Mountains on the west, by the James River and Nelson County on the south, by the Potomac River and Stafford, Spotsylvania, Hanover and Goochland Counties on the east. It includes the following 13 counties: Albemarle, Arlington, Culpeper, Fairfax, Fauquier, Fluvanna, Greene, Loudoun, Louisa, Madison, Orange, Prince William and Rappahannock.

The population in 1930 was 243,000, had increased to 304,500 in 1940 and is now estimated at over 400,000. Two independent cities, Alexandria and Charlottesville, have an estimated population of 58,000 and 25,000 respectively. Several of the rural counties have had a tendency to lose some of their inhabitants while others have gained. Especially noticeable for gains are Arlington - which jumped from 57,000 in 1940 to an estimated present population of 120,000 - and Fairfax which increased from 41,000 in 1940 to 80,000 (estimated) in 1948.

The District is divided into six residencies. The offices of the Resident Engineers are located as follows: Fluvanna and Louisa Counties at Louisa Court House, Albemarle and Greene Counties at

Charlottesville; Culpeper, Orange, and Madison Counties at Culpeper; Fauquier and Rappahannock Counties at Warrenton, Fairfax, Arlington, and Prince William Counties at Fairfax; and Loudoun County at Leesburg. The District office is located at Culpeper.

The primary highway system includes 1175 mi. and the secondary road network has a mileage of 4958. In addition, the County of Arlington maintains its own highway system. Approximately 60 mi. of primary roads have been built to four-lane width, some of them being divided. This last type of mileage will be increased upon completion of the Henry Shirley Memorial Highway.

The principal primary highways in the district are: US Routes 1, 15, 29, 33, 50, 211 and 250. A traffic flow map as prepared by the Division of Traffic and Planning is presented in Figure 1. It will be noted that traffic volume is greatest on the above listed routes and is concentrated particularly in the Washington area. Additional data from the Traffic and Planning Division reveal that while only 13 percent of all roads in the state system are in the Culpeper District, about 17 percent of all traffic on the system is found in this area.

The district can be divided into two major physiographic provinces: the Piedmont Plateau and the Coastal Plain. The latter is extremely limited in extent and stretches along a narrow north-south band of land in Arlington, Fairfax and Prince William Counties bordering the Potomac River. A large part of the Piedmont Plateau in the Culpeper District is occupied by a series of Triassic Basins.

From a geological point of view the formations encountered vary widely. The oldest one is apparently the Catoctin greenstone, an extrusive rock of pre-Cambrian age (most likely Algonkian). It is a basic lava which lies parallel to the eastern flank of the Blue Ridge. Of similar age are the widespread Wissahickon schist (a chlorite-muscovite schist) and several granitic formations such as: the Marshall, Hypersthene, Lovingston and Columbia granites; hornblende gabbro and quartz monzonite are two other igneous pre-Cambrian formations.

In the lower Cambrian are the Loudoun slate and quartzite. Sedimentary rocks are to be found in the Culpeper District. Of Ordivician age are small out-crops of Arvonis and Quantico slate, and Everona limestone. Finally in the Triassic basin are three main groups of sedimentary rocks, namely, conglomerates, sandstones and shales. The conglomerates are usually classified according to component pebbles (limestone, quartz, schist, trap, arkose). The basins as well as the remaining of the plateau are cut by a number of diabase dykes, sills and stocks. In the Coastal Plain are to be found sediments, mostly arkosic, ranging from Cretaceous to Pleistocene in age. At places, along the Potomac, they are wholly unconsolidated and the most recent sediments are sand or peat and muck.

In the northern part of the district the drainage is toward the Potomac River. The central part is drained by the Rappahannock and Rapidan on the one hand and the Anna Rivers on the other. Runoff in the southern part is toward the James River and its tributaries. The drainage pattern is obviously a reflection of the topography. In the Culpeper District the high land lies to the west with a series of foothills stretching about as far as the Triassic basins. In those basins the relief is markedly flatter. The remaining of the district is gently rolling.

Weather conditions in the district, particularly those affecting the spring break-up, may best be illustrated by Figure 2. Data secured from the US Weather Bureau Station at Charlottesville for the months of November, December, and January are presented graphically for all years since 1917. Average mean temperature and total precipitation are plotted and compared with the 35-yr. normal. It will be observed for this 30-yr. period that the winter of 1917-1918 was the coldest with an average mean temperature of 33 F. Next come the winters of 1935-36 and 1939-40 each with a mean temperature of 37 F. The past winter was fourth with a mean temperature of 37.2 F.

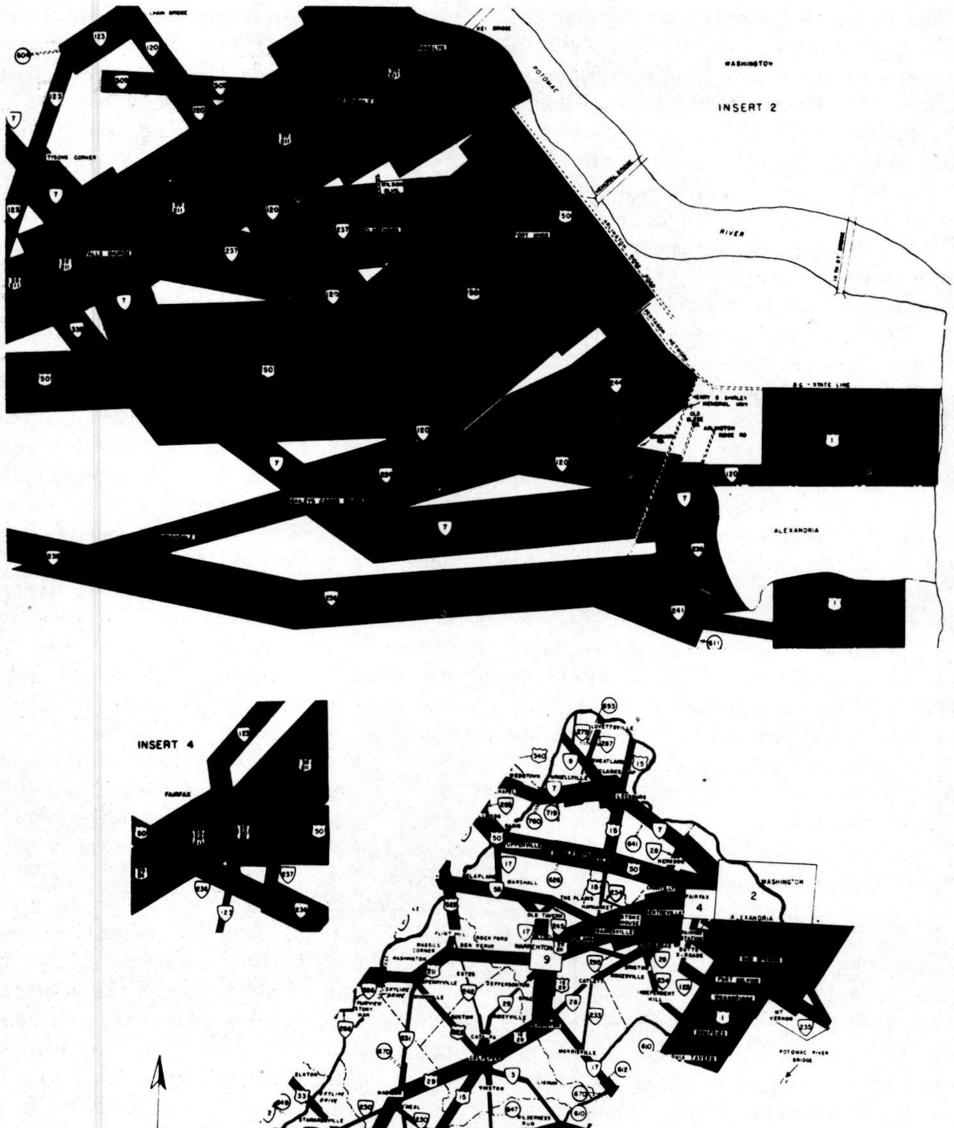

Figure 1. Culpeper District - Traffic Flow Map, 1947 - Traffic Scale: 1/4-in. width = 5000 Vehicles.

