# Evaluation of Pavements to Determine Maintenance Requirements

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Contrary to normal practice employed in the design and construction of a modern highway, the maintenance aspects of providing this facility are seldom based on adequate pre-engineering and evaluation data. Sufficient time is seldom available to perform a thorough diagnosis of the maintenance problem through conventional sampling and testing techniques. A method of pavement evaluation based on surface deflections and observed performance of existing routes is described and summarized in the form of charts which permit a ready appraisal of the problem as an aid in the establishment of maintenance warrants and highway planning.

•FOR THE past several years, the Committee on Pavement Design and Evaluation has been engaged in a cooperative investigation program to develop economical methods of design, strength evaluation and serviceability of rigid and flexible pavements suitable for Canadian conditions of environment and traffic. Generally speaking, our deliberations have been centered on obtaining an inventory of existing pavements and studying their structural serviceability and performance with relation to age and season. Mo recently, our efforts have been drawn to a more detailed study of the numerous variables affecting this performance.

As one would expect, a considerable volume of data has been gathered, some of which has been interpreted and reported during previous sessions and other publications. Methods of design and strength evaluation have been developed and are being applied extensively across the country. Although the detail analysis is still in progress, experience, coupled with knowledge already gained, permits application of the basic approach on an even wider scale.

Contrary to normal practice employed in the design and construction of a modern highway, the maintenance aspects of providing this facility are seldom based on adequate pre-engineering and evaluation data. In most cases, this is not due to a lack of appreciation of the need for these considerations, but rather the circumstances that surround the maintenance problem. Maintenance requirements must be established shortly after the problem occurs. Sufficient time is seldom available to perform a thorough diagnosis of the problem through conventional sampling, testing and interpretive techniques. Remedial measures are, therefore, based on opinion tempered with varying degrees of experience. Preventive maintenance in the highway field is an exception rather than the rule. This hit-or-miss, however unavoidable, technique has not been entirely satisfactory. It would appear that improvement of the situation can only be obtained through a time reduction of the evaluation period.

The overall serviceability of a highway system is dependent on a number of factors such as geometrics, traffic volumes and classification, present and future origin-destination requirements, riding qualities, and its structural capacity. A comprehensive highway needs study must include all these factors. This paper considers the evaluation of its structural capacity as an aid in the assessment of maintenance warrants.

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# BASIC CONSIDERATIONS AND TECHNIQUE

Until very recently it has not been possible to categorize the present, let alone predict the probable future structural serviceability of a highway system, on a basis which is sufficiently convenient and rational to be accepted for general use. During the past several years, it has become increasingly apparent that surface deflections obtained under a standard wheel load provide a relative measure of the structural capacity of a highway at a given point and time. Regarded collectively, these measurements can be used to represent its present structural serviceability. Based on experience and performance study correlations, this basically simple data can be employed to portray the present and predict the future structural performance of the entire highway system.

The deflection test is based on the concept that pavement structures which have been conditioned by a given volume and weight of traffic deform elastically under a test load equal to or less than the magnitude of the conditioning traffic. The test is not considered valid when further densification or displacement within the pavement structure or subgrade occurs under the action of the test load.

When a wheel load is applied to the surface of a flexible pavement, the greatest vertical stresses are concentrated near the surface over an area affected by the applied load. These vertical stresses decrease with depth due to a lateral distribution of forces. The incremental layers of soil beneath the wheel load will therefore be compressed according to the intensity of the vertical stress and compressibility of the material. Since vertical stress intensities decrease laterally from the center of the loaded area, the soil within any horizontal layer will likewise be compressed to a lesser degree in a lateral direction. The sum total of the vertical elastic compressions of all incremental layers of soils under the center of a loaded area is represented by the surface deflection, and if such a summation is integrated over the entire surface area affected by the applied load, the product will result in a deflection bowl developed about the loaded area. (See Fig. 1.)

The magnitude of compression within each incremental layer (under a given stress) is a function of the basement soil type and condition, thickness and quality of the surface, base and subbase courses, drainage condition, the relative density, temperature and a number of other minor variables. It will be recognized that these variables are those commonly associated with the structural capacity (strength properties) of a soil. It would, therefore, follow that an integrated measure of the total compression (surface deflection), within a layered system (such as a highway pavement), subjected to a known surface load (wheel load), provides an index of the structural capacity of the system. Due to the large number of variables affecting this deflection, irrespective of how short the highway section may be, variation in deflections from point to point may be expected. Within the assessment of the structural capacity of a highway section, it is therefore necessary to obtain a sufficient number of readings to portray the nature and magnitude of this variation.

Figure 2 shows a typical distribtuion of deflections within a highway section in the form of a histogram showing a reasonable estimate of a normal curve. Consequently, the statistical properties of the normal distribution may be employed within this study.

Since pavement design is a limit design—i. e., there is little or no factor of safety against overstraining of the asphaltic surface—it is necessary to select a control level of deflection for design and load restriction purposes, which will insure that the greatest majority of the given highway section will meet the requirements of projected traffic weights and volumes, and accept a small percentage as underdesigned. This small area of underdesigned pavement will not be critical as it would still be relatively strong and failure would develop very slowly, probably as small areas of depression or roughness which could be readily repaired before serious breaks occurred, and thus the facility can be economically maintained at an acceptable performance level.

The performance of a section of pavement is associated with the weaker areas of that section. Therefore, the deflection level which is exceeded by about 5 or 10 percent of the length of pavement, rather than the average, is more closely associated with the structural performance of the section. Although it is impossible to determine the true

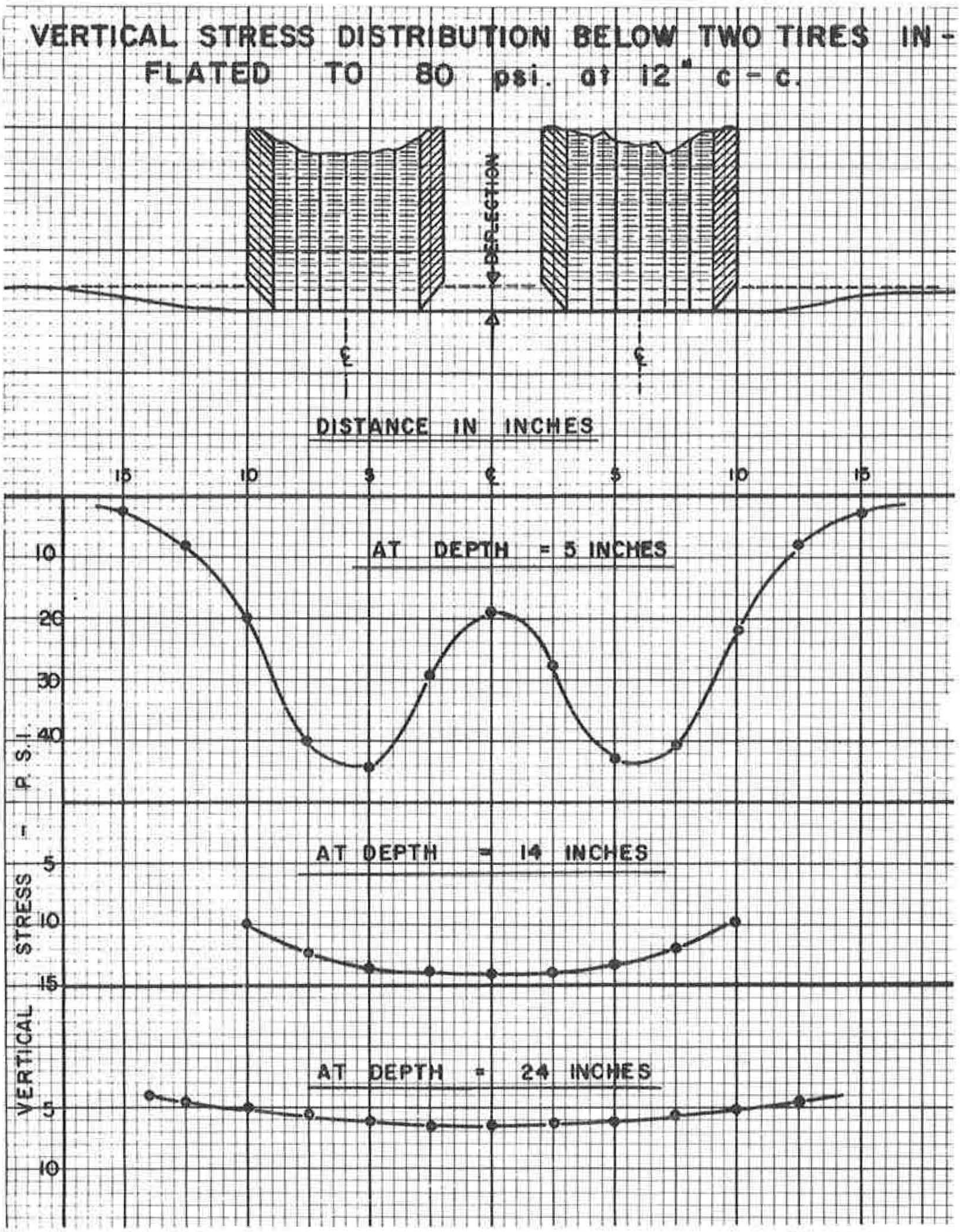
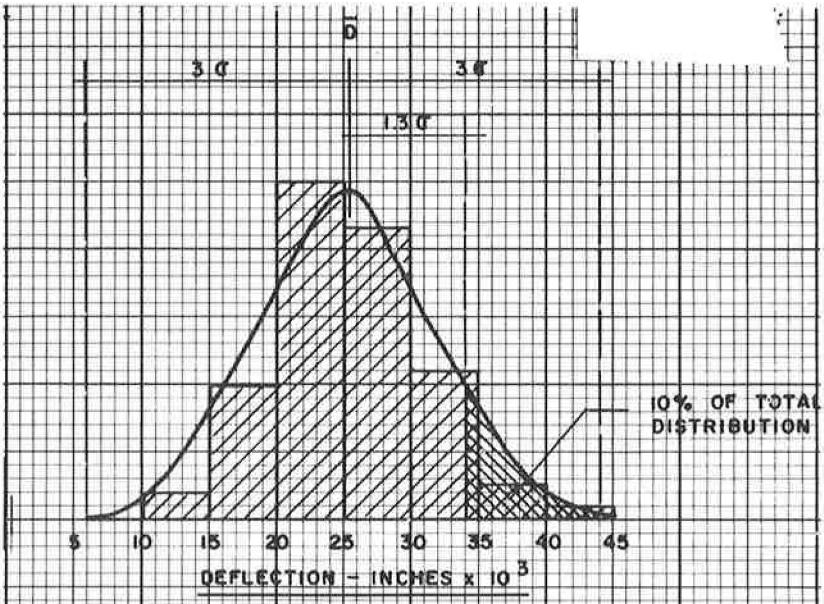



