DISCUSSION

ON

TREATMENT OF ICY PAVEMENTS

DR WM STERICKER (*Philadelphia Quartz Company*) I would like to inquire what concentration of sodium silicate solution was used and the age of the concrete at the time of applying the sodium silicate

MR PAUL W DOWNEY (*Division of Materials, District of Columbia*) A 40 per cent solution of sodium silicate was used and applied on the surface after the concrete had attained an age of six months The surfaces of the specimens were thoroughly brushed before applying the protective coating so as to insure satisfactory bond with the concrete

DR STERICKER I believe more satisfactory results would have been secured had a less concentrated solution been used, approximately one part of sodium silicate to four parts of water A solution of this concentration would more easily penetrate the concrete surface

INVESTIGATION OF MUD JACK SOILS

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SYNOPSIS

Success in raising pavement slabs permanently by the mud-jack process depends to a large degree upon the characteristics of the materials used The effects of texture, amount of organic material present, amount of cement used and amount of water needed for workability upon the shrinkage properties of the soil appear to be the significant factors Two hundred and fifty samples of soils used with mud-jacks of both the piston and compressed air type were analyzed and the range in satisfactory grading for each type determined In general, coarser soil can be used with the compressed air jack than with the piston jack From a series of laboratory tests the effects of texture, organic content, water content and cement content upon shrinkage, workability and stability were studied, resulting in diagrams showing the relation between amount of cement, organic content and shrinkage It appears to be desirable to use as coarse a soil containing as little organic material as possible Unless the amount of organic material is limited, the use of the customary small amount of cement (5 per cent) will have little effect in reducing shrinkage since high organic content requires an excessive amount of water for workability

When the Michigan State Highway Department purchased a Poulter Pavement Mud Jack in 1931, very little definite information was available concerning the manner in which this machine should be operated to produce the best results. There were questions as to what type of

soil should be used, the amount of mixing water and the advantage to be gained by the use of cement in the mixture The work done in Iowa the year before suggested the use of black top soil mixed with about 5 per cent of cement by weight and a sufficient amount of water to produce a mix of workable consistency in the machine, and in general these suggestions were followed during 1931

In 1932 the Department procured two other machines of the compressed air type It was appreciated that these machines, of a radically different design, would be capable of using a coarser soil because the factor of wear of moving parts was eliminated It was found, however, in operating these machines, that a soil of a fairly good grading was necessary in order to prevent the mixing water from being blown out through the coarser particles These things, combined with the fact that in many cases excessive cracking of the slabs occurred during the process of raising and that in others serious subsequent settlement developed, prompted the investigation which this report concerns

Material classified as black top soil in Michigan usually contains an appreciable quantity of organic matter This type of soil, however, in contrast to clays or heavy loams, generally produced an excellent appearing and easily workable grout It was, therefore, only natural under the circumstances to specify its use It was early appreciated, however, that a soil containing an excessive quantity of organic matter would not only require a large amount of mixing water with the attendant danger of high shrinkage on setting but would tend toward conditions of unstable support as well as detrimental frost heaving

A limited series of tests was accordingly made to obtain information on. (1) the grading of soils used in the two types of machines, (2) the effect of organic matter upon shrinkage, workability and flowability of the soil water mixture, and (3) the benefits derived from the use of cement

Approximately 300 samples of soil, obtained from the operators in the field, were analyzed in the laboratory The percentage of organic matter was determined and mechanical analysis made In this way considerable information was disclosed concerning the character and grading of the material being used in the two types of machines Also considerable data were furnished by the operators concerning the workability of the material used at different locations In addition, during the past summer, precise levels were taken at about 50 locations before and after raising the depressed slabs in order that the extent of subsequent settlement could be determined when desired. Information furnished by this part of the investigation will be discussed later on in the report.

STUDY OF SYNTHETIC SOIL MIXTURES

In order to study the effects of organic matter, cement, soil texture and mixing water upon the characteristics of the grout, a series of special

tests was made To a soil of a representative mud jack grading, organic matter was added in the amounts of 6, 10, 15, 22 5 and 30 per cent by weight This material was typical of that existing in the majority of black top soils selected for use in the mud jacks To each of the above mixtures, 3, 6, 9 and 12 parts of cement were added Sufficient water was then introduced to produce a mix of good consistency or one which would be workable in the machine The shrinkage of these mixtures was then determined in accordance with the standard method used by

