ROAD LIFE STUDIES

AND

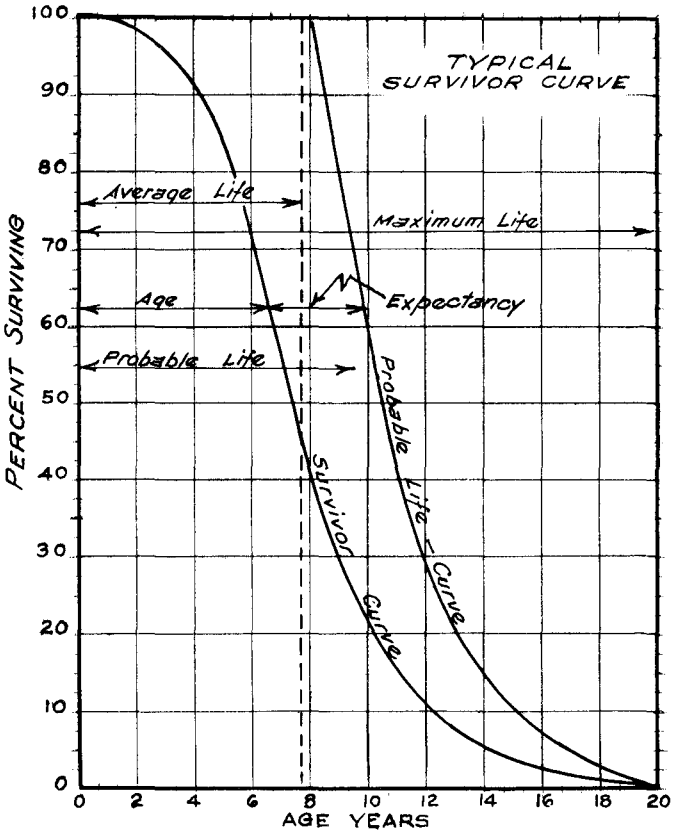
THEIR APPLICATION

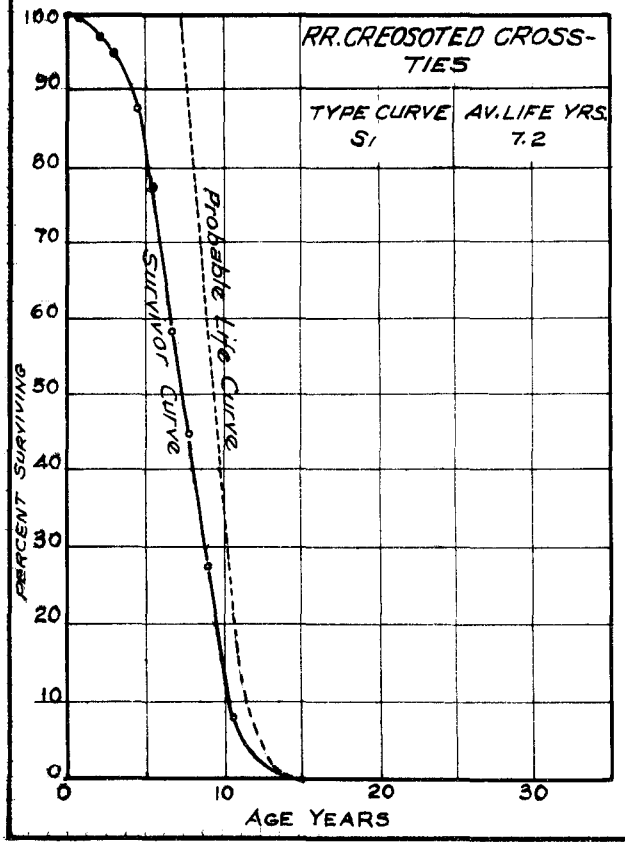
TEXAS HIGHWAY PLANNING SURVEY
FEBRUARY, 1949

It will be the purpose of this discussion to explain the preparation of Survivor Curves in application to Road Life Studies. At the same time, current data obtained by the Highway Planning Survey will be presented for use of engineers having occasion to apply the findings in their operations. This discussion will be strictly confined to rural roadways.

In common form, a Survivor Curve carries the per cent of the survivors of any sample plotted against the ages at which observations were made and extends from the origin of the sample to the age of the last survivor. The upper diagram on Plate I, following this sheet, presents a typical Survivor Curve. The lower left diagram on Plate I, presents such a curve as applied to Rail Road Creosoted Cross Ties.

In a study made by Robley Winfrey, M. S., Research Engineer, and reported in Bulletin 125, Iowa Engineering Experiment Station, entitled "Statistical Analyses of Industrial Property Retirements", the application of Survivor Curves to replacement requirements on many industrial properties has been shown. It is shown that the similarity of the curves for industrial properties of various kinds is such that predictions may be made on any industrial property though only short term records may be available. The principles outlined in this publication have been applied to the various components of highway construction. The Survivor Curve for Bituminous Penetration Surface one inch or more in thickness on Flexible Base as determined from studies of the Texas experience, and for which a long term history is available, is placed on Plate I to illustrate


TYPICAL
SURVIVOR CURVE
Average Life
Maximum Life
Age
Expectancy
Probable Life
Probable Life Curve
Survivor Curve
PERCENT SURVIVING
AGE YEARS


RR. CREOSOTED CROSS-TIES
TYPE CURVE S1
AV. LIFE YRS. 7.2
Survivor Curve
Probable Life Curve
PERCENT SURVIVING
AGE YEARS

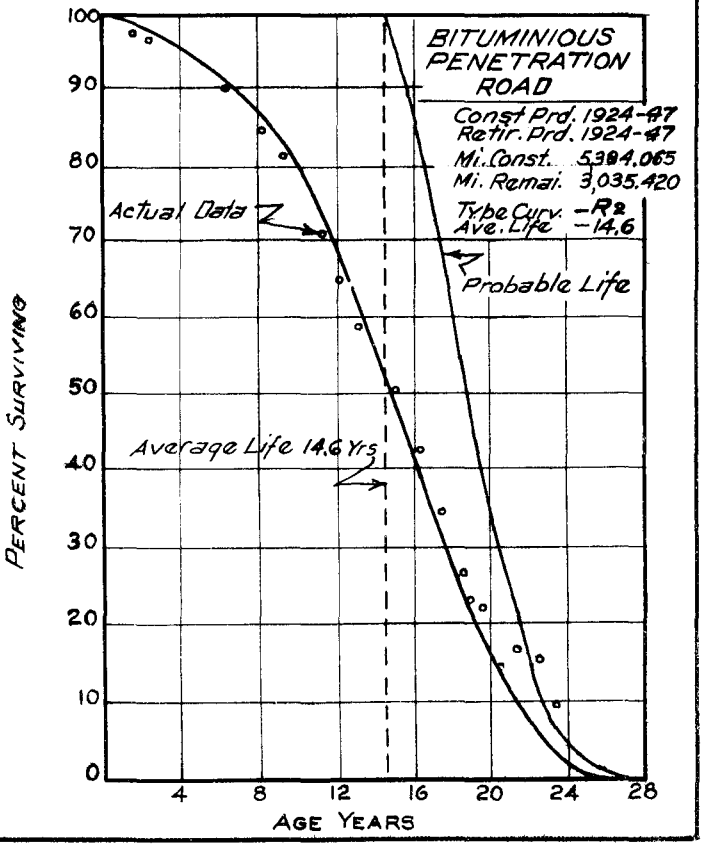

BITUMINIOUS PENETRATION ROAD
Const Prd. 1924-47
Retir. Prd. 1924-47
Mi. Const. 5,384.065
Mi. Remai. 3,035.420
Type Curv. -R2
Ave. Life -14.6
Actual Data
Probable Life
Average Life 14.6 Yrs
PERCENT SURVIVING
AGE YEARS