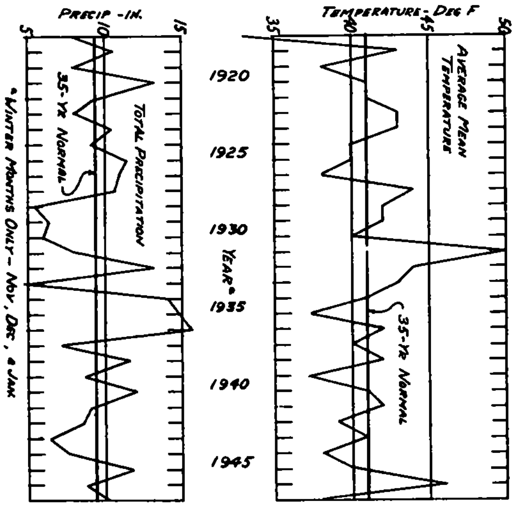

Figure 2 Climatic Data Charlottesville, Va. Data are for November and December of given year plus following January.

In total precipitation the winter of 1936-37 was the wettest with 15.5 in., however, the preceding winter (1935-36) was next with 15 in. These may be compared with a 35-yr. normal for the three months period of 9.3 in. Last winter the precipitation was above normal being 10.4 in.

The most severe spring break-up in recent years occurred in 1935-36. An examination of the chart reveals that an unusually low temperature (second lowest in 30 years) was combined with an abnormally high precipitation (second wettest winter). It may be pointed out that the past winter had the combination of precipitation and temperature most favorable to a severe break-up since 1935-36. The two items appear to go hand in hand and merely a cold winter does not necessarily result in a severe break-up.

Materials for highway construction and maintenance are found in various parts of the district. Sand and gravel in the Coastal Plain are currently being produced at several locations. Natural river sand can also be obtained at several locations where it occurs as an alluvium. Stone from several formations is used as road metal. Several of the granites have been quarried successfully. Quarries opened in the Wissahickon formation have furnished a variety of granitic rocks. A variety of aggregates has also been produced from the Triassic "Red Beds". Several quarries have been operating for a number of years in the conglomerate (trap phase) and in basaltic dykes. The latter are extremely tough with resulting wear on crushers. The Manassas sandstone of Triassic Age also has been used as road metal. Also, greenstone has been a source for road aggregates.

As may be expected, the soils of the area are a reflection of the geology. On the basis of parent materials the district has been divided into five general soil areas as shown in Figure 3. The Coastal Plain soils vary widely from sand and pebbles to interbedded sand and clay. Along the shore line some unconsolidated peat may be found in marshy land. On the Piedmont Plateau the granitic rocks (whether metamorphosed or not) weather into clays to sandy clays. The soil type is a function of the amount of quartz present in the parent material - the more quartz present, the less plastic the soil. As a rule, the amount of quartz in the granitoids varies inversely as the amount of clay forming minerals such as the feldspars, micas and members of the hornblende family. The weathering process which transforms them is not a simple one but it can be stated that through physical and chemical actions they are changed into elastic and (or) plastic soils. Wherever the quartz and other siliceous elements are predominant, the resulting soils are essentially granular and non-plastic (sandy to silty).

The Triassic basin is very properly described as the "Red Bed" area since the soils weather into deep red-brown clay. Though the top horizon is rather shallow near the Potomac, it becomes deeper further south. The soil is one of the most unfavorable for highway work and, as is often the case, it is also among the most favorable in the State from an agricultural point of view. The diabase dykes often weather into a sand before breaking down

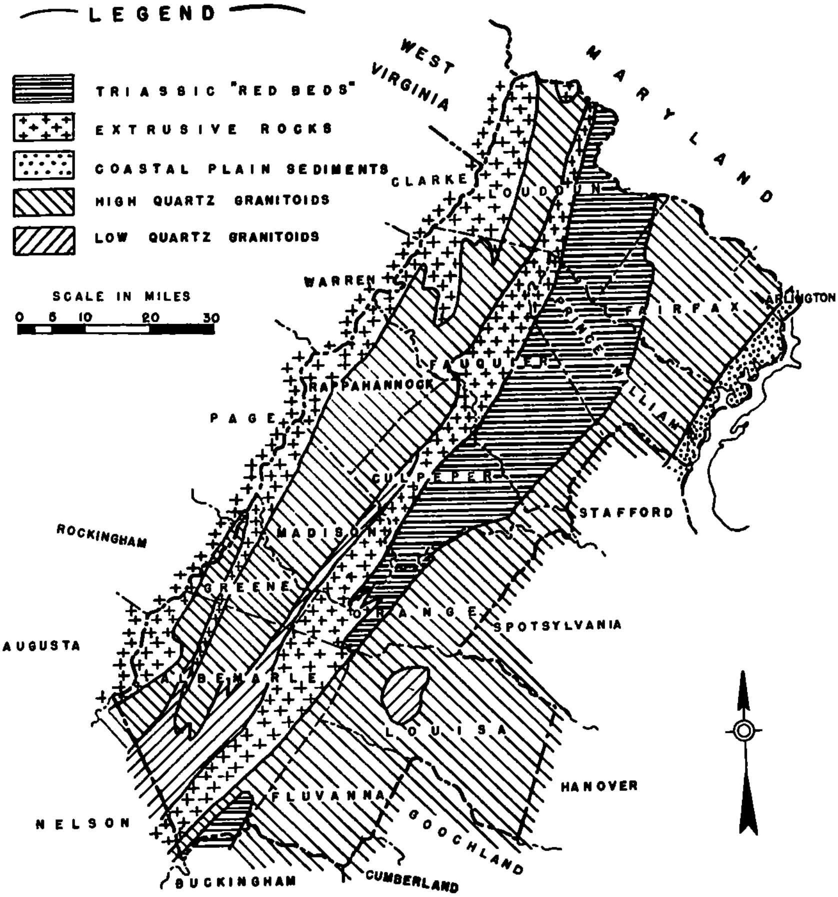

Figure 3. Culpeper District - General Soil Areas.

into a very heavy clay (agriculturally known as the Iredell), which has justly been nicknamed "black jack soil". The Triassic sand as well as the clay is most unfavorable for highway work. The volcanic rocks which are mostly greenstone also break down into clay. As a whole, it may be stated that from a highway standpoint, soils encountered in the Culpeper District present problems because of poor internal drainage and variable bearing power.