Figure 1.

population mean and standard deviation deflection of a pavement section, we are assured that these values, calculated from readings obtained at 10 or more random points, are good estimates of the true values. The mean and standard deviation thus obtained can be used to determine deflection values corresponding to various probability levels such as shown in the table of Figure 2.




FREQUENCY DISTRIBUTION OF DEFLECTION VALUES FOR A HIGHWAY SECTION WITH AN AVERAGE DEFLECTION, $\bar{D}$ = .0255 INCHES, AND A STANDARD DEVIATION OF, $\sigma$ = .0065".

| DEFLECTION | NORMAL CURVE PARAMETERS APPLIED | PROBABLE PERCENTAGE OF TEST VALUES EXCEEDING GIVEN DEFL. |
|---|---|---|
| .0255 | $\bar{D}$ | 50 % |
| .034 | $\bar{D}$ + 1.3 $\sigma$ | 10 % |
| .036 | $\bar{D}$ + 1.6 $\sigma$ | 5 % |
| .0385 | $\bar{D}$ + 2 $\sigma$ | 2 % |
| .045 | $\bar{D}$ + 3 $\sigma$ | 0.1 % |

ESTIMATED PROBABLE PERCENTAGE OF ALL POSSIBLE TEST VALUES WITHIN PAVEMENT SECTION EXCEEDING GIVEN DEFLECTIONS.

Figure 2.

For purposes of this study, the 90-percentile level of deflection was selected as representative of the pavement strength limiting the structural capacity of the highway section. Theoretically, the selection of this control level implies that one will allow 10 percent of the section to be overstressed to some degree during its service life and that the authority is prepared to maintain that portion of the 10 percent which may fail from time to time during the life of the pavement.

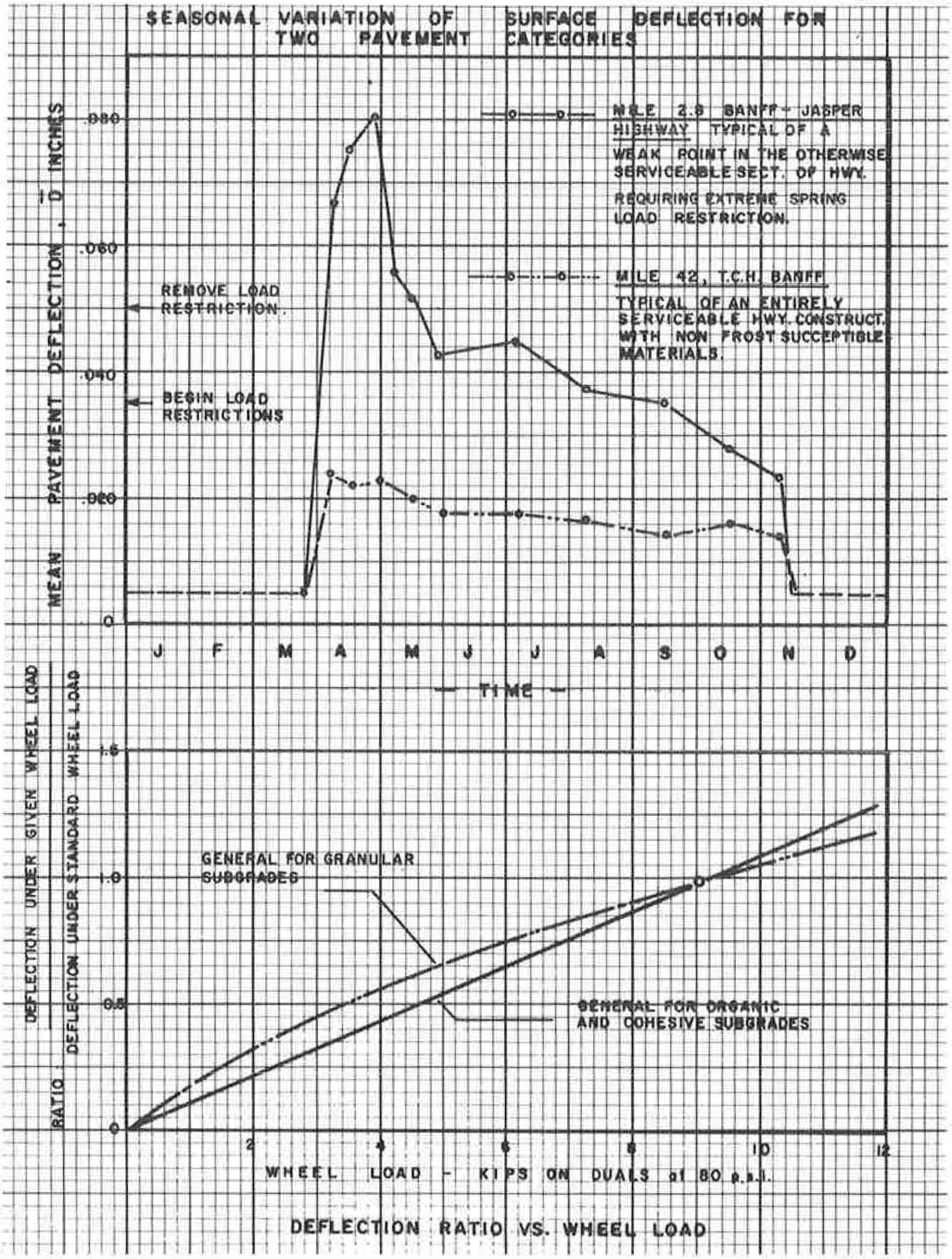



Figure 3.