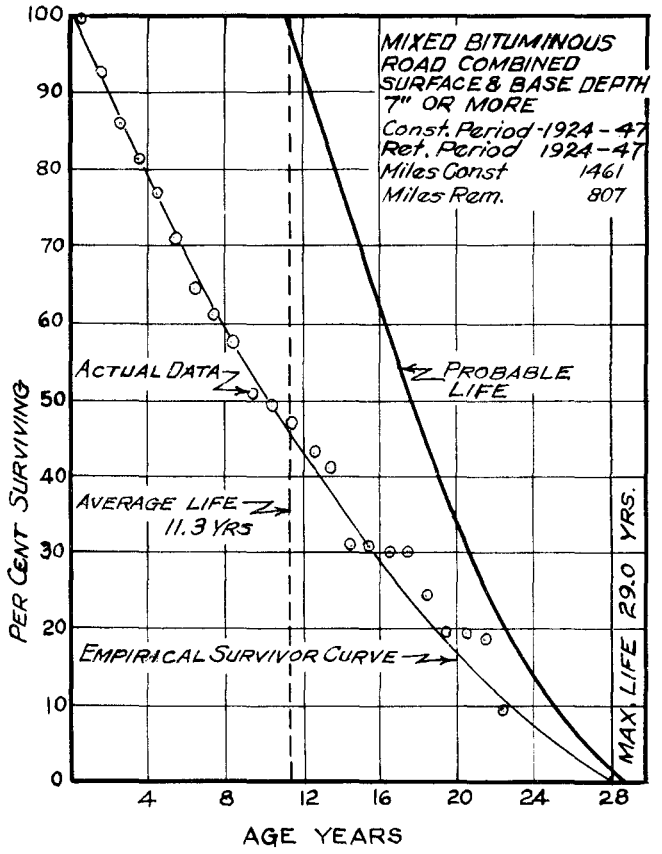
PLATE I

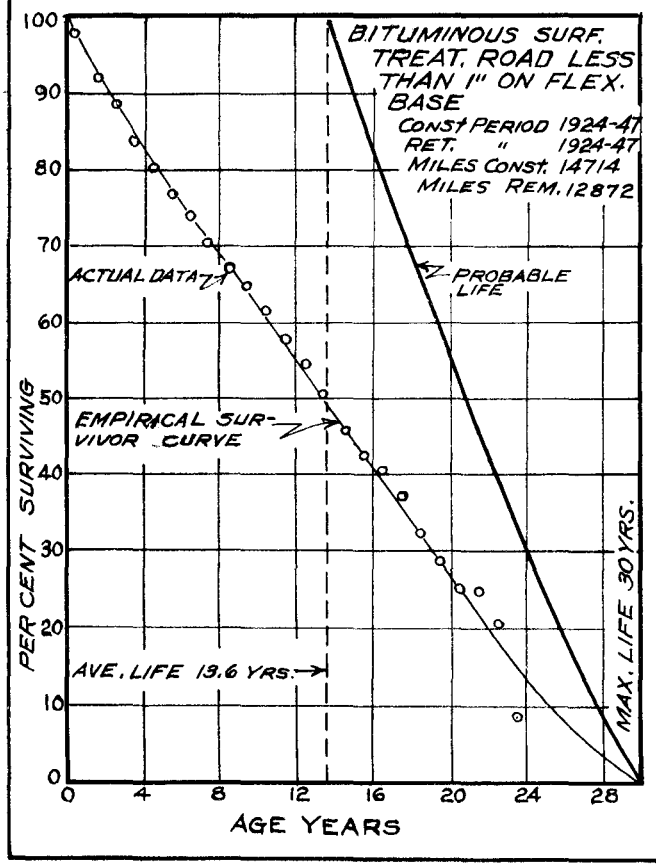
this similarity.

The Texas Highway Planning Survey has developed Survivor Curves, based on physical retirement, from the complete experience records of the Texas Highway Department to cover the common types of pavement. The unit of measurement in this study is the mile. Abandonment, relocation, reconstruction to the same or any other type, or transfer from the Highway System constitutes retirement. The application of a seal coat, widening without reconstruction of the base and surface, or extensive special maintenance not effecting a change in type, does not constitute a retirement. These facts should be known for intelligent use of the determinations.

Plate II, following this sheet, presents Survivor Curves for "Bituminous Surface Treated Road less than one inch in thickness on Flexible Base," "Bituminous Penetration Surface one inch or more in thickness on Flexible Base where the combined thickness of base and surface is seven inches or more," and "Mixed Bituminous Surface where the combined thickness of Base and Surface is seven inches or more," Plate III, in a like manner, presents curves for "Bituminous Concrete, Sheet Asphalt or Rock Asphalt one inch or more in thickness on bases of all types," and "Portland Cement Concrete Road."

These curves are produced by the Annual-Rate method whereby the percentage of retirements is calculated for each year of age for all surfaces of that age exposed to retirement. The sample thus becomes smaller as the age increases and it will be noted that the actual data for the advanced


MIXED BITUMINOUS ROAD COMBINED SURFACE & BASE DEPTH 7" OR MORE
Const. Period 1924-47
Ret. Period 1924-47
Miles Const 1461
Miles Rem. 807
ACTUAL DATA
PROBABLE LIFE
AVERAGE LIFE 11.3 YRS
EMPIRICAL SURVIVOR CURVE
MAX. LIFE 29.0 YRS.
PER CENT SURVIVING
AGE YEARS


BITUMINOUS SURF. TREAT. ROAD LESS THAN 1" ON FLEX. BASE
CONST PERIOD 1924-47
RET. " 1924-47
MILES CONST. 14714
MILES REM. 12872
ACTUAL DATA
PROBABLE LIFE
EMPIRICAL SURVIVOR CURVE
AVE. LIFE 13.6 YRS.
MAX. LIFE 30 YRS.
PER CENT SURVIVING
AGE YEARS

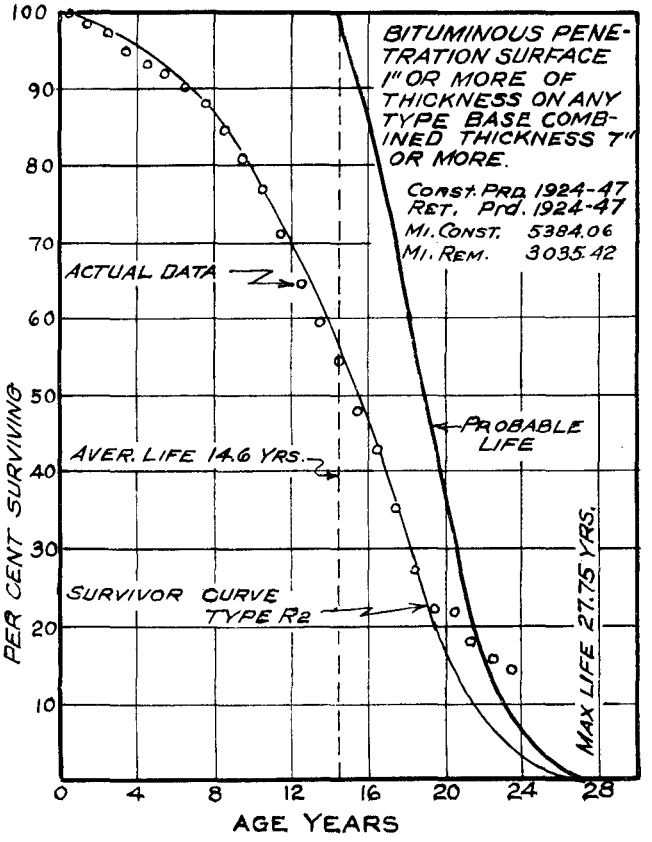
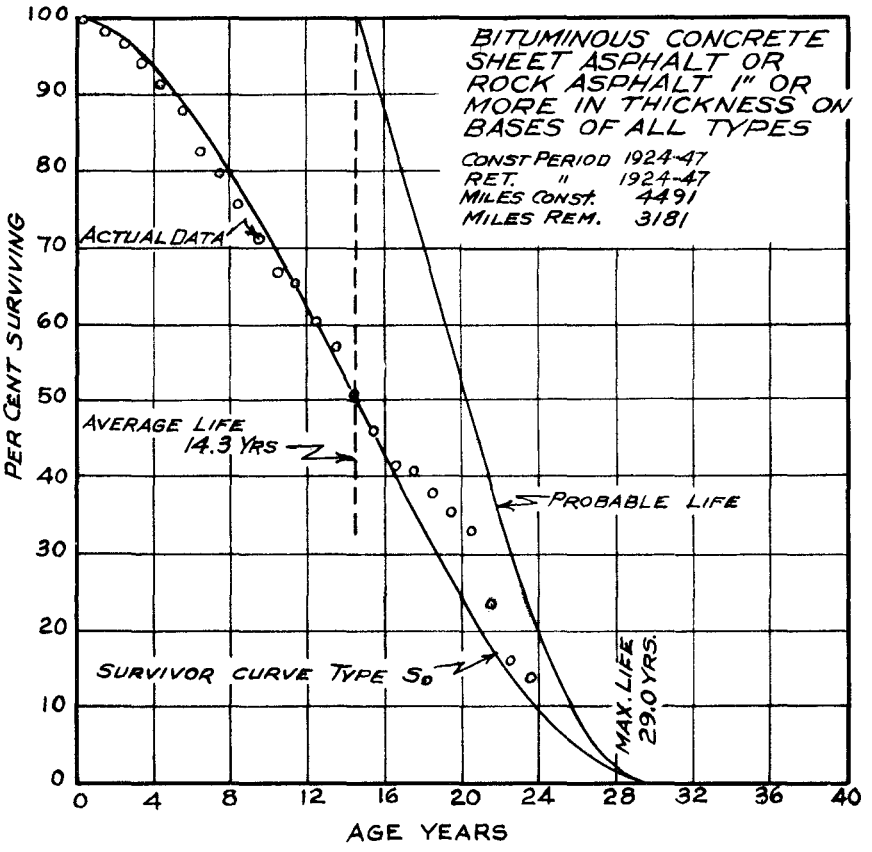

