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RUNWAY LOAD TESTS

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SUMMARY OF THE FRENCH REPORT

Runways for heavy aircraft must be designed to carry loads of 67.5 metric tons, distributed over an area of about 0,8 m2 (74,3 short tons over about 8,6 sq. feet). the average pressure being between 7 and 10 Kg/cm2 (100 to 142 psi); under certain conditions this pressure could amount to 20 Kg/cm2 (285 psi).

In the case of most soils and as far as foundations of flexible pavements are concerned, such loads require a thickness of base from 0.6 to 1 m (2' to 3'); for runways with rigid pavement the thickness of concrete varies from 30 to 40 cm (12" to 16").

The problem of determining the nature of the base course and the thickness of the various layers of material is very intricate. The mathematical method does not give a definite answer for, on one hand, it meets with considerable analytical difficulties, if an excessive simplification of the problem is to be avoided, on the other hand the problem is based on physical data, i.e. soil-characteristics which are determined by the soil's history. Experimentation is therefore called upon to play a highly important part in both the determination of soil-characteristics and the behaviour of runways under service conditions.

During road and runway construction at the ORLY Airport, the French Highway Administration has been lead to carry out a certain number of tests.

1) Tests with a view to determining the California Bearing Ratio and the modulus of soil reaction;

2) Direct load tests on subsoil, subgrade and finished pavement.

The numerous field-tests were not carried out systematically for a detailed study of a general subject. On the contrary, they were made in order to obtain results on particular points. (For instance, determination of the settlement of a runway under load increments on a plate of a given diameter).

Nevertheless, a comparison of the various test results, enables us to come to partial but interesting conclusions concerning;

1) Pressure distribution upon a subgrade consisting of various layers;
2) Settlement variation in terms of pressure;
3) Settlement variation in terms of the diameter of the load-plate,
and this for loads up to 40 Tons.

We therefore mainly submit test-results and endeavour to draw conclusions of a limited nature.

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SUB-SECTION VIII b

METHODS OF FLEXIBLE PAVEMENT DESIGN

VIII b 6

WYOMING METHOD OF FLEXIBLE PAVEMENT DESIGN

I.E. RUSSEL
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SYNOPSIS

The purpose of this paper is fourfold:

1. A review of the fundamentals upon which the selection of the design method was based and an explanation of the method selected.
2. A presentation of a typical soil profile showing the data necessary to support this method of design.
3. An explanation of the use of the soil profile in developing the preliminary design.
4. A demonstration of the final or construction design based upon sample taken from the grade as constructed.

HISTORY

The first systematic method of design for flexible pavements, based on soil characteristics, was adopted in this State in 1940.

This method was based on a soil value formula as developed by the Keith Boyd 1).

Some changes in the original formula were made to more nearly fit local conditions and under the revised formula total surfacing thickness ranged from 4½"-3"-4½" to 10½"-9"-10½" depending upon the soil value.

In 1944 the soil value method of design was abandoned in favor of the Group Index method 2). As a result of a survey made thruout the state of previously constructed projects and a comparison of the group index of the soils and the thickness of total surface as constructed, a schedule of total thickness of base and surface courses was agreed upon between the Public Roads Administration and the State. These thicknesses ranged from 5"-3½"-5" to 18"-16½"-18" for group indexes ranging from 0 to 20.

The group index method of design was unquestionably a decided improvement over past practice but in some instances thicknesses were indicated which were at decided variance with actual experience.

DESIGN

The California Division of Highways had been making extensive surveys and studies of flexible pavement design and these data together with design curves that had been developed were published in articles by Mr. Fred J Grumm 3). The data presented by Mr. Grumm took into account load repetitions and this factor plus the design curves seemed an excellent basis from which to develop a design procedure. Moreover, a review of the design procedures in use indicated that the C.B.R. method, being a laboratory method would fit in well with the procedure followed in working out final design in this State. The practice here is to complete all design in the laboratory and pass it on to the plans division.

The California experience indicated a 7,000 lb. wheel load curve for light highway traffic and a 12,000 lb. wheel load curve for medium highway traffic. The 7,000 lb. curve gave thickness values in excess of those deemed necessary in the case of the more lightly traveled roads in Wyoming and accordingly it was deemed advisable to use the 4,000 lb. curve shown by Mr. Porter 4), and to interpolate between that and the 12,000 lb. curve. To take care of the most extreme condition a 15,000 lb. curve was also included.