## SEASONAL VARIATION OF PAVEMENT STRENGTH

Under a given load, the maximum deflection of a particular pavement is usually evident within the spring thaw period. The deflection will then decrease to a minimum value by August or September. It has also been observed that a secondary increase in deflection may occur during the latter part of the initial thawing period. This is tentatively attributed to a readjustment in the thermal regime beneath the pavement when some frozen strata still exists at depth. The shape of the deflection curve is dependent on the subgrade soil type, the total thickness and type of pavement structure and the rate and characteristics of the spring thaw (Fig. 3). The cause of this variation is suggested to be the variable amount of water enclosed in the pavement-basement soil system. Upon freezing in late fall and winter, and when accompanied by certain natural conditions of the groundwater supply, sufficient soil pore space and moving frost line, additional water will migrate upwards toward the frozen boundary and freeze there. As thawing progresses, the additional water accumulated during the freezing process is released but may be entrapped by a frozen boundary beneath it. The presence of areas or layers of high water content causes a significant reduction of effective strength within the soil subjected to superimposed wheel loads and results in greater deformation of the structure in order to mobilize equilibrium strength. Thus during the thawing period, we have an accumulation of water in the upper portion of the subgrade and possibly subbase, which results in a decrease in the supporting power of the soil. The relatively rapid release of water during thawing, which depends on the rate of penetration of the thawing isotherm, explains the rapid decrease in bearing strength. The subsequent strength regain is a slower process since the excess water accumulated must be removed in the liquid phase by gravitational drainage or in the vapor phase by evaporation. These processes depend on the excess moisture gradients present and on the permeability of the surrounding soil mass and pavement surface material, respectively.

Tests have shown that for a particular pavement structure a relationship exists between wheel load and deflection. The deflection increases as the wheel load increases on a curvelinear relationship. The load-deflection relationship will vary with the rate of loading, subgrade soil type, the total thickness of pavement structure and the intrinsic properties of the pavement structure, such as type of material, gradation, relative density, etc. This load-deformation relationship, especially for flexible pavements, cannot be defined as a single constant since it depends not only on the fundamental properties of each layer in the system itself, but also on environmental conditions; consequently, these fundamental properties themselves change with season and from year to year.

The CGRA method of deflection testing employed in this survey using a limited period of static loading followed by relatively rapid removal of the load results in a characteristic load-deformation relationship intermediate between the dynamic WASHO method and time-honored plate bearing test. Extensive field testing has shown that the CGRA method is fast and accurate and that results are reproducible on extremely soft pavement and weak subgrade conditions. This is important during spring testing when a large loss in strength is experienced in some subgrades. It is imperative that the method of test is consistent for all sections if spring restrictions are being set on the basis of these tests. The measured strength of the subgrade soil is dependent on the rate of strain applied during loading. This rate of strain is particularly important in tests during the spring when the subgrade is in its weakest condition. The CGRA static method of test minimizes the effect of this variable.

Use of deflection criteria in setting spring load restrictions usually results in restrictions being set slightly later and lifted later than with the old technique of setting restrictions by opinion. Deflection experience to date indicates that setting load restrictions by opinion usually results in restrictions being set too early and lifted at a time when pavement deflection was most critical. Deflection criteria enable load restrictions to be set to protect the pavement structure and also permit the correct percentage of restriction to be imposed. For example, many highways which would have had a 50 percent restriction, may now have a 75 percent restriction (75 percent of normal allowable load) or may require no restrictions.

Deflection data on a highway route give an accurate picture of its strength characteristics at the time of testing. A particular highway may contain only one or two weak sections of limited length. With deflection data it is possible to assess the amount of maintenance required on the weak sections to avoid a lengthy ban. Strengthening of these weak areas may eliminate all ban requirements.

## CRITICAL DEFLECTION VALUES

When we speak of strength, we mean the ability of the pavement structure to sustain superimposed loadings without permanent deformation. Excessive deformation may result in rutting, shoving or any one of a variety of surface cracking patterns. Every pavement system will exhibit a yield point or critical value of internal strain beyond which permanent deformation or rupture will occur.

Obviously, critical deflection values must be set at a level less than that at which permanent deformation or rupture of any element of the pavement will occur.

The properties of the surface are dependent on temperature, and the supporting capacity of the subgrade depends on the content and distribution of moisture which varies seasonally and throughout the life of the pavement. Thus the critical deflection to be selected for any single pavement type is a time-dependent variable. This latter factor is not too important in concrete surfaces since the material itself has the ability to distribute load over a larger area when subsurface support is reduced. The bituminous pavement derives its ability to sustain loads directly from the base and subgrade and its capacity to deform without fracture depends on the temperature. Since the effect of lower temperature is to render the relatively thin bituminous surfacing more brittle, the pavement is more susceptible to detrimental cracking during the spring thawing period when the surface layer cannot deform as readily without rupture. It would be impractical to define a critical deflection value for each pavement system. A field analysis must therefore be directed toward determining an average, safe value of certain generalized groups of pavement structures. Analysis of the WASHO Road Test data suggested critical deflection values of 0.035 and up to 0.050 in. for spring and summer conditions, respectively. These are average values based on the observed distress of several different pavement designs placed on one type of subgrade. Higher deflection values are usually permissible on a lightly traveled highway as compared to a heavily traveled highway for the same magnitude of wheel loads. Some pavements are still in service today with deflections as high as 0.075 in. but carrying relatively low-volume traffic. However, in view of the difficulty of defining an exact critical deflection value for each pavement type, the critical values established at the WASHO test road are considered most practical for present use.

## GENERAL DISCUSSION ON PROCEDURE

As is the case with most problems of this nature, it is desirable to obtain an inventory of the existing highway system. For this detailed inventory the highway routes are divided into uniform sections, ranging from ½ to 5 miles in length, following the establishment of the boundaries of the following variables:

1. Maintenance districts,
2. Construction history limits,
3. Subgrade soil type (natural),
4. Imported subgrade soil type,
5. Drainage conditions,
6. Age of original surfacing,
7. Age of resurfacing,
8. Heavy axle coverage per lane,
9. Current A.A.D.T.,
10. Pavement lane width,
11. Bituminous surface thickness and type,
12. Base course thickness,
13. Subbase thickness,
14. Shoulder type and width,
15. Rainfall,
16. Freezing index, and
17. Height of grade above natural ground.

The mean and standard deviation of the "full" deflections and present performance rating are then measured for each section.

The completed inventory is studied to locate critical sections which are representative of the highway route requiring spring load restrictions. These sections should be representative of soil types, traffic conditions, pavement design and type, and freezing indices. The deflections are then taken in these sections to establish the seasonal variation in strength. An 18,000-lb single-axle load is used to determine this time-deflection relationship. The number of sections to be selected on a particular route will vary with the aforementioned conditions but are kept to a minimum. Testing should commence shortly before thawing and continue until the pavement has started to recover strength. Measurements are taken at intervals of four to five days while load restrictions are in force, so that a minimum of delay may be experienced in lifting restrictions. Each time a section is tested, ten new random test points are selected in the outer wheelpaths of the section. The average deflection value is then obtained for the section from the ten test results. To expedite testing, this procedure was varied by locating and marking one set of random points and repeating the periodic tests at these locations. As the mean deflection values begin to stabilize in the late spring or early summer the time between reading is increased to monthly intervals.