BITUMINOUS PENETRATION SURFACE 1" OR MORE OF THICKNESS ON ANY TYPE BASE COMBINED THICKNESS 7" OR MORE.
Const. Prd. 1924-47
Ret. Prd. 1924-47
Mi. Const. 5384.06
Mi. Rem. 3035.42
ACTUAL DATA
PROBABLE LIFE
AVER. LIFE 14.6 YRS.
SURVIVOR CURVE TYPE R2
MAX LIFE 27.75 YRS.
PER CENT SURVIVING
AGE YEARS

PLATE II


BITUMINOUS CONCRETE SHEET ASPHALT OR ROCK ASPHALT 1" OR MORE IN THICKNESS ON BASES OF ALL TYPES
CONST PERIOD 1924-47
RET. " 1924-47
MILES CONST. 4491
MILES REM. 3181
ACTUAL DATA
AVERAGE LIFE 14.3 YRS
PROBABLE LIFE
SURVIVOR CURVE TYPE S0
MAX. LIFE 29.0 YRS.
PER CENT SURVIVING
AGE YEARS
0 4 8 12 16 20 24 28 32 36 40
0 10 20 30 40 50 60 70 80 90 100

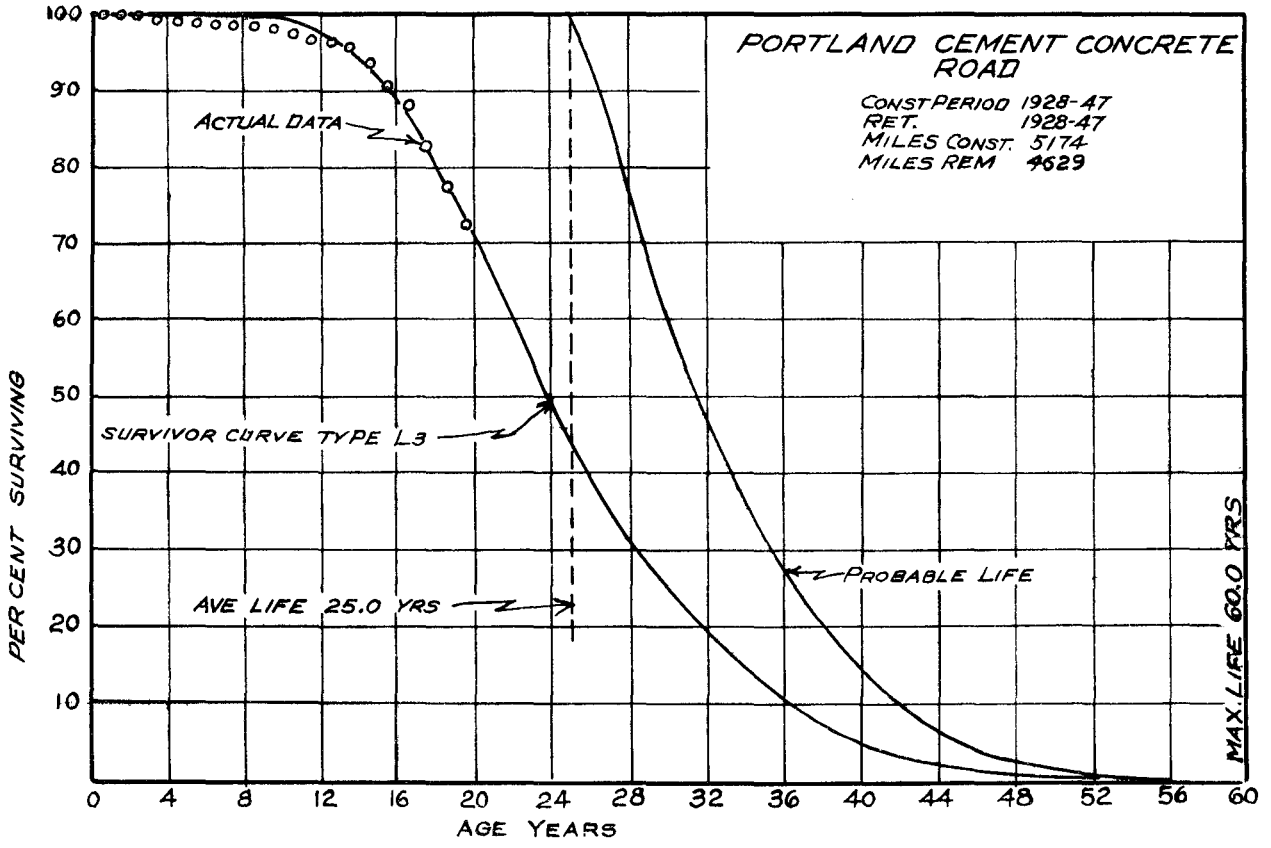

PORTLAND CEMENT CONCRETE ROAD
CONST PERIOD 1928-47
RET. 1928-47
MILES CONST. 5174
MILES REM 4629
ACTUAL DATA
SURVIVOR CURVE TYPE L3
AVE LIFE 25.0 YRS
PROBABLE LIFE
MAX. LIFE 60.0 YRS
PER CENT SURVIVING
AGE YEARS
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60
10 20 30 40 50 60 70 80 90 100

PLATE III

ages tends to become erratic. Retarded retirements during the war years are clearly indicated by the curves of the shorter life pavements. The extent of life available for study is indicated by the actual data plotted.

The Probable Life curves on the diagrams of Plates II and III afford the determination of the remaining useful life to be expected after any given age has been reached. It may be used in assigning a remaining life to existing pavements in economic studies.

The Survivor Curves on Plates II and III reveal retirements for all reasons. To provide for estimating the extent of replacements, the following percentages have been determined.