While soil types and traffic (load repetitions) are admittedly important factors in any design scheme it is likewise apparent that job conditions must be given due consideration. After a thorough discussion with department engineers regarding the factors, other than soil types, which would effect the design, the table of supplemental design data was set up and included as a definite part of the design procedure. The values assigned for the various items in this table are admittedly emperical but are based on past experiences and the studied judgement of department engineers.

SUPPLEMENTAL DESIGN DATA (FIG. 1)

I. Annual Precipitation

The average annual precipitation may be obtained from climatological data furnished by the United States Department of Commerce. Usually the data from the weather station nearest the project is used but corrections are made if conditions are known to be at appreciable variance from such data.

Irrigation is considered as light if past experience shows favorable conditions to exist in the irrigated section or in a similar section nearby. Otherwise irrigation is considered as heavy.

A swamp or evidence of seepage usually justifies the selection of a higher value than the annual precipitation would indicate.

II. Free Water Table

WYOMING HIGHWAY DEPARTMENT
SUPPLEMENTAL DESIGN DATA

ITEM	LIMITS	VALUE	Minimum Center Section of Selected Material Surfacing plus Base Course Surfacing plus Top Course Surfacing within Traffic Group F.I. (IN.)	F (IN.)	S (IN.)
ANNUAL PRECIPITATION	5 to 10 inches	0			
	10 to 15 inches	1			
	15 to 20 inches	3			
	20 to 25 inches - or light irrigation	6			
	25 to 50 inches - or heavy irrigation	10			
WATER TABLE	None evident	0			
	10 to 6 feet below grade	1			
	6 to 4 feet below grade	3			
	4 to 2 feet below grade	5			
FROST ACTION (INDUCING HEAVE)	None	0			
	Light	1			
	Medium	3			
	Heavy	8			
EXISTING CONDITIONS	Excellent	0			
	Fair	2			
	Adverse	6			
TRAFFIC (DESIGN REPETITIONS TRAFFIC IN ONE DIRECTION - IN EQUIVALENT 5000 POUND WHEEL LOADS)	0.0 to 1.0 million	0	[illegible]	[illegible]	[illegible]
	1.0 to 2.0 million	2	3½	3	3
	2.0 to 3.0 million	4	3½	3	3
	3.0 to 5.0 million	6	4	3½	3
	5.0 to 7.0 million	9	4	3½	3
	7.0 to 9.0 million	12	4½	4	3½
	9.0 to 11.0 million	15	4½	4	3½
	11.0 to 13.0 million	18	5	4½	4
	13.0 to 15.0 million	21	5	4½	4
	15.0 plus million	24	5½	5	4½

TRAFFIC STUDY (SEE ATTACHED REPORT FOR TRAFFIC LOAD COMPUTATION)

Road U.S. 87 Sheridan - Buffalo
Section Banner - South
Loadometer Station (1) Average of the 10 stations for 1946.
Average Daily Traffic (1946) 528
Average Daily Commercial Traffic (1946) 143
Estimated Average Daily Commercial Traffic (1966) (2) 286 } Average 215
WHEEL LOAD GROUPS (IN POUNDS)

1. 4500 - 5500	(3) 13.17%	x 215	x 365	x 20	x 1	=	206,703	Equivalent 5000 Pound Wheel Loads
2. 5500 - 6500	15.30%	x 215	x 365	x 20	x 2	=	480,267	
3. 6500 - 7500	11.76%	x 215	x 365	x 20	x 4	=	738,293	
4. 7500 - 8500	14.11%	x 215	x 365	x 20	x 8	=	1,771,652	
5. 8500 - 9500	6.21%	x 215	x 365	x 20	x 16	=	1,599,455	
6. 9500 & over	5.84%	x 215	x 365	x 20	x 32	=	2,933,082	

Total estimated 5000 Lb. wheel loads in 20 years 7,689,452
Design repetitions - Traffic in one direction 3,844,726
(1) Actual report on individual projects may be used when available
(2) 100% increase in 20 years (variable depending on the road)
(3) Factors for converting to wheel loads (from loadometer station)

If								
Use Design Curve	4	5	6	7	8	9	12	15
Total Value is within limits of	0-2	3-6	7-11	12-17	18-24	25-32	33-41	42-53

EXAMPLE 1

Section thru a heavily irrigated flat; water table 3 feet below grade; heavy frost action evident; existing conditions adverse due to drainage plus other conditions; traffic, as computed in the traffic study above, 3.8 million; total value 35 designates use of the design curve 12.