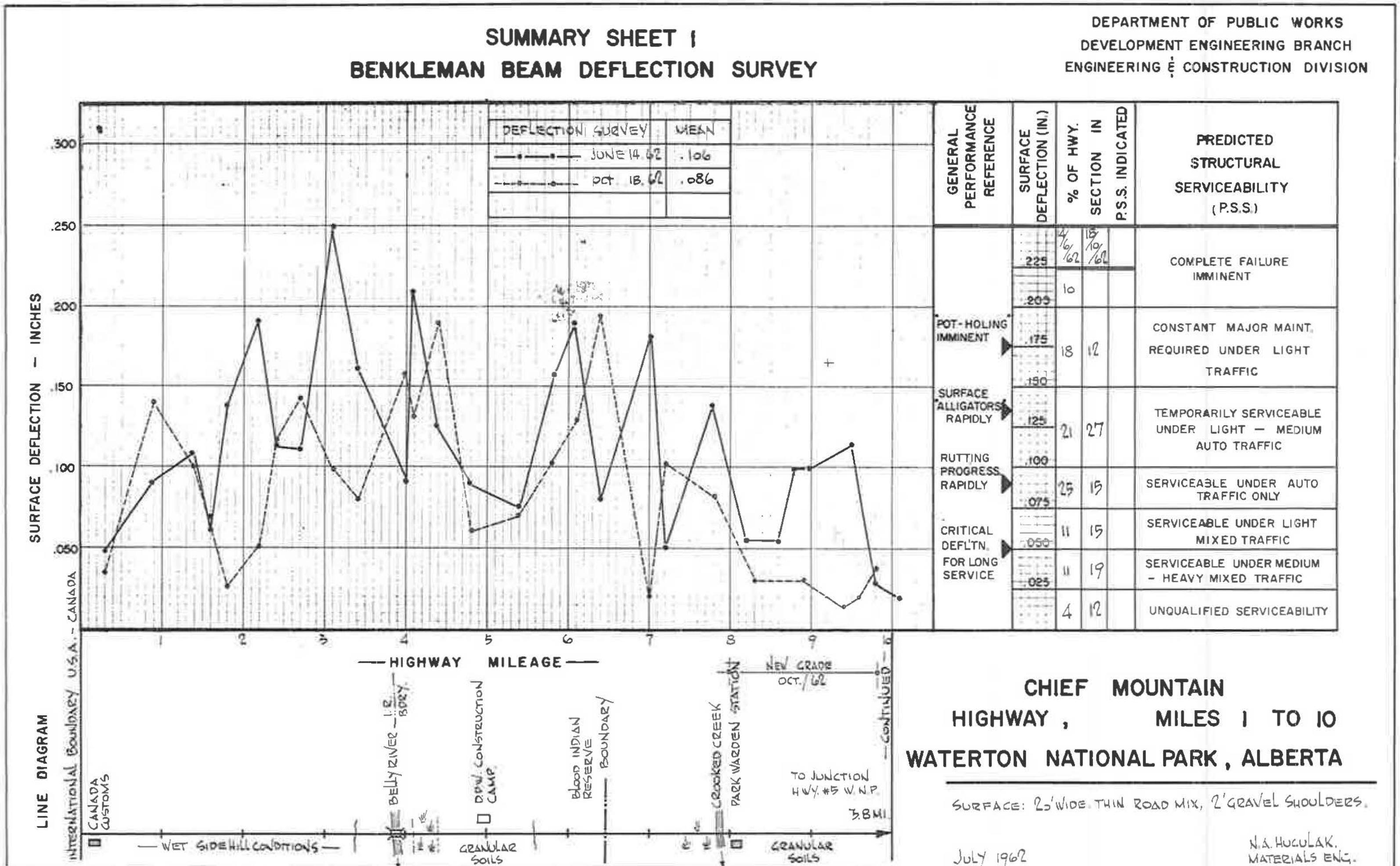
Pavement inventories, as described above, have been obtained by most highway agencies in Canada during Stage I of the work undertaken by the Pavement Design and Evaluation Committee. A majority of the data necessary for this purpose is therefore available and may be extracted from the printouts of Stage I. For other highways, i.e., those not included in the detailed inventory, deflections at three to four random points per mile were obtained in the outer wheelpath. General notes on the performance of the surface at each deflection point should also be taken to assist in the interpretation of these results. One crew can cover about 25 miles per day in obtaining these results. Deflections during the spring breakup period need only be obtained on highway routes which are judged susceptible to frost action and would therefore lose a high percentage of their normal load-carrying capacity.

The results of this survey are plotted in the form of deflection profiles (Figs. 3 through 7), usually in 10-mi sections. Out of several hundred miles covered within the first year of this work, five sections covering a wide range of highway categories (in terms of their structural serviceability) are included in this paper. The summary sheets (Figs. 4-8) include a graphic-tabular interpretation of these readings for ready assessment of the general structural serviceability of the section. The spectrum of readings is divided into various levels of deflection and their percentage noted opposite the appropriate structural serviceability (traffic handling ability) category. The column entitled "General Performance Reference" is applicable for highways carrying medium-heavy mixed traffic and should only be used in conjunction with the surface deflection scale and not with the last column entitled "Structural Serviceability."

A considerable amount of information concerning each highway section can be obtained by close examination of the summary sheet. For example, if we refer to Summary Sheet #1 (Fig. 4), covering miles 1 to 10 of the Chief Mountain Highway, we find the following:

1. From the table: (a) in spring complete failure is imminent for 10 percent of the section; (b) constant major maintenance is required under light traffic over 18 percent of the section in spring and 12 percent of the section under fall conditions; (c) 27 and 21 percent of the section are temporarily serviceable under light-medium auto traffic under fall and spring conditions, respectively; (d) 15 and 25 percent of the section are serviceable under auto traffic under fall and spring conditions, respectively; (e) 15 and 11 percent of the section are serviceable under light mixed traffic under fall and spring conditions, respectively; (f) 19 and 11 percent of the section are serviceable under medium-heavy mixed traffic under spring and fall conditions, respectively; (g) 12 and 4 percent of the section is serviceable without reservation under all conditions of traffic under fall and spring conditions, respectively; and (h) the critical deflection of 0.050 in. is exceeded in approximately 80 percent of the section under truck traffic.

2. During the spring the mean deflection is equal to 0.106 in. with a standard deviation of 0.052 in., and during the fall period the mean deflection is equal to 0.086 in. with a standard deviation of 0.041 in.



SUMMARY SHEET 1
BENKLEMAN BEAM DEFLECTION SURVEY
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
ENGINEERING & CONSTRUCTION DIVISION
DEFLECTION SURVEY | MEAN
JUNE 14. 62 | .106
OCT. 18. 62 | .086
SURFACE DEFLECTION - INCHES
.300
.250
.200
.150
.100
.050
GENERAL PERFORMANCE REFERENCE
SURFACE DEFLECTION (IN.)
% OF HWY. SECTION IN P.S.S. INDICATED
PREDICTED STRUCTURAL SERVICEABILITY (P.S.S.)
COMPLETE FAILURE IMMINENT
CONSTANT MAJOR MAINT. REQUIRED UNDER LIGHT TRAFFIC
TEMPORARILY SERVICEABLE UNDER LIGHT - MEDIUM AUTO TRAFFIC
SERVICEABLE UNDER AUTO TRAFFIC ONLY
SERVICEABLE UNDER LIGHT MIXED TRAFFIC
SERVICEABLE UNDER MEDIUM - HEAVY MIXED TRAFFIC
UNQUALIFIED SERVICEABILITY
POT-HOLING IMMINENT
SURFACE ALLIGATORS RAPIDLY
RUTTING PROGRESS RAPIDLY
CRITICAL DEFL'TN. FOR LONG SERVICE
.225 .200 .175 .150 .125 .100 .075 .050 .025
14/6/62 18/10/62
10
18 12
21 27
25 15
11 15
11 19
4 12
HIGHWAY MILEAGE
1 2 3 4 5 6 7 8 9 10
LINE DIAGRAM
INTERNATIONAL BOUNDARY U.S.A. - CANADA
CANADA CUSTOMS
WET SIDEHILL CONDITIONS
BELLY RIVER - I.R. BDRY.
D.P.W. CONSTRUCTION CAMP
GRANULAR SOILS
BLOOD INDIAN RESERVE BOUNDARY
CROOKED CREEK
PARK WARDEN STATION
NEW GRADE OCT./62
CONTINUED
TO JUNCTION HWY. #5 W.N.P. 3.8 MI.
GRANULAR SOILS
CHIEF MOUNTAIN HIGHWAY, MILES 1 TO 10
WATERTON NATIONAL PARK, ALBERTA
SURFACE: 22' WIDE THIN ROAD MIX, 2' GRAVEL SHOULDERS.
JULY 1962
N.A. HUCULAK. MATERIALS ENG.


F' 4.