SURVEY PROCEDURE

Immediately after the assignment of the state-wide road condition survey to the Research Section, the first step was the preparation of a working plan. Meetings were held with the field forces who were to conduct the survey. Specific instructions were issued to the District Materials Engineers, the District Soil Engineers, Testing Division staff members and field men assigned to the survey. The District Materials Engineer was placed in charge of the field survey and held responsible for its conduct in each district. Four or five field parties, consisting of a driver and a recorder, were organized in each district. Thus, for conducting such an extensive survey in a relatively short time the services of about 100 men were required.

The field parties worked in close cooperation with the District Engineers and Resident Engineers and checked with the latter at least once a day to report extensive or severe failures so that they could be corrected and thus expedite traffic. The driver of the two-man party was usually a road patrolman who was intimately familiar with local conditions. The recorder prepared the log, rated the roads, took pictures to illustrate typical conditions and kept all notes.

Prior to beginning the survey each party was supplied a list of road sections by counties which had been prepared on the I.B.M. machine by the Auditing Division. These tabulations contained the following information. (1) county code, (2) route number, (3) description (from, to), (4) surface type (by code), (5) base type (by code), (6) road width and (7) length. In addition, each party was furnished the following supplies and equipment: field note book (one per county), code of counties, code for base and surface types, county maps, state maps, list of Resident Engineers and counties in each Residency, colored pencils, pick, shovel, scale, camera, supply of film, working plan and set of instructions.

The survey was made by driving at slow speed over each section of road, noting and recording conditions in a field note book. The same general procedure was followed in each of the eight districts. For each road section the following information was recorded in the county field book: (1) survey party, (2) date inspected, (3) weather conditions, (4) log of section locating type and extent of failures, and other information pertinent to performance such as: topography, predominating soil type, position of grade line with respect to ground surface and water table, drainage conditions, unusual traffic conditions, etc.

Immediately after logging and inspecting a given section, an estimate was made of the degree of distress and a rating was given on the basis of the arbitrary evaluations listed in Table 1.

As soon as the rating had been estimated, the road was colored on the county map according to the color code given in the Table. If only surface failures were encountered, short lines perpendicular to the road were colored on the map. When the failures were found in both surface and base, a solid color was used. Thus, uniform rating and color schemes were used in all districts. It is realized that it is not always easy to distinguish between "winter damage" and that resulting from delayed or deferred maintenance. The ratings reflect conditions existing at the time of the spring break-up, regardless of their cause.

About 600 pictures were taken to record typical road conditions and to illustrate both good and poor performance. At the completion of the survey each District Materials Engineer prepared a report and submitted the data for each district. Included in the report was a colored map of each county showing the rating of each road section. The reports contained tabulations showing the number of miles of primary and secondary roads in each rating by counties. Secondary roads were further divided into those with hard surfaces and the ones without. Some of the reports supplied information concerning the different types of construction and some contained recommendations for improvements in design, construction and maintenance procedures.

In order to secure further information concerning the effect of such variables as soil area, base and surface types, an analysis of the survey results in one typical district (Culpeper) was attempted.

CULPEPER DISTRICT SURVEY RESULTS

Primary Roads - Results of the condition survey of primary roads have been summarized according to ratings for each of the 13 counties in Table 2. The summary includes not only the total mileage but also the percentage in each rating. These data are also presented graphically in Figure 4. It will be observed that about 505 mi. or 43 percent of the primary roads were giving good performance (ratings 1 and 2). In contrast, only about 348 mi. or 29.5 percent were considered as giving poor performance (rating 4 and 5). More than 50 percent of the primary roads in two counties, Albemarle and Fairfax, were rated good. Incidentally, these two counties are two of the heaviest populated counties in the District and the primary

TABLE 1

Hard Surface Roads

Rating	Description	Color Code
1. Excellent Performance	Roads showing no break-up and in perfect condition.	Blue
2. Good performance	Roads showing only a slight amount of distress such as an occassional alligator crack or some surface raveling.	Green
3. Slight Distress	Those roads with less than 5% of the total area showing base and surface movement.	Brown
4. Secondary Distress	Those roads showing 5 to 20 % of the total area with movement in the base and surface.	Orange
5. Primary Failure	Those roads with over 20% of the surface showing base and surface movement.	Red

Non-Hard Surface Roads

Rating	Description	Color Code
1. Excellent	Remained smooth with no break-ups.	Blue
2. Good	No break-up. Slick in places but no ruts deeper than 1 in. Traffic moving in high gear on entire section.	Green
3. Fair	Not over 5% badly rutted so as to force traffic to change gears.	Brown
4. Poor	From 5% to 20% badly rutted. Traffic may get stuck in places.	Orange
5. Very Poor	Over 20% of surface badly rutted. Very difficult for traffic to pass without getting stuck.	Red

roads in them carry more traffic than in most of the other counties. On the other hand, more than 50 percent of the primary roads in Fauquier, Fluvanna, Greene and Loudoun counties were rated as showing considerable distress (ratings 4 and 5).

A map of the primary highways was prepared to show the condition rating of each road section (Figure 5). It will be noted that considerable mileage of Rts. 7, 15, 17, 28 and 233 were rated as primary failure (rating 5). Typical performance pictures are illustrated in Figures 6-9 inclusive.

Secondary Roads - Results of the survey on secondary roads have been summarized in a similar manner for the twelve counties included in this system (Table 3). The secondary roads have been further divided into two groups: hard and non-hard surfaces. Of the 4958.47 mi. of secondary roads, only 857.48 mi. or 17.3 percent have a hard surface. While both classes of secondary roads were included in the survey, only those secondary roads with hard surfaces are included in the analysis. Conditions of the unsurfaced secondary roads change so rapidly that their

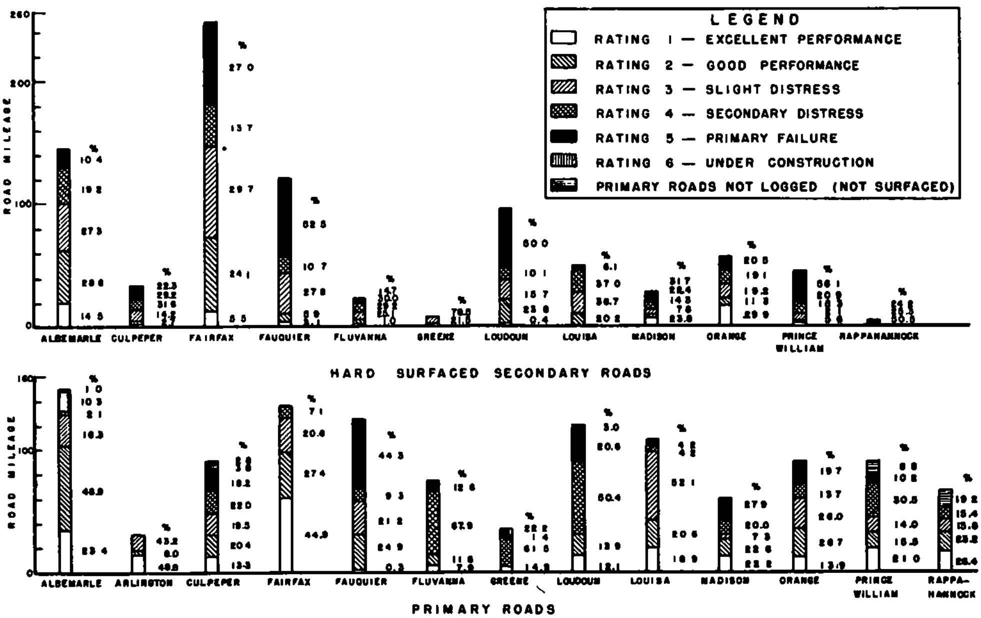

Figure 4. Road Mileage and Condition Ratings by Counties.

rating is extremely difficult. Such a road may be impassible one day and rated as a primary failure; however, after blading and drying by sun and wind its condition may have improved so much as to class it as fair. Failures of hard surface roads are not so easily repaired and tell-tale patches indicate past conditions.