EXAMPLE 2

Section thru high bench; annual precipitation less than 10 inches; no water table evident; no frost apparent; existing conditions to be considered excellent due to drainage plus other conditions; traffic 3.8 million; total value 6 designates use of design curve [illegible]

Assuming soils with a C. B. R. less than 3 %, see Figure 2 for continuation.

Different design curves are used, throughout a project, as changing conditions show total values indicating the use of a different design curve in any section.

FIG. 1

The depth below finished grade of any known water table elevation is selected for determining the appropriate value to be used under this item.

III. Apparent Frost Action (Inducing Heaving)

Values are assigned under this item in accordance with the amount of heaving known to occur in a particular section or similiar nearby section and the apparent detrimental effect of such heaving in respect to subgrade support. Frost action is considered light if only slight heaving is observed, medium if heaving approaches two inches and there appears to be some evidence of weakening of subgrade support and heavy if heaving is in excess of two inches with noticable weakening of subgrade support.

IV. Existing Conditions

Existing conditions are evaluated as excellent, fair or adverse depending upon such factors as surface drainage, subdrainage, snow or other conditions which might effect the design.

V. Traffic

Traffic is evaluated in respect to the repetitions of equivalent 5,000 lb. wheel loads in one direction, computed from traffic studies. For the year of 1946 loadometer studies were made at only ten checking stations thruout the State and computations are based on a summary from these ten stations. The factors used for converting the total loads from the traffic study to equivalent 5,000 lb. wheel loads include a correction for the average number of axles per vehicle. Only wheel loads of 4,500 lbs. or more are used in these computations. The minimum center thickness shown in Figure 1 for Federal Interregional, Federal and State roads represent the lower limit that would be

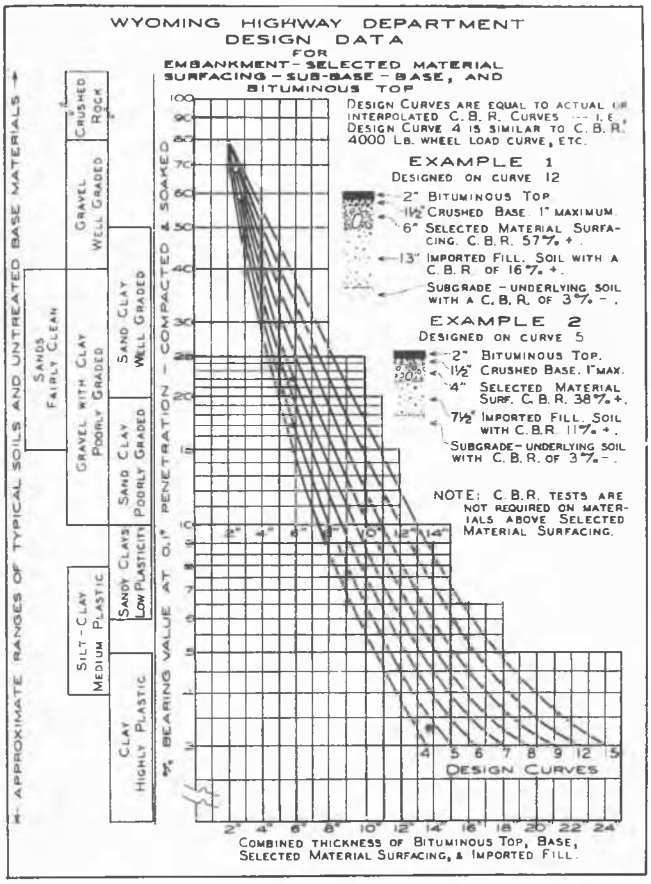
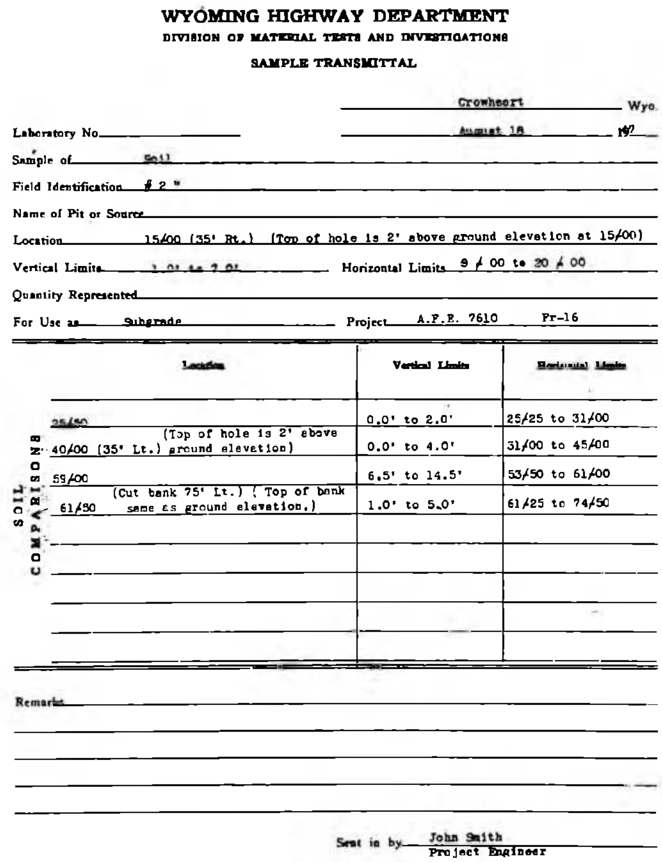