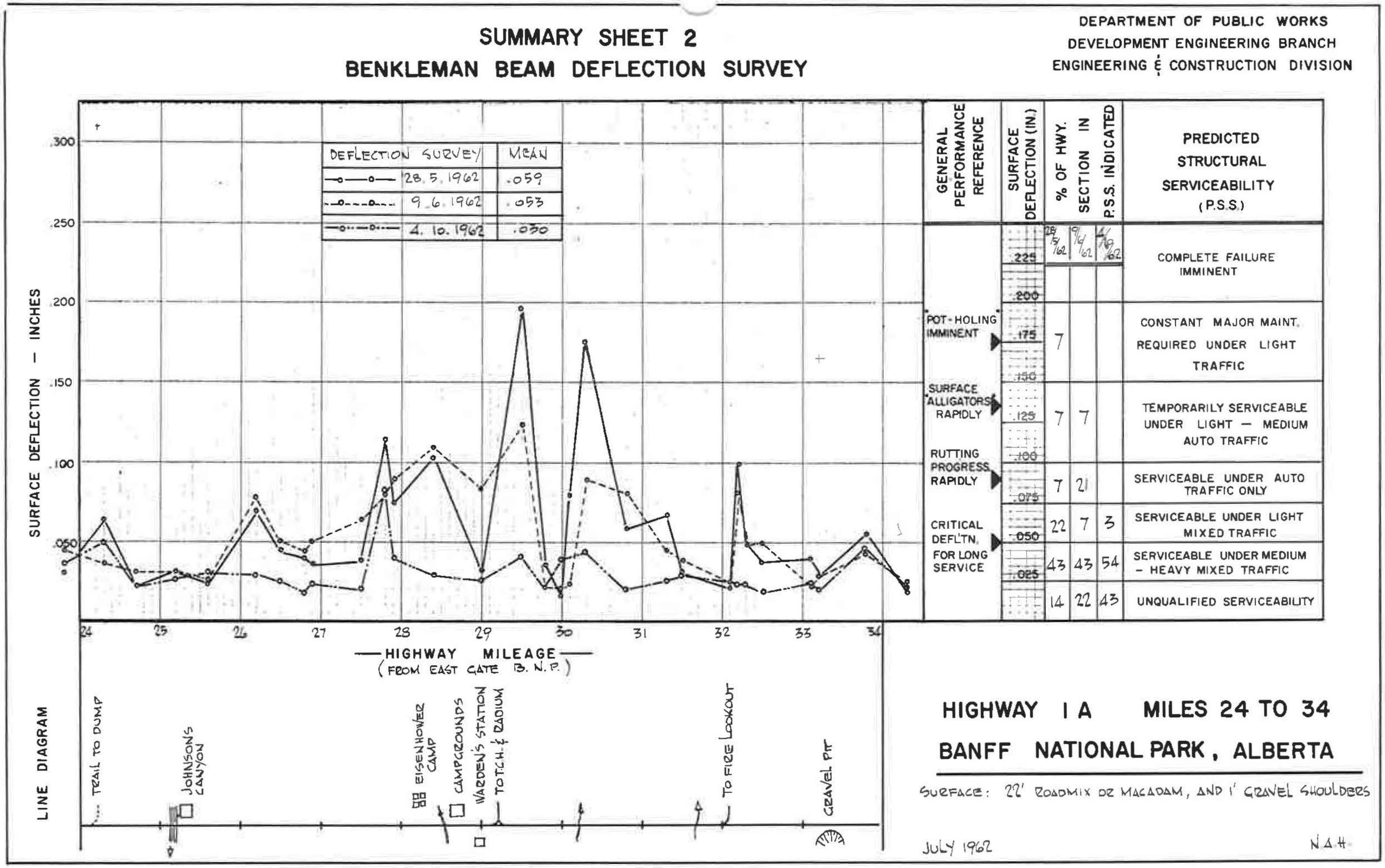

SUMMARY SHEET 2
BENKLEMAN BEAM DEFLECTION SURVEY
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
ENGINEERING & CONSTRUCTION DIVISION
DEFLECTION SURVEY | MEAN
28.5.1962 | .059
9.6.1962 | .053
4.10.1962 | .030
SURFACE DEFLECTION – INCHES
.300
.250
.200
.150
.100
.050
24 25 26 27 28 29 30 31 32 33 34
HIGHWAY MILEAGE
(FROM EAST GATE B.N.P.)
GENERAL PERFORMANCE REFERENCE
SURFACE DEFLECTION (IN.)
% OF HWY. SECTION IN P.S.S. INDICATED
PREDICTED STRUCTURAL SERVICEABILITY (P.S.S.)
28/5/62 9/6/62 4/10/62
.225
COMPLETE FAILURE IMMINENT
.200
POT-HOLING IMMINENT
.175
7
CONSTANT MAJOR MAINT. REQUIRED UNDER LIGHT TRAFFIC
.150
SURFACE ALLIGATORS RAPIDLY
.125
7 7
TEMPORARILY SERVICEABLE UNDER LIGHT – MEDIUM AUTO TRAFFIC
RUTTING PROGRESS RAPIDLY
.100
7 21
SERVICEABLE UNDER AUTO TRAFFIC ONLY
.075
CRITICAL DEFL'TN. FOR LONG SERVICE
22 7 3
SERVICEABLE UNDER LIGHT MIXED TRAFFIC
.050
43 43 54
SERVICEABLE UNDER MEDIUM – HEAVY MIXED TRAFFIC
.025
14 22 43
UNQUALIFIED SERVICEABILITY
LINE DIAGRAM
TRAIL TO DUMP
JOHNSONS CANYON
EISENHOWER CAMP
CAMPGROUNDS
WARDEN'S STATION
TOTCH. & RADIUM
TO FIRE LOOKOUT
GRAVEL PIT
HIGHWAY 1 A MILES 24 TO 34
BANFF NATIONAL PARK, ALBERTA
SURFACE: 22' ROADMIX OR MACADAM, AND 1' GRAVEL SHOULDERS
JULY 1962
N.A.H.

Figure 5.