Classification of Retirements
1917 thru 1947

Class	Asphalt Types %	Concrete and Brick %
Resurfaced	59	51
Reconstructed	24	18
Abandoned*	3	3
Transferred*	14	28
Total	100	100

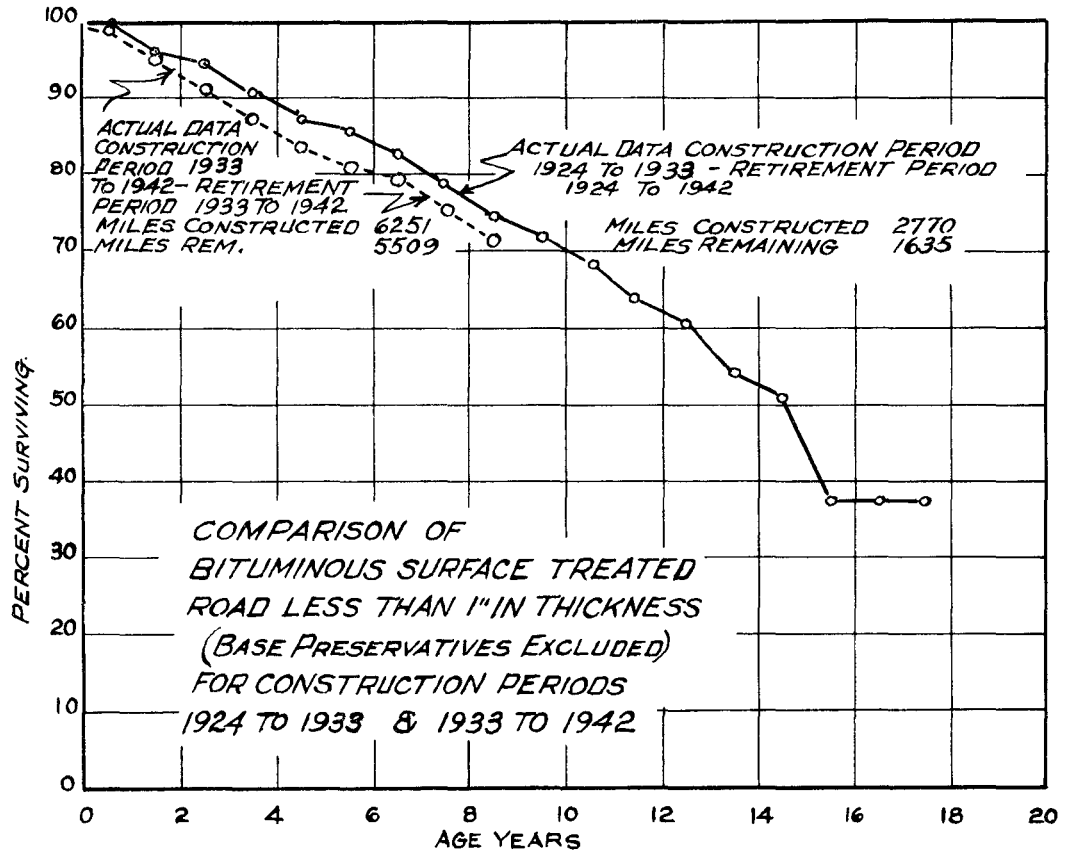
* Abandoned and transferred represent principally replacements by new construction on relocations.

These curves may be used in estimating the future pavement replacement requirement of the Texas Highway System. There was once a common belief that

a highway became permanent when paved. It is now known that only the demand for traffic service is permanent. The fact that periodic replacement to a higher standard at increased cost is required to provide for heavier traffic volumes and increased wheel loads is accepted. Past history may serve to guide the engineering profession in estimating the extent of the replacement problem. The argument that better construction has broken the trend is unfounded. Advancement in design has been more than equalized by the increase in traffic demand, and as a whole, the life of roads has not varied greatly with the times. With continued increase in knowledge of road construction and funds for expenditure, a balance has hardly been maintained with the increasing destruction by traffic. Plate IV presents the actual data for retirements on construction from 1924 to 1932 compared with that from 1932 to 1941 for the prevailing asphalt types. These data support the fact that past trends may reasonably be expected to continue.

The Survivor Curves have been prepared to cover a long period of construction and retirement. On occasion, it may be desirable to consider construction over a short period of time in order to illustrate an advance in design or a particular service condition. This may readily be accomplished from Road Life records. It must be borne in mind that determinations are applicable as averages. Individuals may be expected to vary greatly. The averages will, however, hold true.

In estimating the replacements which will be required on the Texas system as a whole, it is convenient to break it into two general classifications. All asphalt types have been combined as one class and concrete and brick


ACTUAL DATA CONSTRUCTION PERIOD 1933 TO 1942 - RETIREMENT PERIOD 1933 TO 1942
MILES CONSTRUCTED 6251
MILES REM. 5509
ACTUAL DATA CONSTRUCTION PERIOD 1924 TO 1933 - RETIREMENT PERIOD 1924 TO 1942
MILES CONSTRUCTED 2770
MILES REMAINING 1635
COMPARISON OF BITUMINOUS SURFACE TREATED ROAD LESS THAN 1" IN THICKNESS (BASE PRESERVATIVES EXCLUDED) FOR CONSTRUCTION PERIODS 1924 TO 1933 & 1933 TO 1942
PERCENT SURVIVING
AGE YEARS

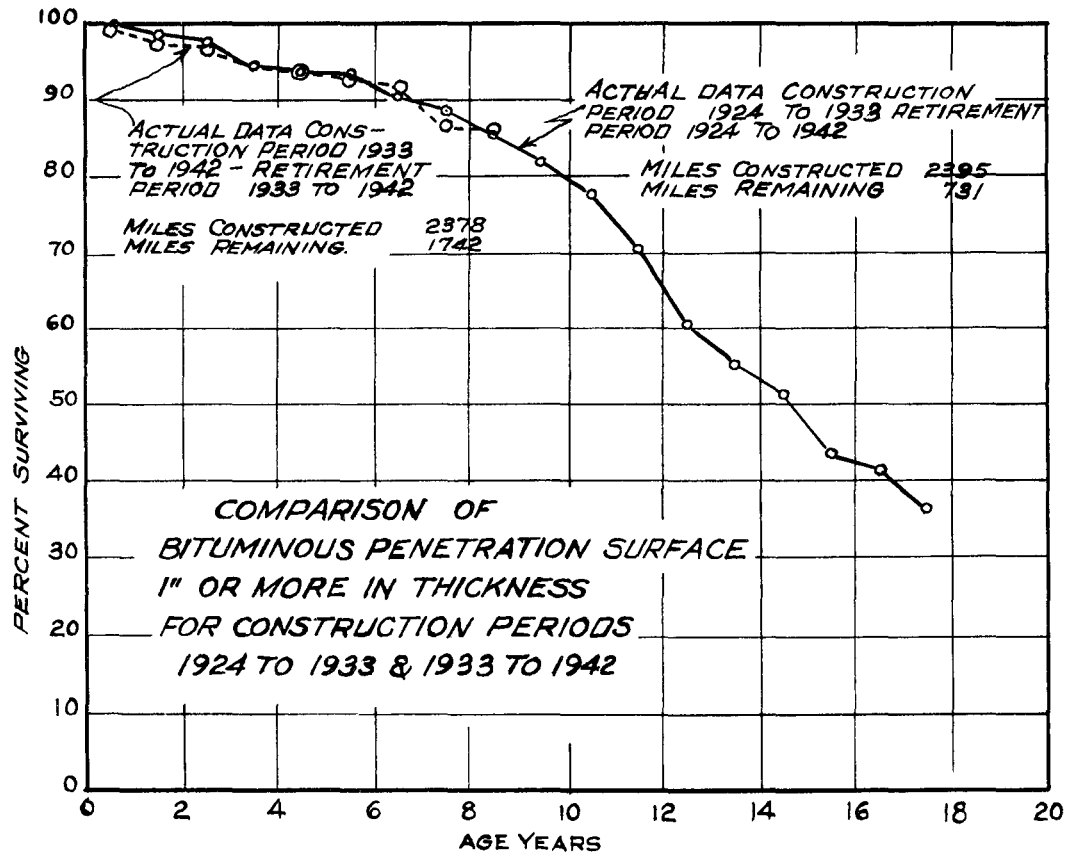

ACTUAL DATA CONS-TRUCTION PERIOD 1933 TO 1942 - RETIREMENT PERIOD 1933 TO 1942
MILES CONSTRUCTED 2378
MILES REMAINING 1742
ACTUAL DATA CONSTRUCTION PERIOD 1924 TO 1933 RETIREMENT PERIOD 1924 TO 1942
MILES CONSTRUCTED 2395
MILES REMAINING 731
COMPARISON OF BITUMINOUS PENETRATION SURFACE 1" OR MORE IN THICKNESS FOR CONSTRUCTION PERIODS 1924 TO 1933 & 1933 TO 1942
PERCENT SURVIVING
AGE YEARS

PLATE IV

as another. Farm to Market roads built to a low standard are not yet influencing the percentages of survivors. The diagrams on Plates V and VI are expressive in showing replacement requirements. They also show an age grouping. These diagrams have been produced from composite survivor curves covering the several construction periods for the two classes mentioned. The diagrams indicate that 2,691 miles of concrete pavement and 12,569 miles of asphalt pavement or a total of 15,260 of the 25,233 miles of pavement comprising the State Rural Highway System on January 1, 1948, will be retired by January 1, 1960. Replacements will vary in degree from resurfacing of existing pavements to construction of divided highways.