FIG. 2



WYOMING HIGHWAY DEPARTMENT
DIVISION OF MATERIAL TESTS AND INVESTIGATIONS
SAMPLE TRANSMITTAL

Crowheart Wyo.
Laboratory No. ____ August 18 19__
Sample of Soil
Field Identification # 2 *
Name of Pit or Source
Location 15/00 (35' Rt.) (Top of hole is 2' above ground elevation at 15/00)
Vertical Limits [illegible] Horizontal Limits 9 / 00 to 20 / 00
Quantity Represented
For Use as Subgrade Project A.F.E. 7610 Pr-16

SOIL COMPARISONS

Location	Vertical Limits	Horizontal Limits
25/50	0.0' to 2.0'	25/25 to 31/00
40/00 (35' Lt.) (Top of hole is 2' above ground elevation)	0.0' to 4.0'	31/00 to 45/00
59/00	6.5' to 14.5'	53/50 to 61/00
61/50 (Cut bank 75' Lt.) (Top of bank same as ground elevation.)	1.0' to 5.0'	61/25 to 74/50

Remarks

Sent in by John Smith
Project Engineer

FIG. 3

used even though existing soil conditions are very granular and have relatively high bearing ratios. The design usually is well in excess of these minimum values.

VI Selection of Design Curve

The accumulated value arrived at by use of the Supplemental Design Data is used to designate the design curve. If and when job conditions change sufficiently to indicate the use of a different design curve such change is made. Thus it is apparent that thruout any given project the use of several design curves may be necessary. After the design curve or curves have thus been established. C.B.R. values are used to indicate the thickness of subbase, base and surface course. Notes and examples included with Figures I and II indicate the complete procedure.

THE SOIL PROFILE

The preliminary soils investigation is made immediately after route approval, and the preliminary soil profile is prepared by the locating engineer. A reproduction tracing of the heading (Figure 3) is furnished the engineer. This heading as it goes to the engineer has only those items shown in vertical lettering. All data shown in slant lettering is added later as the soil profile and design is developed. The heading is attached to a full width roll of thin profile paper.

The preliminary soil profile must include notes on all job conditions that may in any way effect the design. Thus it is apparent that a careful study of the particular project is essential if the final design is to be both adequate and economical.

In making up the preliminary soil profile only the profile line and stationing is required to be inked in. All other data is placed on the profile with H pencil since satisfactory prints can be made from an original prepared in this manner. On the profile all locations are shown where samples are taken as well as the depth of sampling and all soil changes at each such location.
Where similar soils are encountered only one sample is taken and this is indentified by means of an asterisk. Similar soils are indicated by using the same field number as the one that has been sampled. This proceedure is clearly indicated on Sample Transmittal when used in conjunction with soil profile. Approximate balance points are indicated since they can be more accurately determined in the field. All available sources of matarial suitable for subbase, base or surface courses are investigated and the data included on the profile.

PRELIMINARY DESIGN

The preliminary soil profile is submitted to the soils division along with all samples lifted for the project. Samples are tested and classified in accordance with the Highway Research Board Classification scheme. California Bearing Ratios are determined and all data is entered on the soil profile. In order to reduce the amount of lettering, rubber stamps are used for this purpose and only the actual test data has to be lettered in.