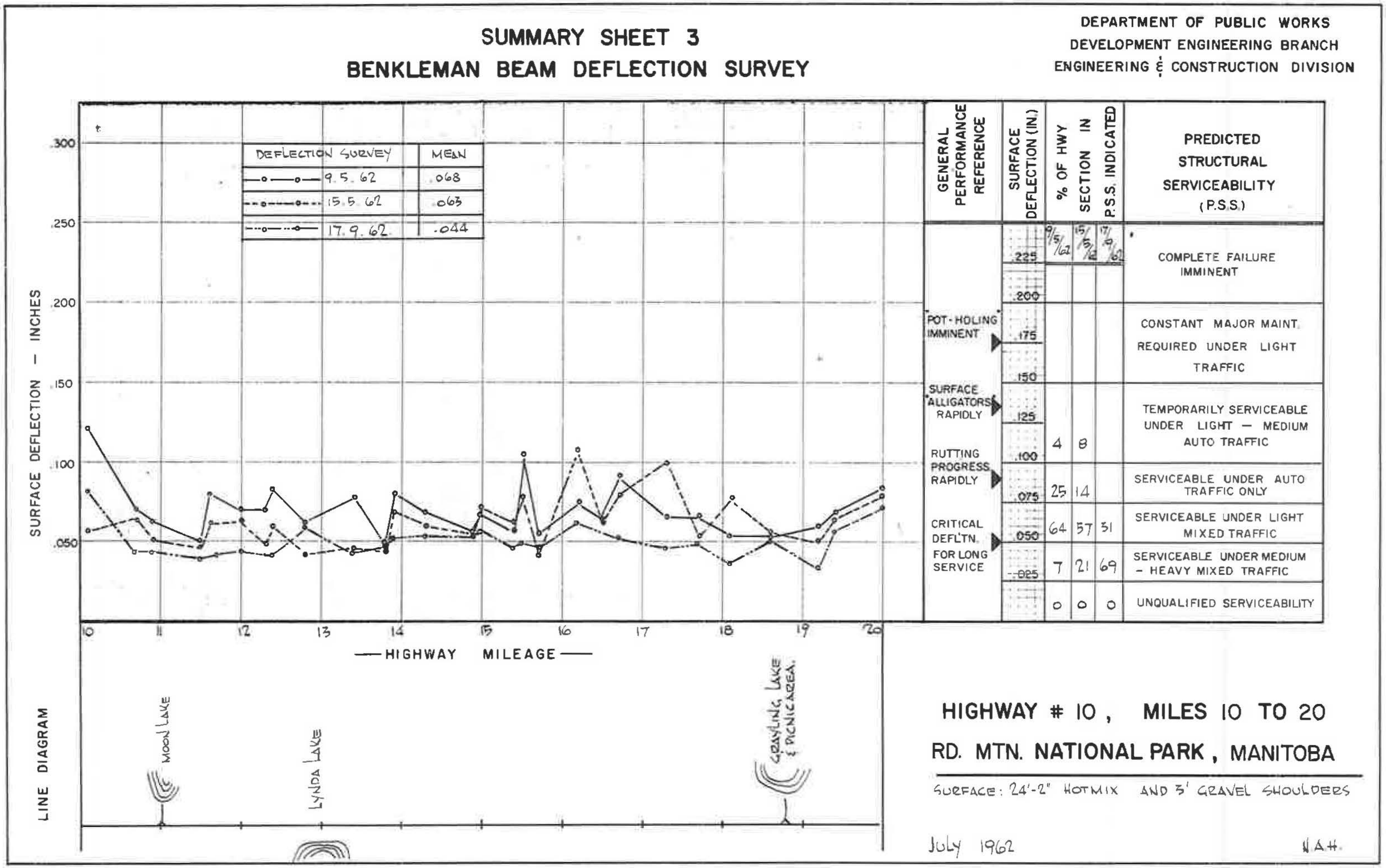

SUMMARY SHEET 3
BENKLEMAN BEAM DEFLECTION SURVEY
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
ENGINEERING & CONSTRUCTION DIVISION
DEFLECTION SURVEY
MEAN
9.5.62
.068
15.5.62
.063
17.9.62
.044
SURFACE DEFLECTION - INCHES
.300
.250
.200
.150
.100
.050
GENERAL PERFORMANCE REFERENCE
SURFACE DEFLECTION (IN.)
% OF HWY SECTION IN P.S.S. INDICATED
PREDICTED STRUCTURAL SERVICEABILITY (P.S.S.)
9/5/62
15/5/62
17/9/62
.225
.200
.175
.150
.125
.100
.075
.050
.025
COMPLETE FAILURE IMMINENT
POT-HOLING IMMINENT
CONSTANT MAJOR MAINT. REQUIRED UNDER LIGHT TRAFFIC
SURFACE ALLIGATORS RAPIDLY
TEMPORARILY SERVICEABLE UNDER LIGHT — MEDIUM AUTO TRAFFIC
4 8
RUTTING PROGRESS RAPIDLY
SERVICEABLE UNDER AUTO TRAFFIC ONLY
25 14
CRITICAL DEFL'TN. FOR LONG SERVICE
SERVICEABLE UNDER LIGHT MIXED TRAFFIC
64 57 31
SERVICEABLE UNDER MEDIUM - HEAVY MIXED TRAFFIC
7 21 69
UNQUALIFIED SERVICEABILITY
0 0 0
10
11
12
13
14
15
16
17
18
19
20
HIGHWAY MILEAGE
LINE DIAGRAM
MOON LAKE
LYNDA LAKE
GRAYLING LAKE & PICNIC AREA.
HIGHWAY # 10, MILES 10 TO 20
RD. MTN. NATIONAL PARK, MANITOBA
SURFACE: 24'-2" HOTMIX AND 3' GRAVEL SHOULDERS
JULY 1962
N.A.H.

Figure 6.

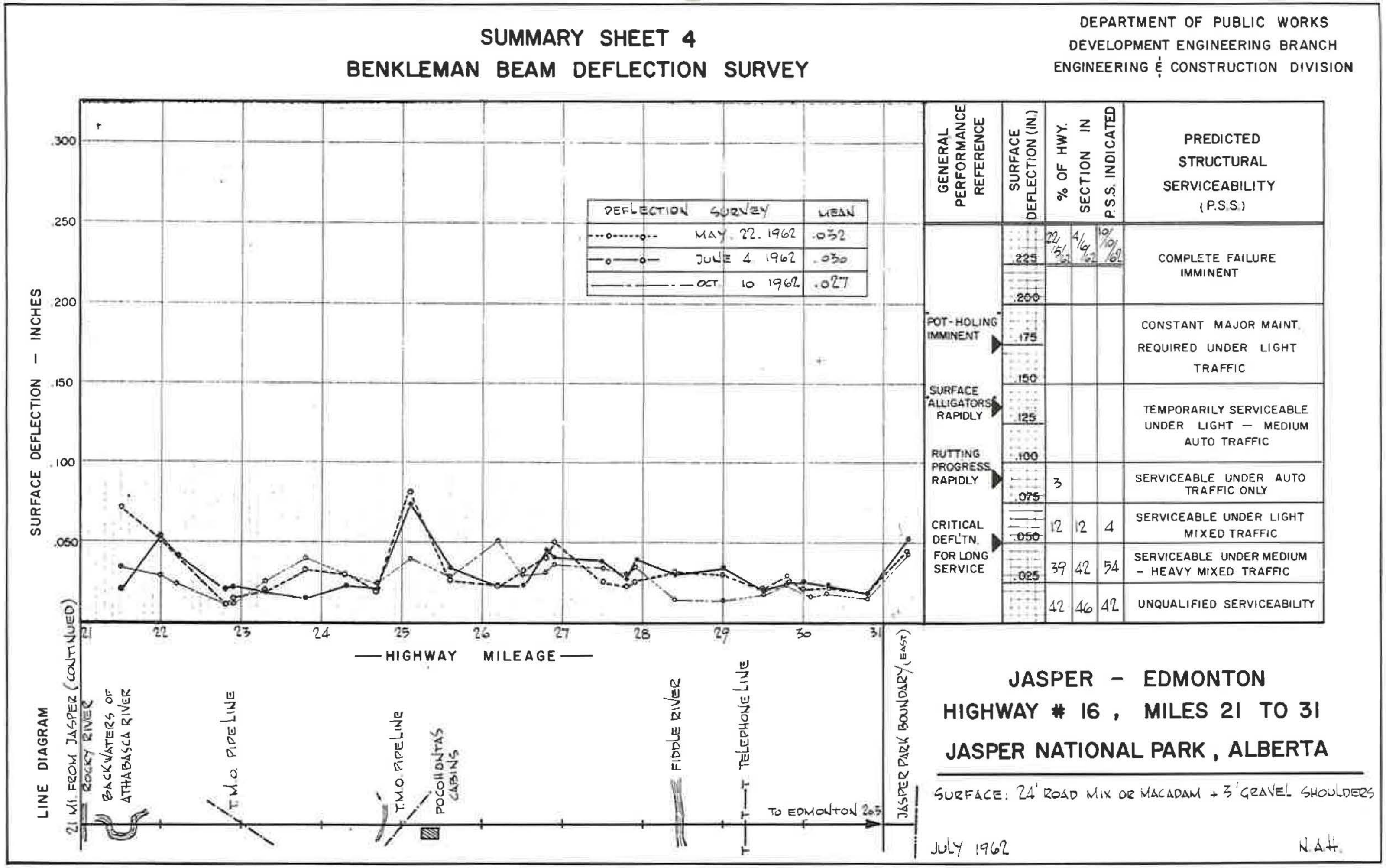
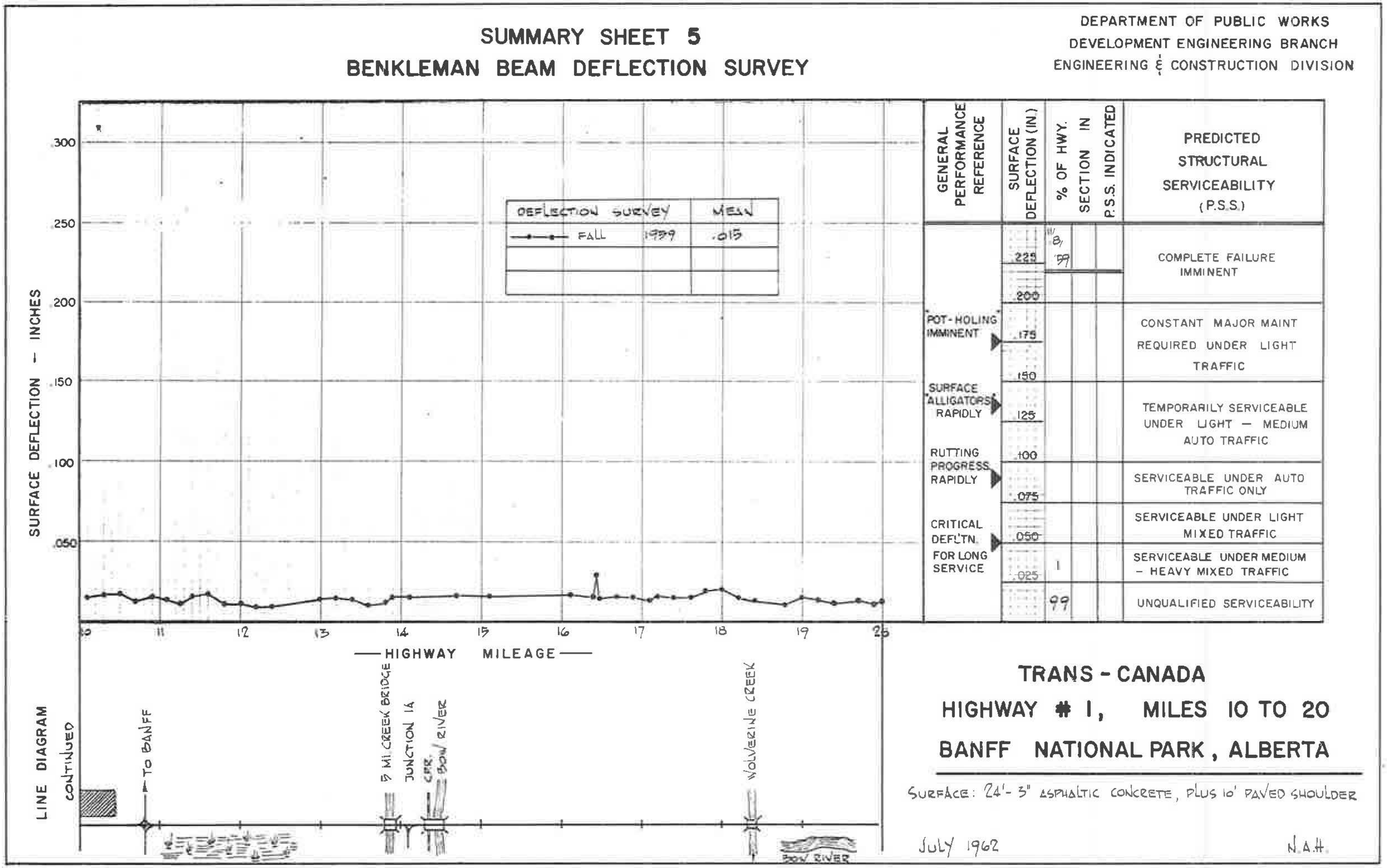