Pavement deficiencies are of first consideration and are reasonably used to measure replacement requirements. The traffic load dictates pavement width and strength. Grading and structures or base may be considered as subsidiary to the pavement with their improvement following the pavement improvement. It follows that it is reasonable to base the overall replacement requirement on the pavement alone. Emphasis should be placed on the fact that in all of the foregoing discussion, no mention is made of replacement costs. The determinations bear solely on the amount of replacement required. Salvage value from the old construction and cost of replacements remain a matter of estimates of cost in a dollar of varying purchase power.

In order to extend the use of Road Life data, a study has been made of the life of the dollar spent on the components of highway construction. The items of "Grading and Small Structures," "Flexible Base," and "Surface" are

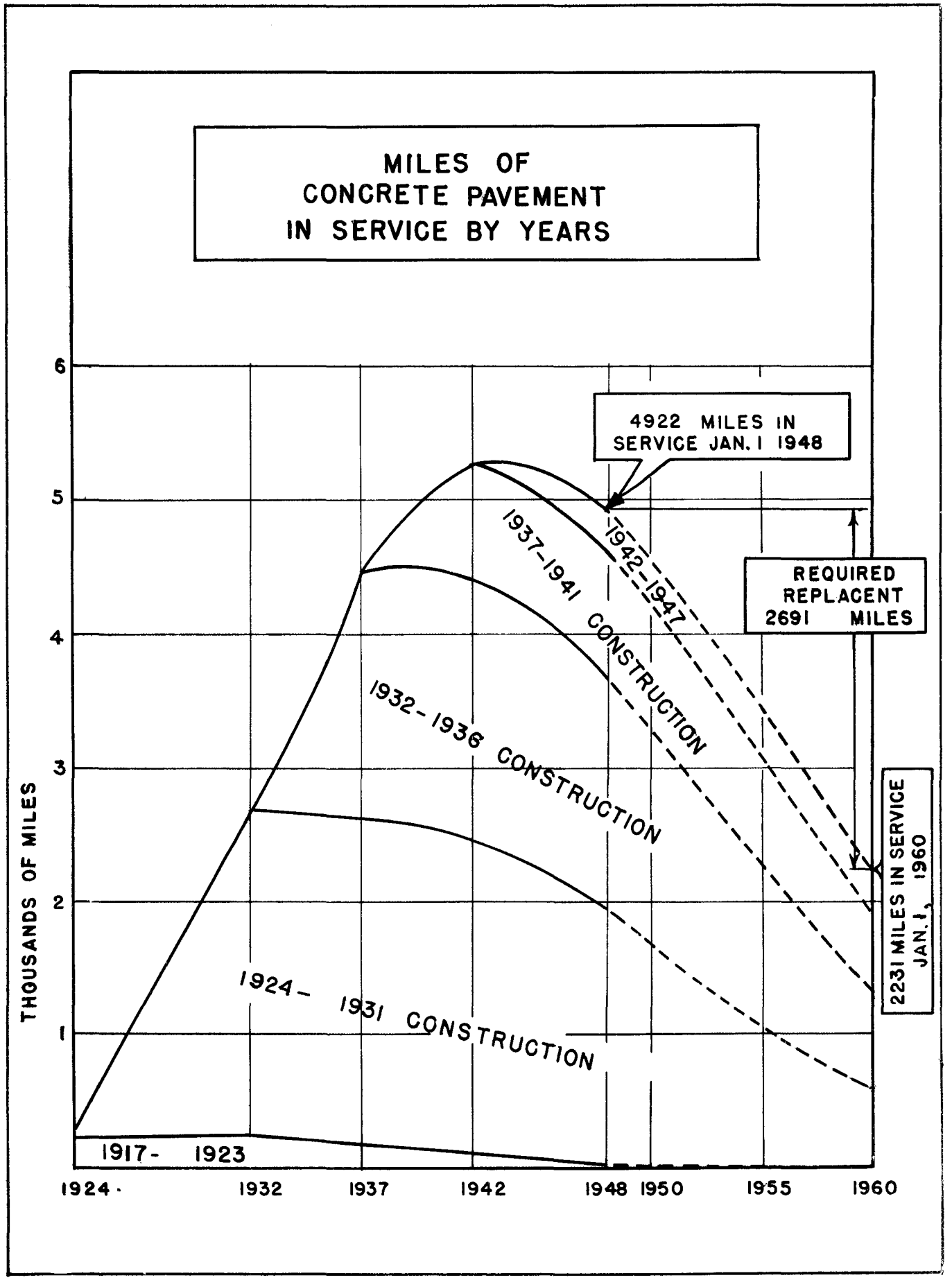

MILES OF
CONCRETE PAVEMENT
IN SERVICE BY YEARS
THOUSANDS OF MILES
6
5
4
3
2
1
4922 MILES IN
SERVICE JAN. 1 1948
1942-1947
1937-1941 CONSTRUCTION
1932-1936 CONSTRUCTION
1924-1931 CONSTRUCTION
1917-1923
REQUIRED
REPLACENT
2691 MILES
2231 MILES IN SERVICE
JAN. 1, 1960
1924
1932
1937
1942
1948
1950
1955
1960