Considering the hard surface secondary roads, 232.35 mi. (27 percent) were rated as giving good performance (ratings 1 and 2) as compared to 399.23 mi. (47 percent) that were showing considerable distress (ratings 4 and 5). In only one county (Rappahannock) were more than 50 percent of the hard surface secondary roads rated as showing good performance (ratings 1 and 2). In contrast, more than 50 percent of the hard surface secondary roads were in poor condition (ratings 4 and 5) in five counties - Prince William, Fauquier, Loudoun, Madison and Culpeper. County maps were prepared showing the rating of each secondary road, however, because of their bulk they are not included in the report. They are quite useful to the Resident and District Engineers for planning maintenance and construction schedules. Conditions typical on secondary roads at the time of the survey are illustrated by Figures 10, 11 and 12.

DISCUSSION OF RESULTS

In order to simplify the analysis of the data, ratings 1 and 2 were combined and classified as good performance. Also, ratings 4 and 5 were combined and reclassified as poor performance. The data for the primary roads was then rearranged and summarized according to soil area by base and surface types (Table 4). It was thought that such a summary might be more revealing concerning the factors upon which road performance is dependent. It is recognized that there are many variations of soil due to topography and other factors within the five general soil areas; however, the areas are based upon predominating parent materials. Information on base and surface types were secured from the road inventories as prepared by the Division of Traffic and Planning. Data on hard surface secondary roads was tabulated in a similar manner and is summarized in Table 5.