From the actual job conditions shown on the soil profile and data obtained from the traffic flow map, the Preliminary Supplemental Data table is completed and the total points arrived at indicates the design curve to be used. As conditions vary thruout a given project changes from one curve to another may be necessary. A study of the soil profile will show just how the preliminary design is developed.

The design is then reviewed with the construction engineer and if deemed necessary thickness of base courses may be increased. Rarely however, is the design reduced. If Federal funds are involved on the project the design is finally reviewed by a representative of the Public Roads Administration before being turned over to the plans division.

CONSTRUCTION DESIGN

More often than not, projects as awarded in this State include grading, subbase, base and surface course. In order for the plans division to arrive at proper quantities of materials as well as to insure correct grade widths for the total surfacing sections it is, of course, necessary to predicate the design on preliminary samples of the soil to be used in the grade.

Due to unavoidable blending of soils on actual construction as well as to some unforseen job conditions that develop changes in the preliminary design are sometimes necessary. Usually such changes are not sufficient to cause any difficulty as regards width of finished surface and even if so, changes in the grade width can be made if the necessary design change is recognized before construction has progressed too far. Samples of the finished grade are submitted as construction proceeds. These samples are taken for every apparent soil change thruout the project. Classification tests and California Bearing Ratios are rerun and changes in the preliminary design are made where necessary. The engineer is kept fully informed of such changes.

CONCLUSIONS

The design proceedure makes use of well established data relative to the supporting value of the soils used in construction to which has been added a method of evaluating job conditions. It is, of course, based on the assumption that the grade has been compacted to at least 95% of A.A.S.H.O. density. With proper control of moisture and rolling this degree of compaction can readily be secured. The sheepsfoot roller unit used, and paid for by the unit hour, consists of a double drum having a total width of 10 feet and a ground pressure of 325 pounds per square inch.

The method is particularly adapted to laboratory control of design in that the preliminary design can be worked out previous to construction and readily corrected wherever necessary as construction progresses. As has been stated the assigned values in the Supplemental Data table are emperical and as further experience is gained changes in these values may be indicated. The thoroughness of the field engineer in furnishing information on job conditions is, of course, very essential if the resulting design is to be reasonably accurate. This design is a decided improvement over any previously used in this State but with the interest that is being shown in the matter of design it is reasonable to expect that new and better methods will be evolved which may result in a complete change in proceedure.

REFERENCES

1. Keith Boyd, "Soil Number Developed to Aid Engineering Judgement." Roads and Streeets, October 1940.
2. D.J. Steele, "Discussion of Application of Classifications and Group Index in Estimating Desirable Subbase and Total Pavement Thickness." Proceedings, Highway Research Board, Volume 25.
3. Fred J. Grumm, "Designing Foundation Courses for Highway Pavements and Surfaces." California Highways and Public Works, November 1941 and March 1942.
4. O.J. Porter, "Foundations for Flexible Pavements." Proceedings, Highway Research Board, Volume 22.

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VIII b 7 KANSAS TRIAXIAL METHOD OF FLEXIBLE PAVEMENT DESIGN x)

State Highway Commission of Kansas

The triaxial compression test provides lateral support to a specimen while it is subjected to a vertical load. Water is expelled during the progress of the test, simulating field conditions. The stress coincident with strain is obtained at regular intervals. This data is used for determining the thickness of flexible pavement required, using the modulus of deformation. Proven formulas are correlated with service records of specific conditions. Variables affecting design are traffic, climate and materials involved. All conditions existing on each project are evaluated. The frequency of sampling depends upon the topography. Preliminary investigation is made to determine the locations to be sampled. Usually an average of three samples per mile are obtained on most projects in Kansas.

Subgrade soils are tested preferably with their natural or existing structures in an undisturbed condition; they may be molded for estimating purposes. Undisturbed samples are obtained by forcing a sampler into the subgrade and pulling it out with the sample contained therein. These samples are packed in damp saw dust in boxes or in galvanized metal cans, using a material similar to the sample for packing. These cans are sealed with adhesive tape.

x) A complete report on this method of design was published in September 1947 as Bulletin Number 8, Highway Research Board, National Research Council, National Academy of Sciences, 2102 Constitution Avenue, Washington 25, D.C. The title is "Design of Flexible Pavement Using the Triaxial Compression Test".