PLATE V

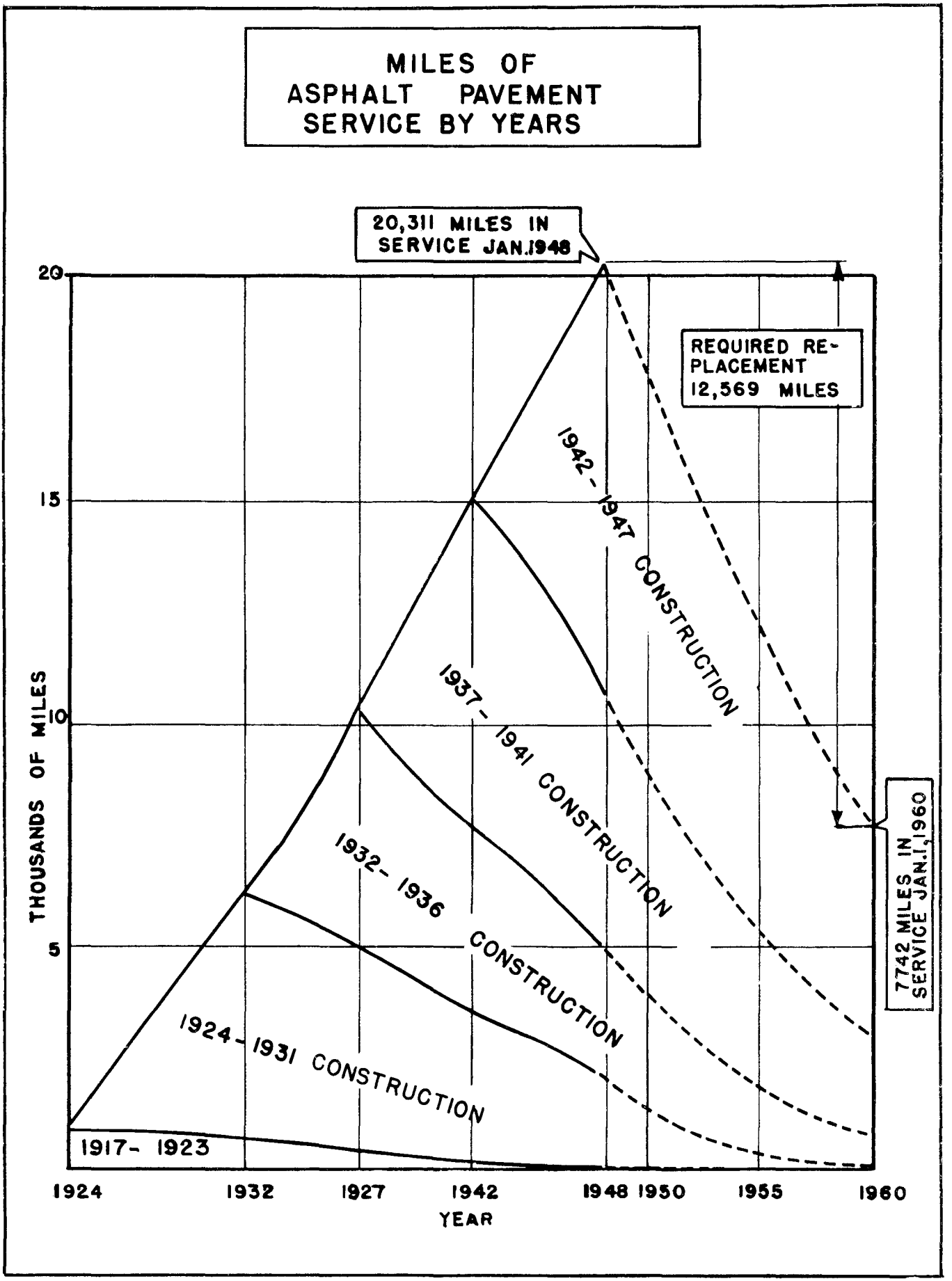

MILES OF
ASPHALT PAVEMENT
SERVICE BY YEARS
20,311 MILES IN SERVICE JAN.1948
REQUIRED RE-PLACEMENT 12,569 MILES
1942-1947 CONSTRUCTION
1937-1941 CONSTRUCTION
1932-1936 CONSTRUCTION
1924-1931 CONSTRUCTION
1917-1923
7742 MILES IN SERVICE JAN.1,1960
THOUSANDS OF MILES
20
15
10
5
1924
1932
1927
1942
1948
1950
1955
1960
YEAR

PLATE VI

considered in this study. "Concrete Pavement," being both base and surface, has been considered separately. The dollar invested in the above named components of construction has been followed through the available life history.

In this study, dollars are retired by estimating the physical proportions of the old work taken into the new construction and retiring the old dollars proportionately. This eliminates the effect of the varying purchase power of the dollar. As examples, a seal coat replaces a worn away portion of an asphalt surface, hence retires some portion of the original surface dollars, or an underseal or leveling course on concrete pavement is an expenditure to rehabilitate the pavement to extend its useful life, and is considered as retiring some of the original dollars invested but not necessarily an amount equal to the new dollars invested. The policy was to retire the older dollars first, the theory being that each reconstruction or rehabilitation formed a unit of construction and that retirement could be made from the unit as a whole. This was to avoid the unreasonable perpetual life which would be shown in an instance where an old surface is covered by a new thereby subjecting only the top surface to wear and repair and in similar cases in both base and grading.

With the dollar set up in this manner, variations in purchasing power have no effect on its life. The total number of dollars remaining in the construction is known as the Remaining Investment. To convert the Remaining Investment to dollars of any given purchasing power requires the application of an index to the remaining dollars according to their purchasing power when invested.

Survivor Curves on Dollar Life are similar in every respect to those on Physical Life. The salvage value of old construction is, however, reflected in Dollar Life curves and tends to increase the life above that shown on Physical Life curves.

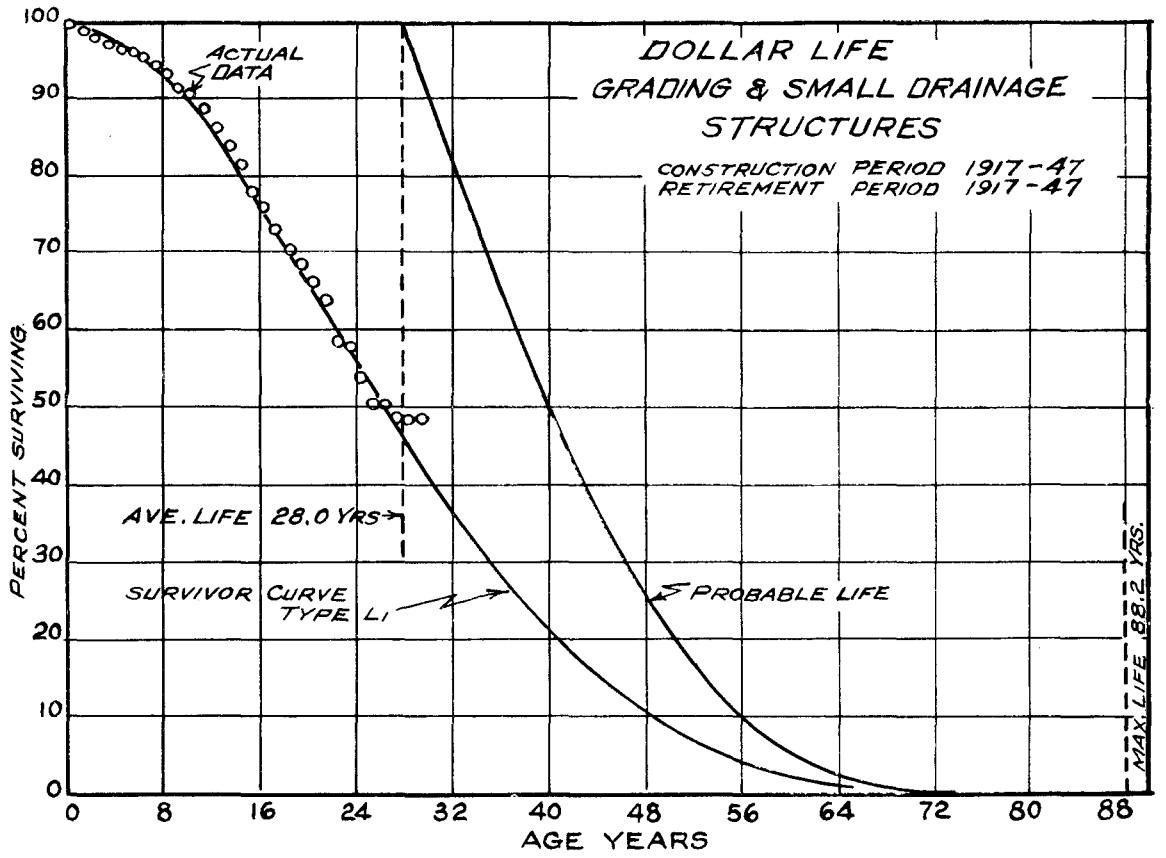
Because of the extensive work involved, a ten per cent sample of the rural highway system was used in the survey. The sample was selected to represent all sections of the State proportionate to their highway mileage. The results are considered representative of the State as a whole.

Plates VII, VIII, and IX, following, show the life of a dollar as determined from Dollar Life studies when invested in the following components of construction:

Grading and Small Drainage Structures
Flexible Base
Bituminous Surface less than 1 inch thickness
Bituminous Penetration 1 inch or more in thickness
Asphaltic Concrete and Rock Asphalt 1 inch or more in thickness
Concrete Pavement

In all of the Road Life data presented in this discussion, no regard has been given to traffic volume. As a general rule, the higher types of pavements are carrying the heavier traffic and are subject to greater destructive forces. The assumption that this practice will continue can be made. In comparing the life of different classes of pavement, however, care should be exercised and due regard given to the traffic factor.