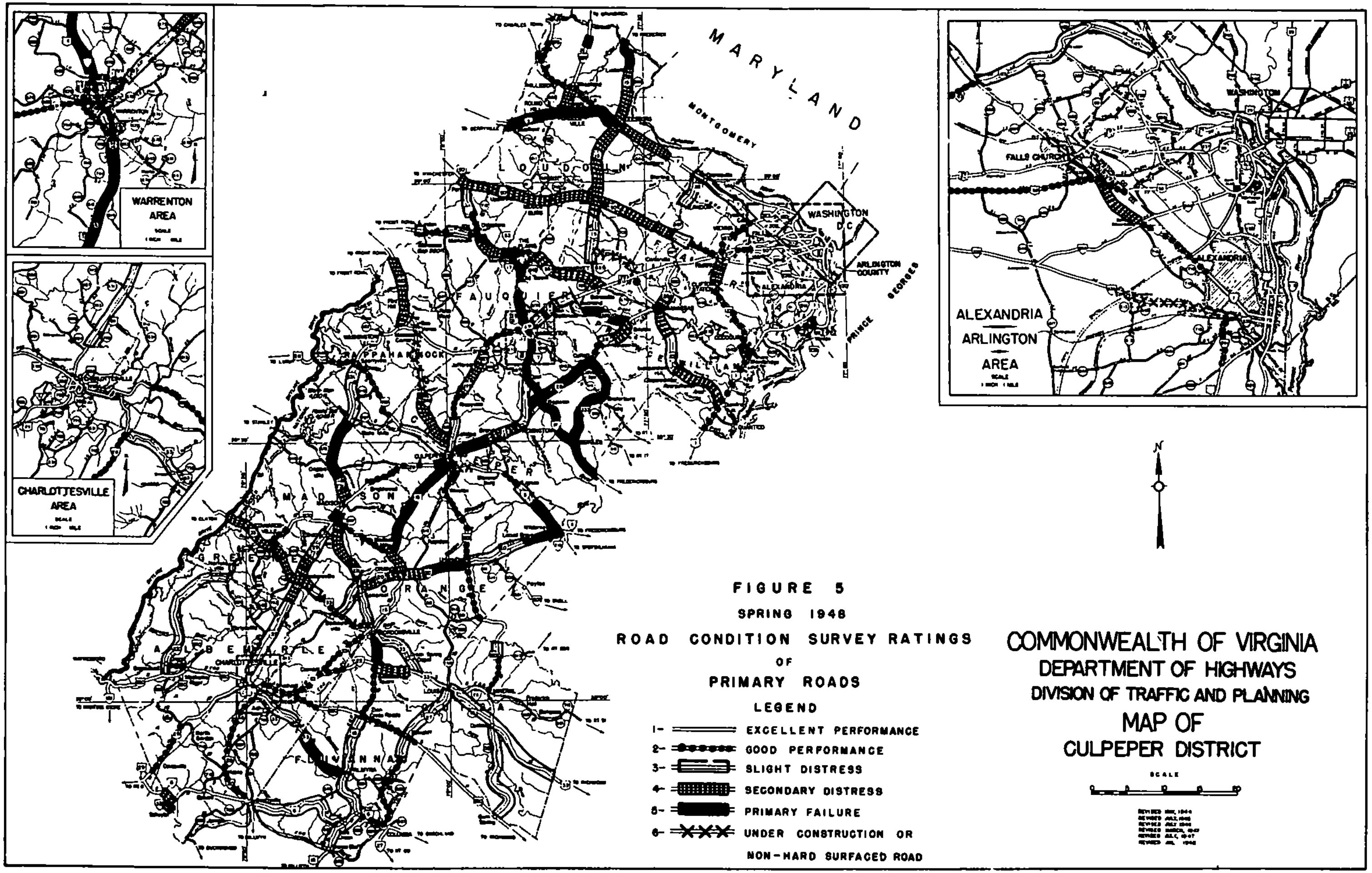

FIGURE 5
SPRING 1948
ROAD CONDITION SURVEY RATINGS OF PRIMARY ROADS

TABLE 2

MILEAGE AND PERCENTAGE BY CONDITION RATINGS

Primary Roads - Culpeper District

County		Condition Ratings 1	2	3	4	5	6[a]	7[b]	Total
Albemarle	mi.	34 95	70.21	24.30	3.12	None	15.49	1.50	149.57
	%	23.4	46 9	16 3	2.1	None	10.3	1.0	100.0
Arlington	mi.	15.30	2.50	13.56	None	None	None	None	31.36
	%	48 8	8.0	43.2	None	None	None	None	100.0
Culpeper	mi.	12.08	18 35	17.71	20.15	16.55	3.50	2.57	91 11
	%	13 3	20.4	19.5	22.0	18.2	3.8	2.8	100.0
Fairfax	mi.	60.78	37.18	27.85	9.62	None	None	None	135.43
	%	44.9	27.4	20 6	7.1	None	None	None	100.0
Fauquier	mi.	0.42	31.00	26 38	11.66	55.15	None	None	124.61
	%	0.3	24.9	21 2	9.3	44.3	None	None	100.0
Fluvanna	mi.	5.93	8.70	51.14	None	9.50	None	None	75.27
	%	7.9	11.6	67.9	None	12.6	None	None	100.0
Greene	mi.	None	5.40	None	22.39	0.50	8.10	None	36.39
	%	None	14.9	None	61.5	1.4	22.2	None	100.0
Loudoun	mi.	14.46	16.55	None	60.18	24.60	3.60	None	119 39
	%	12 1	13.9	None	50.4	20.6	3.0	None	100.0
Louisa	mi.	20.39	22.19	56.01	4.54	4.59	None	None	107.72
	%	18.9	20.6	52.1	4 2	4.2	None	None	100 0
Madison	mi.	13.30	13.55	4.40	12.00	16 80	None	None	60.05
	%	22.2	22.6	7.3	20.0	27.9	None	None	100 0
Orange	mi.	12.44	23 93	23.34	12.23	17.63	None	None	89.57
	%	13.9	26.7	26.0	13.7	19.7	None	None	100.0
Prince William	mi.	18.70	13.80	12.40	27.16	9.03	None	7.81	88.90
	%	21.0	15.5	14.0	30.5	10.2	None	8.8	100.0
Rappahannock	mi.	17.43	15.28	10.39	10 19	None	None	12.70	65.99
	%	26.4	23 2	15.8	15 4	None	None	19.2	100.0
Totals	mi.	226 18	278.84	267.48	193.24	154.35	30.69	24.58	1175.36
	%	19.3	23.8	22.7	16.4	13.1	2.6	2.1	100.0

[a]Under construction
[b]Non-hard surface

Primary Road Bases - Primary road bases were of five types with macadam and natural soil, gravel and stone predominating. These two represent 81.1 percent of primary road bases in the district. Slightly more than 100 mi. of concrete bases and 82.6 mi. of stabilized selected material bases were available for study. Also, one project of soil-cement, 6.8 mi. in length was included. Considering all base types, 44.6 percent were rated good, 22.2 percent fair, and the remaining 33.2 percent classified as poor. The concrete, soil-cement and macadam bases rated above the average for the district. Performance of the stabilized selected materials bases was better than that for the natural soil, gravel, stone, etc. bases.

Figure 13 illustrates variations in performance of the two predominating base types according to soil area. The mileage in percent for each of the three performance ratings is plotted according to the five general soil areas. The upper graphs represent the natural soil, gravel, stone, etc. base while macadam bases are shown below. It will be seen that in all soil areas macadam bases were superior in performance. Both base types performed best when located in the Coastal Plain

TABLE 3
ROAD CONDITION RATINGS BY CLASSIFICATION
Secondary Roads - Culpeper District

County		Hard Surface						Non-Hard Surface						Under Const.	Total Hard Surface, Non-Hard Surface and Under Const.						
		1	2	3	4	5	Sub-total	1	2	3	4	5	Sub-total	6[a]	1	2	3	4	5	6[a]	Total
Albemarle	mi.	21.00	41.41	39.49	27.74	15.15	144.79	46.55	205.76	150.75	81.34	29.66	514.06	None	67.55	247.17	190.24	109.08	44.81	None	658.85
	%	3.2	6.3	6.0	4.2	2.3	22.0	7.1	31.2	22.8	12.4	4.5	78.0	None	10.3	37.5	28.8	16.6	6.8	None	100.0
Culpeper	mi.	0.90	4.69	10.47	9.68	7.35	33.09	None	57.66	171.94	45.60	76.56	351.76	3.80	0.90	62.35	182.41	55.28	83.91	3.80	388.65
	%	0.2	1.2	2.7	2.5	1.9	8.5	None	14.8	44.3	11.7	19.7	90.5	1.0	0.2	16.0	47.0	14.2	21.6	1.0	100.0
Fairfax	mi.	13 62	59 80	73.80	34.04	66.99	248.25	0.85	20 99	74.97	100.48	170.28	367.57	7.64	14.47	80.79	148.77	134.52	237.27	7.64	623.46
	%	2.2	9.6	11.8	5.5	10.7	39.8	0.1	3.4	12.1	16 1	27.3	59.0	1.2	2.3	13.0	23.9	21.6	38.0	1.2	100.0
Fauquier	mi.	3.70	7 14	33.58	12.90	63.62	120.94	4.90	7.10	227.20	158.42	178 82	576.44	None	8.60	14.24	260.78	171.32	242.44	None	697.38
	%	0.5	1.0	4.8	1.9	9.1	17.3	0.7	1.0	32.6	22.8	25.6	82.7	None	1.2	2.0	37.4	24.7	34.7	None	100.0
Fluvanna	mi.	0.20	5.55	6.45	6.65	3 26	22.11	5.70	75.40	62.49	56.20	22.75	222.54	None	5.90	80.95	68.94	62.85	26.01	None	244.65
	%	0.1	2.3	2.6	2 7	1.3	9.0	2 3	30.8	25.6	23.0	9 3	91.0	None	2.4	33.1	28.2	25.7	10.6	None	100.0
Greene	mi.	2.00	None	7.30	None	None	9.30	None	47.19	52.43	11.92	38.21	149.75	None	2.00	47.19	59.73	11.92	38.21	None	159.05
	%	1.3	None	4.6	None	None	5.9	None	29.6	33.0	7.5	24.0	94.1	None	1.3	29.6	37.6	7.5	24.0	None	100.0
Loudoun	mi.	0.35	22.82	15.00	9.78	47.83	95.78	None	88.85	269.60	59.60	126.54	544.59	None	0.35	111.67	284.60	69.38	174.37	None	640.37
	%	0.1	3.6	2.3	1.5	7.5	15.0	None	13.9	42.1	9.3	19.7	85.0	None	0.1	17.5	44.4	10.8	27.2	None	100.0
Louisa	mi.	None	10.00	18.12	18 25	3.00	49.37	None	56.44	114.86	104.40	70.75	346.45	7.30	None	66.44	132.98	122.65	73.75	7.30	403.12
	%	None	2.5	4.5	4.5	0.7	12.2	None	14.0	28.5	25.9	17.6	86.0	1.8	None	16.5	33.0	30.4	18.3	1.8	100.0
Madison	mi.	6.85	2.26	4.10	6.44	9.07	28.72	10.40	53 58	38.61	69.96	98.15	270.70	None	17.25	55.84	42.71	76.40	107.22	None	299.42
	%	2.3	0.8	1.4	2.1	3.0	9.6	3.5	17.9	12.9	23.3	32.8	90.4	None	5.8	18.7	14.3	25.4	35.8	None	100.0
Orange	mi.	16.95	6.44	10.88	10 84	11.86	56.97	6.50	28.49	56.27	58.24	115.10	264.60	None	23.45	34.93	67.15	69.08	126.96	None	321.57
	%	5.2	2.0	3.4	3.4	3.7	17.7	2.0	8.9	17.5	18 1	35.8	82.3	None	7.2	10.9	20.9	21.5	39.5	None	100.0
Prince William	mi.	2.47	0.90	6.70	9.16	24.58	43.81	None	22.92	139.27	79.72	40.01	281.92	None	2.47	23.82	145.97	88.88	64.59	None	325.73[b]
	%	0.8	0.3	2.1	2.8	7.5	13 5	None	7.0	42.7	24.5	12.3	86.5	None	0.8	7.3	44.9	27.3	19.8	None	100.0
Rappahannock	mi.	2.20	1.10	None	None	1.05	4.35	None	2.50	35.05	63.05	91.27	191.87	None	2.20	3.60	35.05	63.05	92.32	None	196.22[c]
	%	1.1	0.6	None	None	0.5	2.2	None	1.3	17.9	32.1	46.5	97 8	None	1.1	1.9	17.9	32.1	47.0	None	100.0
Totals	mi.	70.24	162.11	225.89	145.48	253.76	857.48	74.90	666.88	1393.44	888.93	1058.10	4082.25	18.74	145.14	828.99	1619.33	1034.41	1311.86	18.74	4958.47
	%	1.4	3.3	4.5	2.9	5.2	17.3	1.5	13.5	28.1	17.9	21.3	82.5	0.4	2.9	16.8	32.6	20.8	26.5	0.4	100.0