SUMMARY SHEET 4
BENKLEMAN BEAM DEFLECTION SURVEY
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
ENGINEERING & CONSTRUCTION DIVISION
SURFACE DEFLECTION - INCHES
.300
.250
.200
.150
.100
.050
DEFLECTION SURVEY
MEAN
MAY 22. 1962 .032
JUNE 4 1962 .030
OCT. 10 1962 .027
21
22
23
24
25
26
27
28
29
30
31
HIGHWAY MILEAGE
GENERAL PERFORMANCE REFERENCE
SURFACE DEFLECTION (IN.)
% OF HWY. SECTION IN P.S.S. INDICATED
PREDICTED STRUCTURAL SERVICEABILITY (P.S.S.)
22/5/62
4/6/62
10/10/62
.225
.200
.175
.150
.125
.100
.075
.050
.025
COMPLETE FAILURE IMMINENT
POT-HOLING IMMINENT
CONSTANT MAJOR MAINT. REQUIRED UNDER LIGHT TRAFFIC
SURFACE ALLIGATORS RAPIDLY
TEMPORARILY SERVICEABLE UNDER LIGHT — MEDIUM AUTO TRAFFIC
RUTTING PROGRESS RAPIDLY
3
SERVICEABLE UNDER AUTO TRAFFIC ONLY
CRITICAL DEFL'TN. FOR LONG SERVICE
12 12 4
SERVICEABLE UNDER LIGHT MIXED TRAFFIC
39 42 54
SERVICEABLE UNDER MEDIUM - HEAVY MIXED TRAFFIC
42 46 42
UNQUALIFIED SERVICEABILITY
LINE DIAGRAM
21 MI. FROM JASPER (CONTINUED)
ROCKY RIVER
BACKWATERS OF ATHABASCA RIVER
T.M.O. PIPE LINE
T.M.O. PIPELINE
POCOHONTAS CABINS
FIDDLE RIVER
TELEPHONE LINE
TO EDMONTON 203
JASPER PARK BOUNDARY (EAST)
JASPER - EDMONTON
HIGHWAY # 16 , MILES 21 TO 31
JASPER NATIONAL PARK , ALBERTA
SURFACE: 24' ROAD MIX OR MACADAM + 3' GRAVEL SHOULDERS
JULY 1962
N.A.H.

Figure 7.


SUMMARY SHEET 5
BENKLEMAN BEAM DEFLECTION SURVEY
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
ENGINEERING & CONSTRUCTION DIVISION
SURFACE DEFLECTION - INCHES
.300
.250
.200
.150
.100
.050
DEFLECTION SURVEY
MEAN
FALL 1959
.015
10
11
12
13
14
15
16
17
18
19
20
HIGHWAY MILEAGE
GENERAL PERFORMANCE REFERENCE
SURFACE DEFLECTION (IN.)
% OF HWY. SECTION IN P.S.S. INDICATED
PREDICTED STRUCTURAL SERVICEABILITY (P.S.S.)
POT-HOLING IMMINENT
SURFACE ALLIGATORS RAPIDLY
RUTTING PROGRESS RAPIDLY
CRITICAL DEFL'TN. FOR LONG SERVICE
.225
.200
.175
.150
.125
.100
.075
.050
.025
1
99
COMPLETE FAILURE IMMINENT
CONSTANT MAJOR MAINT REQUIRED UNDER LIGHT TRAFFIC
TEMPORARILY SERVICEABLE UNDER LIGHT - MEDIUM AUTO TRAFFIC
SERVICEABLE UNDER AUTO TRAFFIC ONLY
SERVICEABLE UNDER LIGHT MIXED TRAFFIC
SERVICEABLE UNDER MEDIUM - HEAVY MIXED TRAFFIC
UNQUALIFIED SERVICEABILITY
LINE DIAGRAM
CONTINUED
TO BANFF
5 MI. CREEK BRIDGE
JUNCTION 1A
CRK.
BOW RIVER
WOLVERINE CREEK
BOW RIVER
TRANS - CANADA
HIGHWAY # 1, MILES 10 TO 20
BANFF NATIONAL PARK, ALBERTA
SURFACE: 24'- 3" ASPHALTIC CONCRETE, PLUS 10' PAVED SHOULDER
JULY 1962
N.A.H.

F' re 8.

3. Besides giving the observer a quick general impression of the structural capacity of the highway, the deflection profile indicates that there are numerous weak areas within the section and where these weak areas are located.

4. Assuming that this section was required to carry light mixed traffic (say less than 300 cars, 15 buses and 5 heavy trucks daily), it can readily be seen that over 50 percent of the highway is not capable of performing under these conditions over a reasonable period of time. Thus one would conclude that severe load restrictions are required or that reconstruction of the section must be carried out in the very near future.

As mentioned previously, a study of the deflection profile will readily show the areas of greatest weakness. Where deflections much higher than the average occur over short isolated stretches such as miles 29-31 of Summary Sheet #2 (Fig. 5), consideration should be given to strengthen these points to a level at least equivalent to adjacent areas. This would reduce spring load reduction requirements significantly and possibly eliminate a reoccurring problem area.

Summary Sheet #3 (Fig. 6) is a good example of a highway section which is "uniformly weak." This section is quite capable of handling light mixed traffic except during the breakup season during which time severe load restrictions are warranted. It is typical of a substandard pavement whose structural serviceability can be raised with subexcavation and backfill with nonfrost-susceptible materials at a small number of short areas and the application of an overlay of several inches of gravel and a thin surface course.

The type of highway summarized on sheet #4 (Fig. 7) is very similar to that described for sheet #3 except that weak areas are more isolated and overlay load restriction requirements are not as great.

Summary Sheet #5 (Fig. 8) is an example of a highway section which may be described as serviceable without reservation, and which will perform for a long period with little maintenance under most traffic conditions.

As stated earlier, it is apparent that surface deflections obtained under a standard wheel load provide a relative measure of the structural capacity of a highway at a given point and time. Regarded collectively, these measurements can be used to represent its present structural serviceability. Based on experience and performance study correlations, these basically simple data can be employed to portray the present and probable future structural performance and maintenance requirements of the entire highway system.

A review of the deflection profiles by one who is familiar with the performance of the various highways will show that the average deflections alone do not provide an adequate index of structural capacity. This is not unexpected since the mean value only tells us that 50 percent of the data were below and 50 percent of the data were above that level of deflection. Obviously, two sections of highway which have the same average deflection but very different standard deviations of deflection will perform radically different under a given set of traffic conditions. The highway section with a high standard deviation will have many soft areas which will fail early. A more accurate representation of the structural serviceability of the section is therefore obtained when some significance is given to the degree by which the various deflections along the route vary about the mean value (standard deviation).

A Highway Category and Action Chart (Fig. 9) has been designed as a further interpretation and application of the data obtained in this survey. The chart is entered at the mean and standard deviation values of deflection for each section of highway. The other properties and categories of the section are then picked off the appropriate scales.