In economic studies of routes or projects extensive use is being made of the life expectation of both new construction and existing construction. Annual costs made up of an annual maintenance cost plus an allowance for annual construction retirement calculated from the original cost spread


DOLLAR LIFE
GRADING & SMALL DRAINAGE STRUCTURES
CONSTRUCTION PERIOD 1917-47
RETIREMENT PERIOD 1917-47
ACTUAL DATA
AVE. LIFE 28.0 YRS
SURVIVOR CURVE TYPE L1
PROBABLE LIFE
MAX. LIFE 88.2 YRS.
PERCENT SURVIVING
AGE YEARS
0
8
16
24
32
40
48
56
64
72
80
88
10
20
30
40
50
60
70
90
100

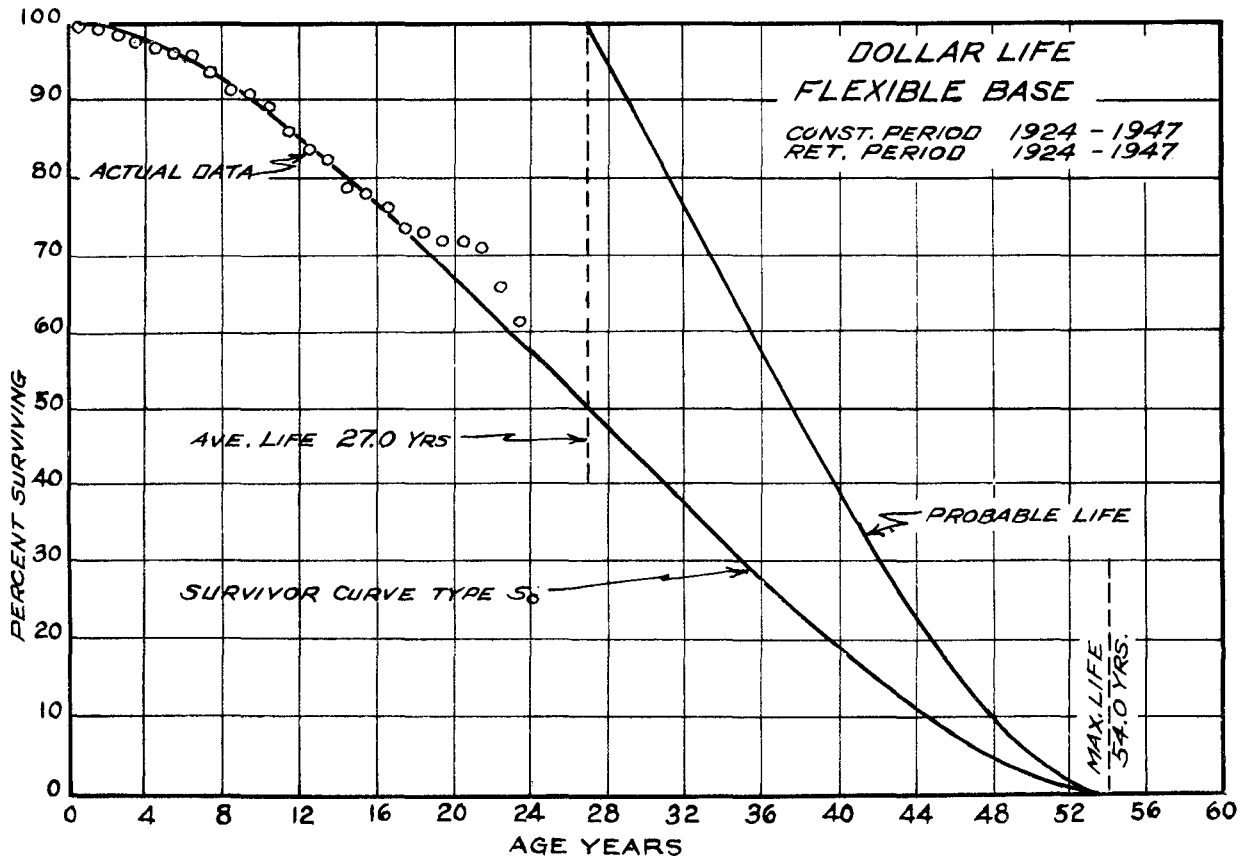

DOLLAR LIFE
FLEXIBLE BASE
CONST. PERIOD 1924 - 1947
RET. PERIOD 1924 - 1947
ACTUAL DATA
AVE. LIFE 27.0 YRS
SURVIVOR CURVE TYPE S0
PROBABLE LIFE
MAX. LIFE 54.0 YRS.
PERCENT SURVIVING
AGE YEARS
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
10
30
50
70
80
90
100

PLATE VII

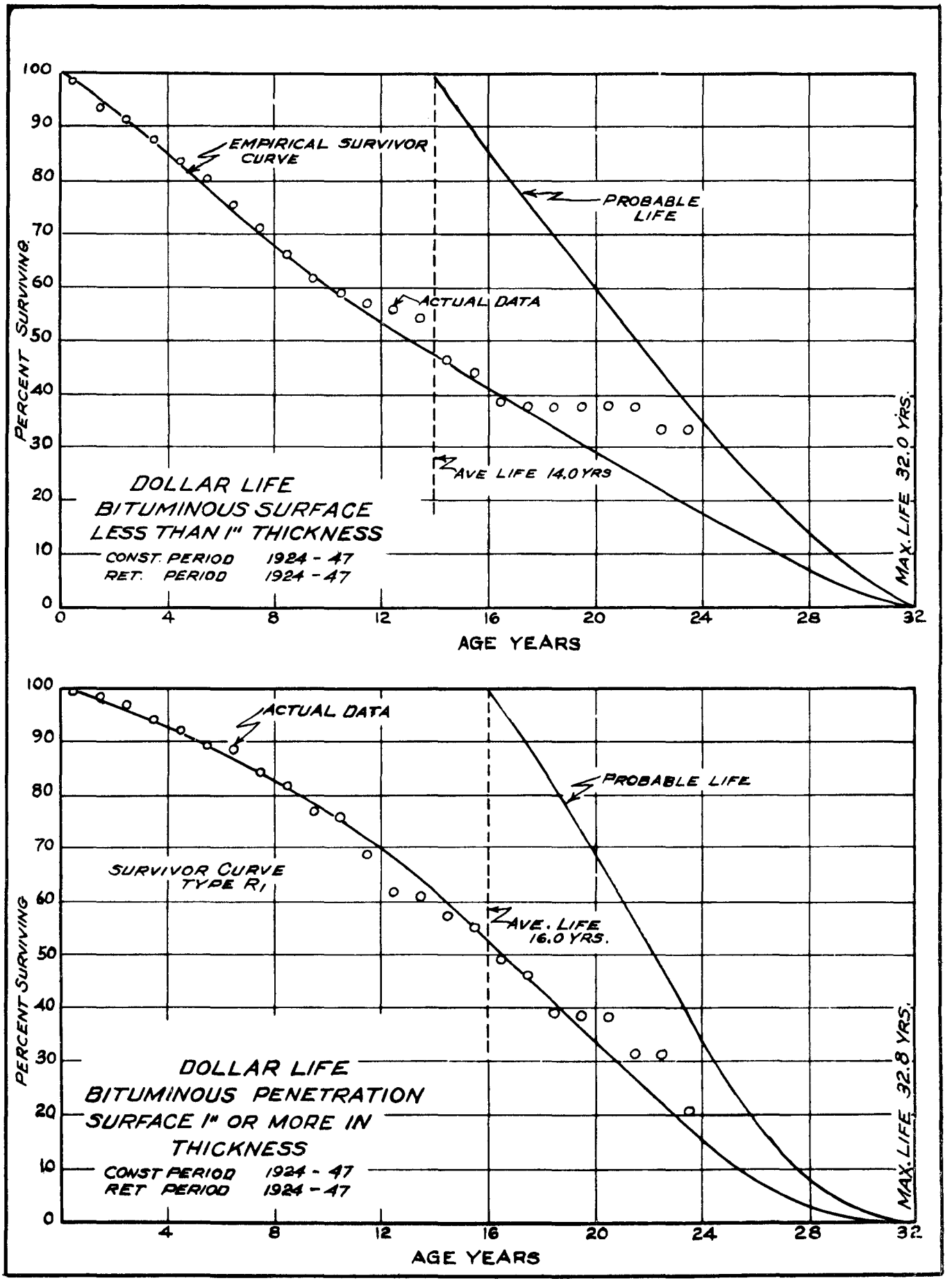
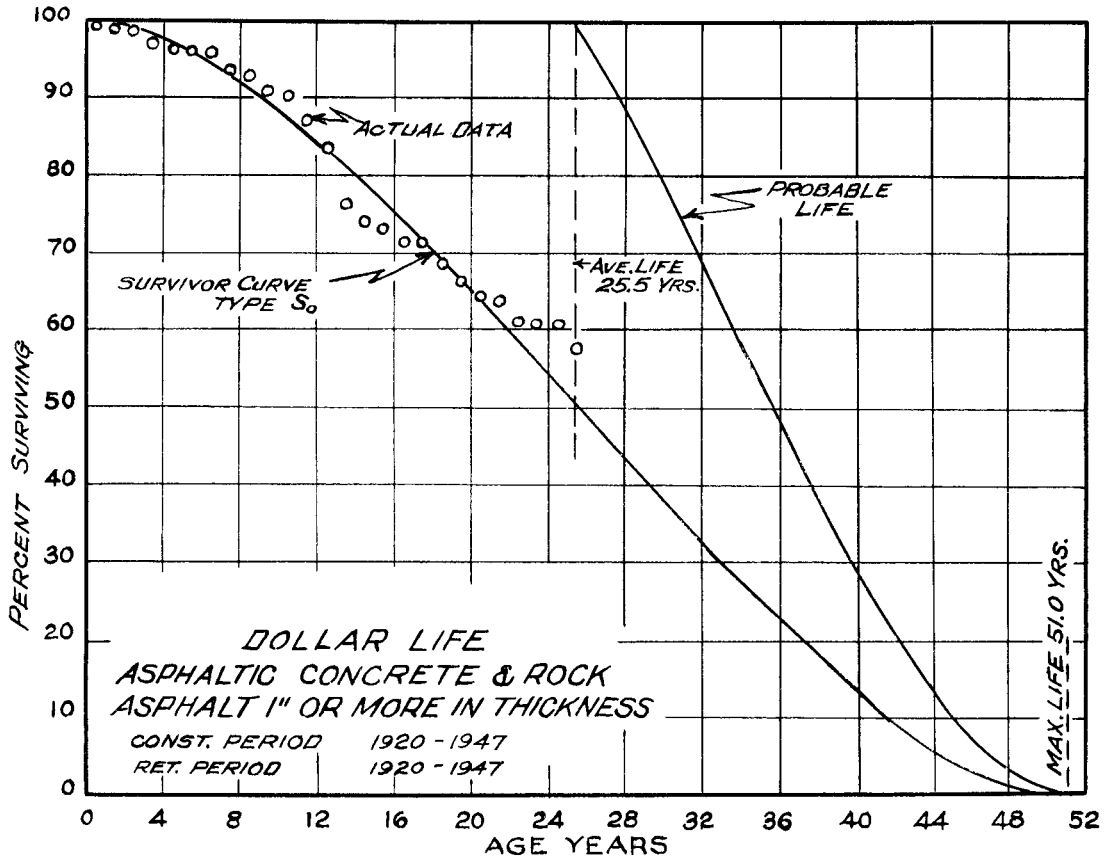