[a]Under construction
[b]Does not include 53.46 miles of secondary road which received no maintenance
[c]Does not include 5.90 miles not shown on map

TABLE 4

PRIMARY ROAD MILEAGE ACCORDING TO PERFORMANCE BY SOIL AREAS, BASE AND SURFACE TYPES

Culpeper District

	Soil Area		Coastal Plain Sediments			High Quartz Granitoids			Low Quartz Granitoids			Extrusive Rocks			Triassic "Red Beds"			Totals for Dist.			Totals
	Performance		Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Totals
Base Type	1[a] Natural Soil, Gravel, etc.	mi.	5.0	0	2.2	43.6	102.7	62.3	0	11.1	2.4	1.3	13.3	10.8	5.9	5.5	72.9	55.8	132.6	150.6	339.0
		%	69.5	0	30.5	20.9	50.6	29.5	0	82.3	17.7	5.1	52.4	42.5	6.9	6.5	86.6	16.5	39.1	44.4	31.8
	2. Stabilized Selected Material	mi.	0	0	0	24.0	17.6	18.8	0	0	0	0	0	8.8	4.9	2.4	6.1	28.9	20.0	33.7	82.6
		%	0	0	0	39.8	29.2	31.0	0	0	0	0	0	100.0	36.6	17.9	45.5	35.0	24.3	40.7	7.8
	3. Soil-Cement	mi.	0	0	0	6.8	0	0	0	0	0	0	0	0	0	0	0	6.8	0	0	6.8
		%	0	0	0	100.0	0	0	0	0	0	0	0	0	0	0	0	100.0	0	0	0.6
	7. Macadam	mi.	2.0	0	0	112.7	24.7	31.1	44.8	0	6.5	84.9	28.8	57.3	37.4	30.2	75.7	281.8	83.7	170.6	536.1
		%	100.0	0	0	66.8	14.7	18.5	87.4	0	12.6	49.6	16.9	33.5	26.1	21.1	52.8	52.4	15.6	32.0	50.3
	8. Concrete	mi.	28.2	0	0	46.5	0	0	1.8	0	0	10.1	0	0	16.2	0	0	102.8	0	0	102.8
		%	100.0	0	0	100.0	0	0	100.0	0	0	100.0	0	0	100.0	0	0	100.0	0	0	9.5
	Totals	mi.	35.2	0	2.2	233.6	145.0	112.2	46.6	11.1	8.9	96.3	42.1	76.9	64.4	38.1	154.7	476.1	236.3	354.9	1067.3
		%	94.1	0	5.9	47.5	29.6	22.9	69.9	16.7	13.4	44.7	19.6	35.7	25.0	14.8	60.2	44.6	22.2	33.2	100.0
Surface Type	5[a] Surface Treatment	mi.	7.0	0	2.2	157.7	145.0	107.2	7.7	11.1	8.9	52.0	40.2	48.7	48.2	38.1	152.3	272.6	234.4	319.3	826.3
		%	76.1	0	23.9	38.5	35.4	26.1	27.8	40.1	32.1	36.9	28.6	34.5	20.2	16.0	63.8	33.0	28.4	38.6	77.4
	6. Plant Mix	mi.	28.2	0	0	67.9	0	5.0	38.9	0	0	34.2	1.9	28.2	13.2	0	2.4	182.4	1.9	35.6	219.9
		%	100.0	0	0	93.1	0	6.9	100.0	0	0	53.2	3.0	43.8	84.6	0	15.4	82.9	0.9	16.2	20.6
	8. Concrete	mi.	0	0	0	8.0	0	0	0	0	0	10.1	0	0	3.0	0	0	21.1	0	0	21.1
		%	0	0	0	100.0	0	0	0	0	0	100.0	0	0	100.0	0	0	100.0	0	0	2.0
	Totals	mi.	35.2	0	2.2	233.6	145.0	112.2	46.6	11.1	8.9	96.3	42.1	76.9	64.4	38.1	154.7	476.1	236.3	354.9	1067.3
		%	94.1	0	5.9	47.5	29.6	22.9	69.9	16.7	13.4	44.7	19.6	35.7	25.0	14.8	60.2	44.6	22.2	33.2	100.0
	Totals by Soil Areas	mi.	37.4 mi. (3.5%)			490.8 mi. (46.0%)			66.6 mi. (6.2%)			215.3 mi. (20.2%)			257.2 mi. (24.1%)			1067.3 mi. (100.0%)			

[a]Traffic and Planning Division Code Numbers

Figure 6. Failure of A Primary Highway (Surface Treated Water-Bound Macadam) - Rt. 29, Culpeper County - This portion of the road is located in Triassic "Red Bed" soil area. Approximately 60 percent of the primary roads in this soil area were rated as poor at the time of the spring break-up.

Figure 7. Failure of a Surface Treated Selected Soil Base Road in the Triassic "Red Bed" Soil Area - Rt. 15, Culpeper County - Note typical topography and drainage for this soil area.

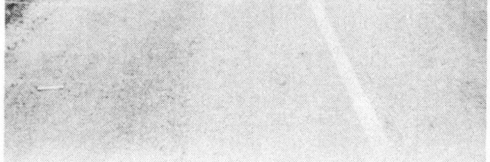

Figure 8. Good Performance of Bituminous Surface Treated Macadam Base in Extrusive Rocks Soil Area - Rt. 15, Orange County.

Sediments soil area. Poorest performance was obtained in the Triassic "Red Bed" soil area.

Hard Surface Secondary Road Bases - According to the road inventories, hard surface secondary road bases include 689.2 mi. (80 percent) stabilized selected materials, 160.9 mi. (18.9 percent) macadam

Figure 9. Alligator Cracking and Disintegration of Surface Treated Selected Soil Base Road in High-Quartz Granitoid Soil Area - Rt. 3, Orange County. Because of their high silt content these soils are subject to frost action.

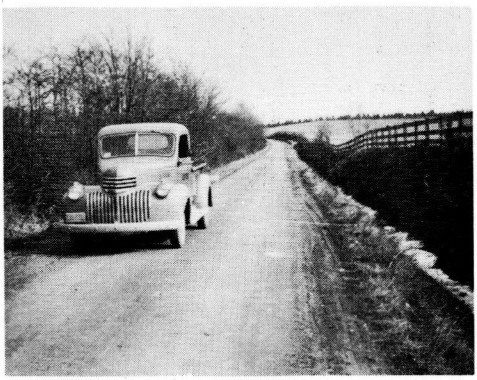

Figure 10. Failure of a Surface Treated Mechanically Stabilized Base Secondary Road in the Triassic "Red Bed" Soil Area Rt. 669, Culpeper County.