For example, if we refer to Summary Sheet #3 covering highway 10, miles 10-20, we find that this section has a mean fall deflection value of 0. 044 in. with a standard deviation of 0. 014 in. Upon entering the chart at these values we find that this section of highway: (a) requires a spring load reduction of 50 percent; (b) is capable of carrying an axle load of 9. 0 kips without distress during the spring; (c) has a 90 percentile deflection level of 0. 060 in. during the fall period; (d) requires the addition of eight "inches of gravel" plus two inches of asphaltic surface if spring reductions are to be

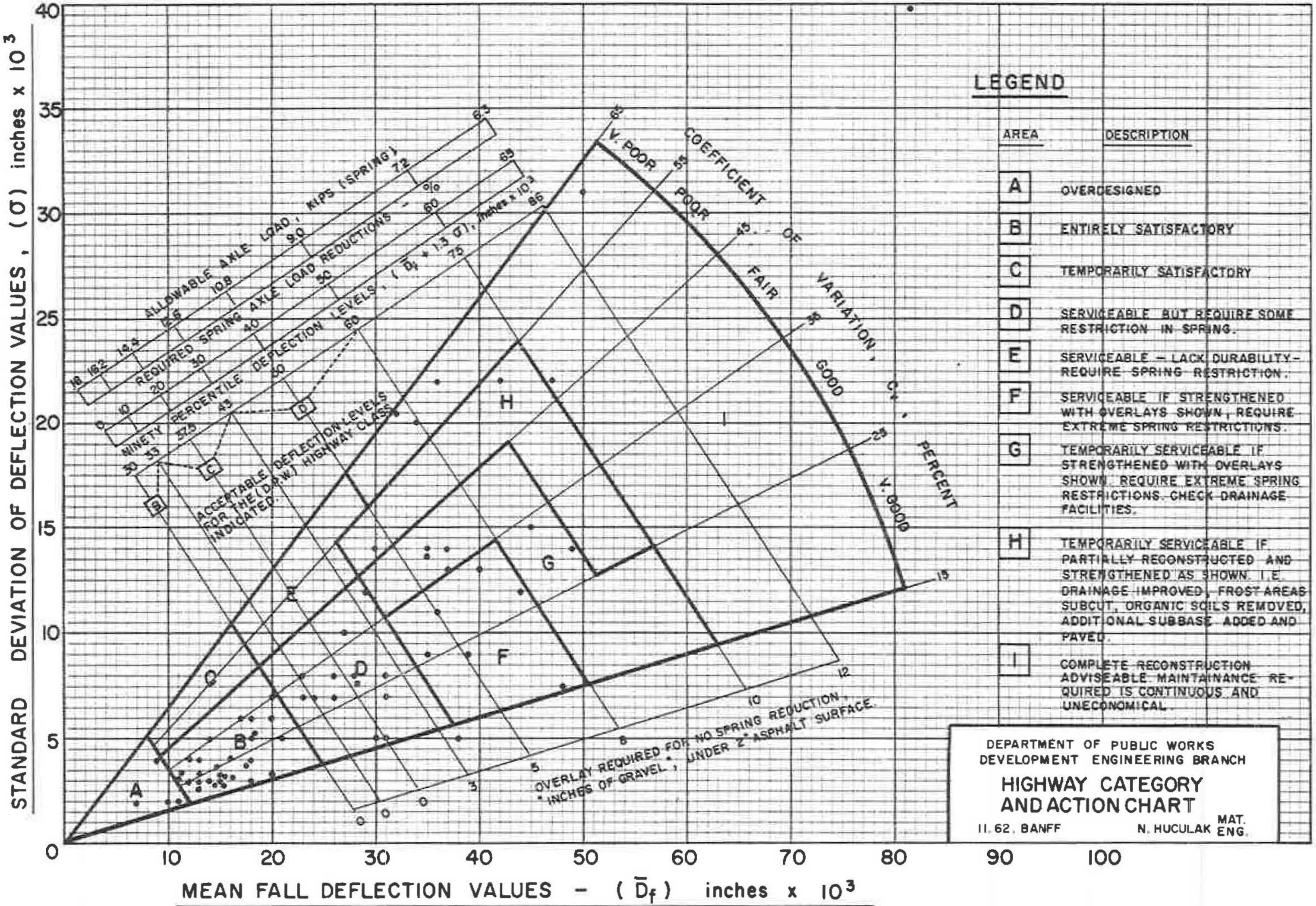

LEGEND
AREA
DESCRIPTION
A OVERDESIGNED
B ENTIRELY SATISFACTORY
C TEMPORARILY SATISFACTORY
D SERVICEABLE BUT REQUIRE SOME RESTRICTION IN SPRING.
E SERVICEABLE – LACK DURABILITY – REQUIRE SPRING RESTRICTION.
F SERVICEABLE IF STRENGTHENED WITH OVERLAYS SHOWN, REQUIRE EXTREME SPRING RESTRICTIONS.
G TEMPORARILY SERVICEABLE IF STRENGTHENED WITH OVERLAYS SHOWN. REQUIRE EXTREME SPRING RESTRICTIONS. CHECK DRAINAGE FACILITIES.
H TEMPORARILY SERVICEABLE IF PARTIALLY RECONSTRUCTED AND STRENGTHENED AS SHOWN. I.E. DRAINAGE IMPROVED, FROST AREAS SUBCUT, ORGANIC SOILS REMOVED, ADDITIONAL SUBBASE ADDED AND PAVED.
I COMPLETE RECONSTRUCTION ADVISEABLE. MAINTAINANCE REQUIRED IS CONTINUOUS AND UNECONOMICAL.
DEPARTMENT OF PUBLIC WORKS
DEVELOPMENT ENGINEERING BRANCH
HIGHWAY CATEGORY AND ACTION CHART
11. 62. BANFF
N. HUCULAK MAT. ENG.
ALLOWABLE AXLE LOAD, KIPS (SPRING)
REQUIRED SPRING AXLE LOAD REDUCTIONS – %
NINETY PERCENTILE DEFLECTION LEVELS, ( D̄f + 1.3 σ), inches x 10³
ACCEPTABLE DEFLECTION LEVELS FOR THE (D.P.W.) HIGHWAY CLASS INDICATED.
COEFFICIENT OF VARIATION, Cv, PERCENT
V. POOR
POOR
FAIR
GOOD
V. GOOD
OVERLAY REQUIRED FOR NO SPRING REDUCTION, " INCHES OF GRAVEL, UNDER 2" ASPHALT SURFACE.
STANDARD DEVIATION OF DEFLECTION VALUES, (σ) inches x 10³
MEAN FALL DEFLECTION VALUES – ( D̄f ) inches x 10³

Figure 9.

avoided; (e) has a structural coefficient of variation, $C_V$ = 33 percent, which is in the "good" category—implying that the quality control during construction was adequate and that areas of extreme weakness are probably limited; and (f) is temporarily serviceable if partially reconstructed and strengthened as shown.

The position of more than 60 sections each representing 10 miles of highway is shown on the chart.

The chart is considered more applicable to highways carrying medium-mixed traffic, although recognition is given to the acceptance of higher deflections for the lower highway classes.

In general, the chart is a comprehensive summary of recent developments in the field of pavement design and evaluation. The location of the boundaries identifying the nine categories (areas on the chart) is an expression of experience with design, construction and maintenance of several hundred miles of highway ranging from minor access roads to the primary thoroughfare.

Every highway system will always contain sections which will fall within most categories shown on the chart. A large percentage will hopefully fall within the category described as "entirely satisfactory" (such as area "B") with 90 percentile deflection levels between 0. 015 and 0. 030 and coefficient of variation between 15 and 45 percent. These highways will obviously require very little or no structural maintenance over a considerable period of service. At the other end of the scale another percentage of the system will be obvious candidates for reconstruction and will fall in area "I," with 90 percentile deflection levels greater than 0. 075 in. The maintenance authority is therefore less concerned with these routes.

The highway categories with which a maintenance authority will be mostly concerned will vary from department to department since this will depend on economics and policy to some extent. It is expected, however, that in the majority they will be those which fall in areas "D" to "H" inclusive, i.e., with 90 percentile deflection levels between 0. 030 and 0. 075 in. Obviously sections which fall in area "D" will require less attention than those which are located in "F" through to "H" as briefly described on the chart.

During development of this chart, an attempt was made to establish a "Useful Life Scale" opposite the 90 percentile fall deflection levels (0. 030 to 0. 090 in.). This would be very useful in highway planning since one could then predict when each section may have to be programmed for reconstruction or improvement. Since these figures did not correlate too well, the scale was omitted. Generally, however, all highways within area "B" are less than 5 years old, sections within area "D" are 4 to 10 years old, areas "G" and "H," 8 to 15 years old, and area "I," 13 to 20 years old.

Assuming that traffic conditions were reasonably uniform throughout the system, a sequence of reconstruction requirements may be established from the chart by the relative position of the various sections on the diagram. At some time during the fiscal year, maintenance and construction requirements for future work are submitted to the central office from the districts. The administrator endeavoring to establish the program for the entire system may find the chart of some value in this regard.

If similar surveys are carried out on these roads in future years, it will be interesting to note how their position on the chart changes with time. It is expected, however, that the variation in strength from point to point within a section of pavement which is built into it at the time of construction remains constant and therefore a pavement will "age" at a constant coefficient of variation.