100
90
80
70
60
50
40
30
20
10
0
PERCENT SURVIVING
EMPIRICAL SURVIVOR CURVE
PROBABLE LIFE
ACTUAL DATA
AVE LIFE 14.0 YRS
MAX. LIFE 32.0 YRS.
DOLLAR LIFE
BITUMINOUS SURFACE
LESS THAN 1" THICKNESS
CONST. PERIOD 1924 - 47
RET. PERIOD 1924 - 47
0
4
8
12
16
20
24
28
32
AGE YEARS
ACTUAL DATA
PROBABLE LIFE
SURVIVOR CURVE
TYPE R1
AVE. LIFE
16.0 YRS.
MAX. LIFE 32.8 YRS.
DOLLAR LIFE
BITUMINOUS PENETRATION
SURFACE 1" OR MORE IN
THICKNESS
CONST PERIOD 1924 - 47
RET PERIOD 1924 - 47
AGE YEARS

PLATE VIII


100
90
80
70
60
50
40
30
20
10
0
PERCENT SURVIVING
ACTUAL DATA
PROBABLE LIFE
AVE. LIFE 25.5 YRS.
SURVIVOR CURVE TYPE S_0
MAX. LIFE 51.0 YRS.
DOLLAR LIFE
ASPHALTIC CONCRETE & ROCK ASPHALT 1" OR MORE IN THICKNESS
CONST. PERIOD 1920 - 1947
RET. PERIOD 1920 - 1947
0 4 8 12 16 20 24 28 32 36 40 44 48 52
AGE YEARS

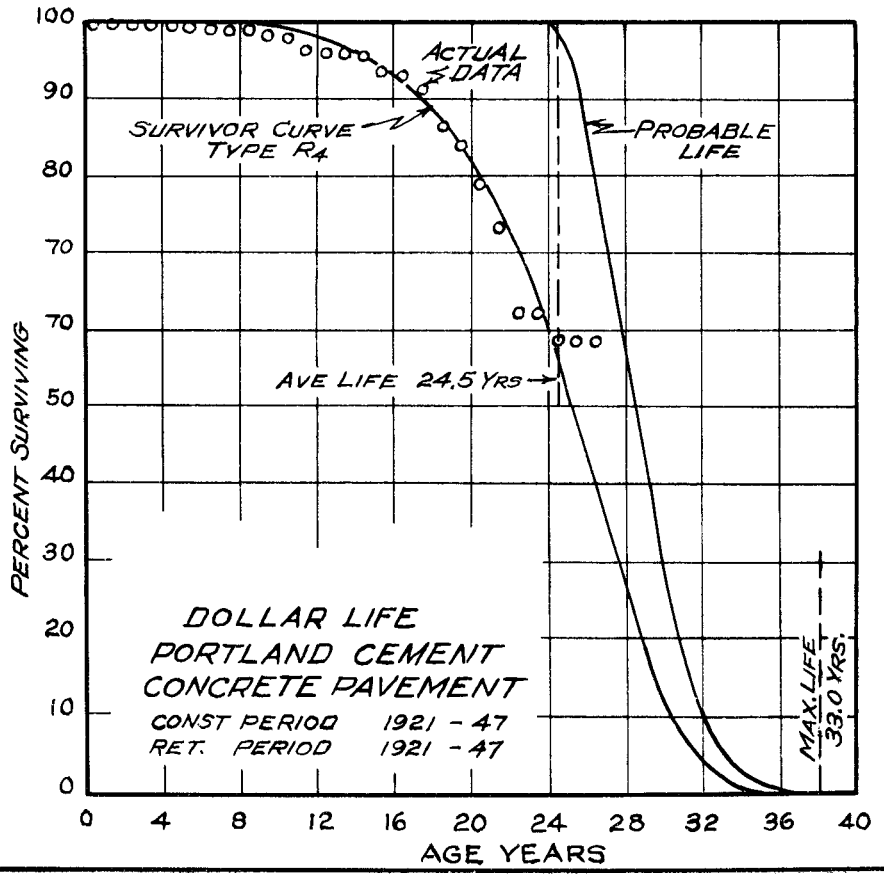

100
90
80
70
70
50
40
30
20
10
0
PERCENT SURVIVING
ACTUAL DATA
SURVIVOR CURVE TYPE R_4
PROBABLE LIFE
AVE LIFE 24.5 YRS
MAX. LIFE 33.0 YRS.
DOLLAR LIFE
PORTLAND CEMENT CONCRETE PAVEMENT
CONST PERIOD 1921 - 47
RET. PERIOD 1921 - 47
0 4 8 12 16 20 24 28 32 36 40
AGE YEARS

PLATE IX

over the expected life, are of importance in these studies. Such economic studies are of increasing importance and will doubtless exert great influence on future highway planning. This presentation has been made in the hope that it may be of interest and use in the Texas Highway Department.

H. P. Stockton, Jr.
February, 1949