Figure 11. Excellent Performance of a Surface Treated Macadam Base Secondary Road, Rt. 627, Orange County.

and only 3.3 miles of concrete bases. In performance the concrete bases rated best followed by the macadam and the stabilized selected materials. Performance of the stabilized selected material and macadam bases according to soil area are illustrated graphically in Figure 14. Again, base performance is variable depending upon the soil area in which it is located. Considering only the stabilized selected material base (which constituted more than 80 percent of the bases), performance was

TABLE 5

HARD SURFACE SECONDARY ROAD MILEAGE ACCORDING TO PERFORMANCE BY SOIL AREAS, BASE AND SURFACE TYPES

Culpeper District

	Soil Area / Performance		Coastal Plain Sediments Good	Coastal Plain Sediments Fair	Coastal Plain Sediments Poor	High Quartz Granitoids Good	High Quartz Granitoids Fair	High Quartz Granitoids Poor	Low Quartz Granitoids Good	Low Quartz Granitoids Fair	Low Quartz Granitoids Poor	Extrusive Rocks Good	Extrusive Rocks Fair	Extrusive Rocks Poor	Triassic "Red Beds" Good	Triassic "Red Beds" Fair	Triassic "Red Beds" Poor	Totals for Dist Good	Totals for Dist Fair	Totals for Dist Poor	Totals
Base Type	2[a] Stabilized Selected Materials	mi	32.2	28.3	24.9	50.0	97.8	214.8	16.3	16.9	14.6	20.8	29.9	35.0	28.3	14.4	65.0	147.6	187.3	354.3	689.2
		%	37.7	33.2	29.1	13.8	27.0	59.2	34.1	35.4	30.5	24.3	34.9	40.8	26.3	13.4	60.3	21.4	27.2	51.4	80.7
	7. Macadam	mi	0	0	0	31.5	11.7	6.4	37.4	5.9	3.3	7.0	9.6	17.7	5.7	9.6	15.1	81.6	36.8	42.5	160.9
		%	0	0	0	63.5	23.6	12.9	80.2	12.7	7.1	20.4	28.0	51.6	18.8	31.5	49.7	50.7	22.9	26.4	18.9
	8 Concrete	mi	1.8	0	0	0.2	0.7	0	0	0	0	0.6	0	0	0	0	0	2.6	0.7	0	3.3
		%	100.0	0	0	22.2	77.8	0	0	0	0	100.0	0	0	0	0	0	78.8	21.2	0	0.4
	Totals	mi.	34.0	28.3	24.9	81.7	110.2	221.2	53.7	22.8	17.9	28.4	39.5	52.7	34.0	24.0	80.1	231.8	224.8	396.8	853.4
		%	39.0	32.4	28.6	19.8	26.7	53.5	56.9	24.1	19.0	23.5	32.8	43.7	24.6	17.4	58.0	27.2	26.4	46.4	100.0
Surface Type	4[a] Light Surface Treatment	mi	32.2	28.3	24.9	81.5	109.5	221.2	51.5	22.8	17.9	25.3	37.0	52.7	34.0	24.0	79.8	224.5	221.6	396.5	842.6
		%	37.7	33.2	29.1	19.8	26.6	53.6	55.9	24.8	19.3	22.0	32.2	45.8	24.7	17.4	57.9	26.6	26.3	47.1	98.7
	5. Heavy Surface Treatment	mi	0	0	0	0	0	0	2.2	0	0	2.5	2.5	0	0	0	0.3	4.7	2.5	0.3	7.5
		%	0	0	0	0	0	0	100.0	0	0	50.0	50.0	0	0	0	100.0	62.7	33.3	4.0	0.9
	8 Concrete	mi.	1.8	0	0	0.2	0.7	0	0	0	0	0.6	0	0	0	0	0	2.6	0.7	0	3.3
		%	100.0	0	0	22.2	77.8	0	0	0	0	100.0	0	0	0	0	0	78.8	21.2	0	0.4
	Totals	mi.	34.0	28.3	24.9	81.7	110.2	221.2	53.7	22.8	17.9	28.4	39.5	52.7	34.0	24.0	80.1	231.8	224.8	396.8	853.4
		%	39.0	32.4	28.6	19.8	26.7	53.5	56.9	24.1	19.0	23.5	32.8	43.7	24.6	17.4	58.0	27.2	26.4	46.4	100.0
	Totals by Soil Areas		87.2 mi. (10.2%)			413.1 mi (48.4%)			94.4 mi. (11.1%)			120.6 mi (14.1%)			138.1 mi (16.2%)			853.4 mi. (100.0%)			

[a]Traffic and Planning Division Code Numbers

Figure 12. Distress of a Surface Treated Mechanically Stabilized Base Secondary Road - Rt. 609, Culpeper County.

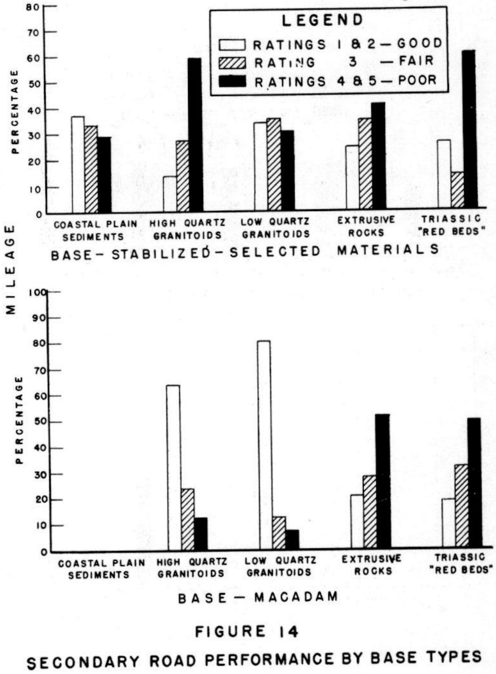

Figure 14. Secondary Road Performance by Base Types.

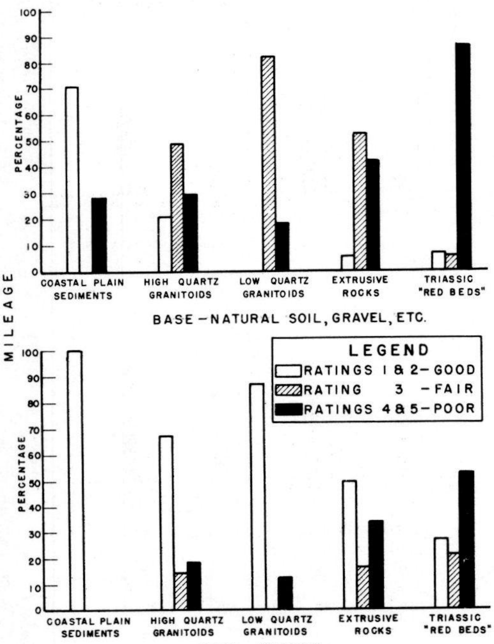

Figure 13. Primary Road Performance by Base Types.

best in the Coastal Plain and poorest in the Triassic soil area.

Primary Road Surfaces - Primary road surfaces are classified into three types by the road inventory, namely surface treatment (77.4 percent), bituminous plant mix (20.6 percent), and portland cement concrete (2.0 percent). All concrete surfaces were rated good in performance. Bituminous plant mix surfaces were generally good and 82.7 percent of them were so rated. Only those that were 8 or 10 yr. old and in need of a seal coat rated fair or poor. About one-third of the bituminous surface treatments rated good, while 38.6 percent were classified as poor. Figure 15 illustrates performance of plant mix and surface treatment.

Secondary Road Surfaces - While the surfaces of secondary roads were of four types, light surface treatments predominate since 98.7 percent were of this category. Performance in the five general soil areas is illustrated by Figure 16.

To further illustrate the correlation of road performance with soil areas Figure 17 has been prepared. The top portion shows that primary road performance is best in the Coastal Plain Sediments and poorest in the Triassic "Red Bed"

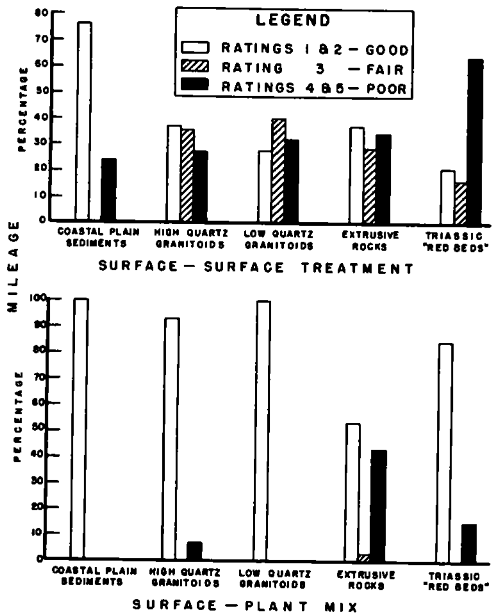

Figure 15. Primary Road Performance by Surface Types.

soils area. In general, this is further emphasized by the lower graphs.

SUMMARY OF RESULTS

Based upon the performance data obtained at the time of the spring break-up on more than 1000 mi. of primary and nearly 5000 mi. of secondary roads in Culpeper District, the following results have been summarized under appropriate headings.

Primary Roads

1. The break-up of this past spring of primary roads in the Culpeper District was more severe than that for the entire state. A comparison of primary highways in each performance rating is as follows:

Performance Rating	Culpeper District %	Entire State %
Good	43	58
Fair	23	23
Poor	29	18
Under Const.	5	1

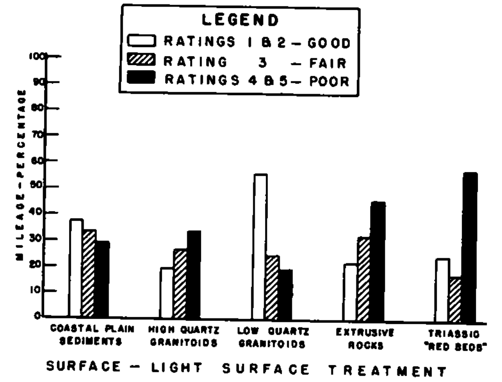

Figure 16. Secondary Road Performance by Surface Types.

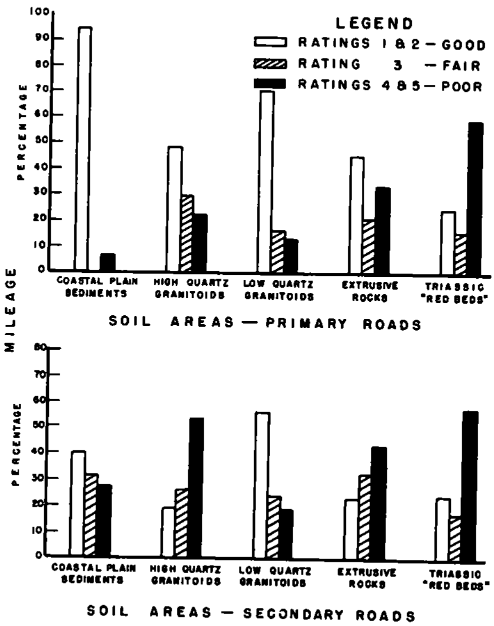

Figure 17. Primary and Secondary Road Performance by Soil Areas.

2. Primary road performance was variable, depending upon the design (base and surface type) and the soil area in which the road was located.

3. The order of rating the performance of bases from best to the poorest was as follows: (1) portland cement concrete, (2) soil-cement, (3) macadam, (4) stabilized selected materials and (5) natural soils, gravel, stone, etc. It

should be pointed out, however, that only one soil-cement project, 6.8 mi. in length was available for this comparison.

4. Considering the bituminous surfaces which comprise 98 percent of the primary road surfaces in the district, the performance of bituminous plant mix was far superior to that of ordinary surface treatment.

5. The study emphasized the importance of the general soil area as a major variable in road performance. Considering all the primary roads, the least amount of distress was found in the Coastal Plain Sediments and the most was evident in the Triassic "Red Bed" soil area.

Secondary Roads

6. Survey results also show that the spring break-up was more severe on secondary roads in the Culpeper District than for the entire secondary system in the state. This statement is based upon the following comparison:

SECONDARY ROAD PERFORMANCE

Performance Rating	Culpeper District	Entire State (8 Districts)
	%	%
Good	19	33
Fair	33	29
Poor	47	37
Under Const.	1	1

It should be emphasized that a greater percentage of Triassic "Red Bed" soil area is located in the Culpeper District than in the entire state and this probably is largely responsible for the differential performance.

7. The hard surface secondary roads performed slightly better than the non-hard surface ones as shown below:

Performance Rating	Hard Sur.	Non-Hard Sur.
	%	%
Good	27	18
Fair	26	35
Poor	47	47

8. As in the case of primary highways, secondary road performance also varied with the design (base and surface type) as well as the soil area.

9. The order of rating secondary road bases from best to poorest in the Culpeper District was as follows: concrete, macadam and stabilized selected material. More than 80 percent of hard surface secondary road bases in the district were of the latter type.

10. While insufficient data were available for conclusive comparisons, it was indicated that heavy surface treatments resulted in better performance than light surface treatments.

General

11. The survey revealed that the higher the class or type of pavement the better the performance.

12. A study of weather records revealed that pavement break-ups are most severe for those winters with low temperatures preceded by subgrade and base saturation (high precipitation). The past winter was second only to that of 1935-36 as to climatic conditions favorable for a severe break-up.

13. The field studies throughout the state emphasized the importance of adequate provisions for drainage if good road performance is to be secured. In cases of flat topography it was indicated that improved performance can be secured by the use of a high level profile.

14. One of the most important results of the survey was the correlation of road performance with soil area. This suggests that design and construction practices should be varied with this important item.

CONCLUSIONS

In conclusion, road condition surveys, if made at a time of a severe spring break-up, are a practical means of securing information on the extent of distress and can be used successfully in evaluating factors affecting performance. Data from such surveys can also be used in conjunction with maintenance or reconstruction programs and for formulating policies regarding design and construction practices.

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