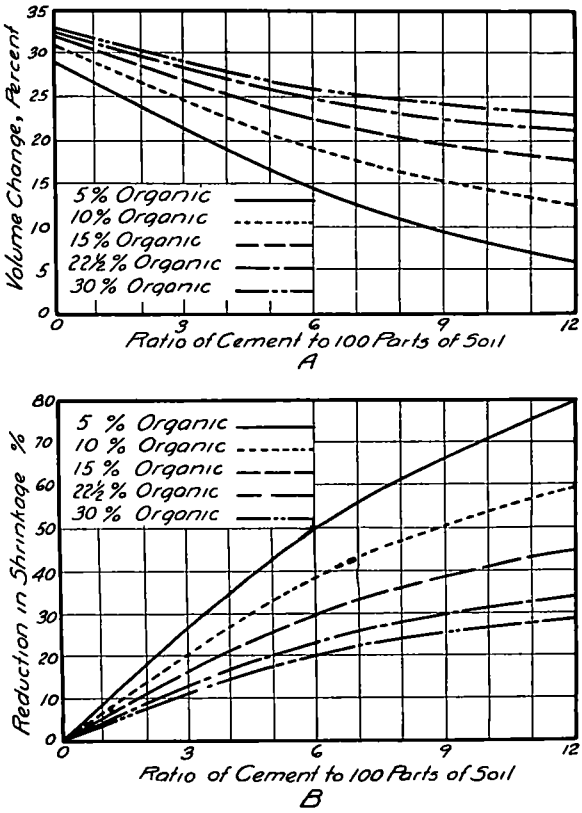

Figure 1. Effect of Cement and Organic Matter upon Volume Change

the Bureau of Public Roads, excepting that the pats were placed in the moist room for 24 hours before drying This precaution was taken in order to permit the cement in the mixture to at least partially hydrate

The results furnished by these tests are shown graphically in Figure 1 It is evident from the family of curves, Figure 1A, that as the per cent of organic matter increases, the effect of increasing amounts of cement upon reduction of shrinkage becomes decidedly less For 5 per cent organic matter the shrinkage is decreased from 29 to 6 per cent by the addition of 12 parts of cement, which is equivalent to about a two per

cent reduction for each part of cement while for 30 per cent organic matter only 10 per cent reduction resulted or less than one per cent for each increment of added cement It is of interest to note that, should it be desired to limit the shrinkage to 20 per cent, 3 5 parts of cement would be needed for a five per cent organic soil, 4 5 for 10, 8 5 for 15 and about 15 parts for a soil containing 22 5 per cent organic material Thus, for each per cent increase in organic content, an increase of approximately 0 5 parts of cement to 100 parts of soil is necessary to maintain the same shrinkage Figure 1B shows the actual percentage of shrinkage reduction obtainable by the use of cement The importance of using black top soil such as is found in Michigan, containing just sufficient organic matter to give desired workability, is clearly apparent from these data

FLOWABILITY

While the use of a soil productive of low shrinkage and high stability is to be desired, the grout must possess a certain measure of flowability or plasticity. The mixture must be such as to flow through a two inch outlet hose and moreover to move and spread out beneath the pavement from the point of entry through a restricted vertical space

A specially designed pressure viscometer was built for the purpose of studying the flowability characteristics of various grouts It consists essentially of a cylinder, in the bottom of which different diameter orifices can be inserted, and a piston, through which pressure can be transmitted to the grout under observation In the tests made, a pressure of 6 5 pounds per square inch was applied and the time required for 141 4 cubic inches of grout to flow from a one half inch diameter orifice recorded

The percentage of mixing water for each grout tested was varied so as to produce a stiff to extremely wet consistency By plotting the values of time of flow obtained from testing the various consistencies in the viscometer against the percentage of mixing water, a family of curves was developed which exhibit a pronounced break between 5 and 10 seconds From the curves in Figure 2A, it is evident that a time of flow of eight seconds intersects the curves at a point generally where the change in curvature is the most pronounced This means that for any further reduction in time of flow, a rapidly increasing percentage of mixing water becomes necessary Incidently, it was noted in connection with these tests that a mix with a time of flow of about eight seconds, particularly in case of the low organic grouts, possessed, what is termed hereafter in this report as, an ideal working consistency

Figure 2 shows the effect of organic matter upon the amount of mixing water required for the same relative flowability It is evident, in part, from 2A that as the organic content of the soil increases more water is required for the same degree of flowability The ratio of increase is

shown in Figure 2B It can be seen that the per cent increase in mixing water for the so-termed ideal consistency is directly proportioned to increase in organic content

In connection with the factor of setting time, which will be discussed later, a ten inch flow-table was used to determine the rate of stiffening of the mix Figure 2C shows a significant relation of spread of the eight-second mix upon this flow-table to the percentage of organic matter Cones of the eight-second flow mix, 2 inches in height and 4 inches in diameter at the base, were subjected to 75 one eighth inch drops of the

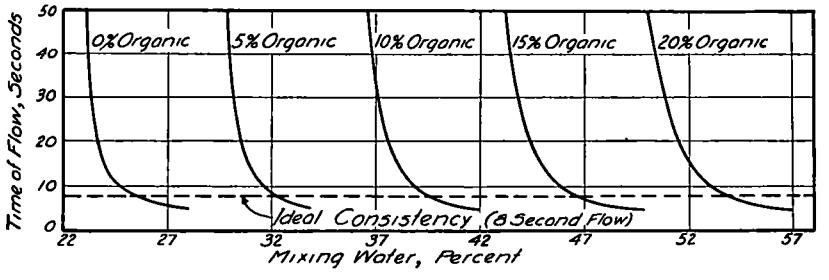

Figure 2a. Effect of Organic Matter upon Mixing Water Required for Workability

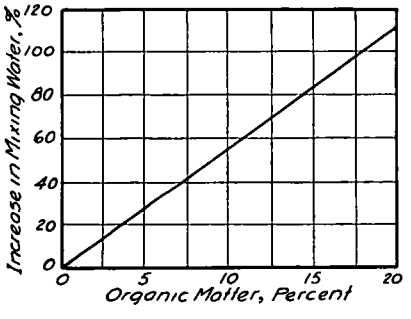

Fig. 2b. Effect of Organic Matter upon Water required for Ideal Consistency (8 Second Flow)

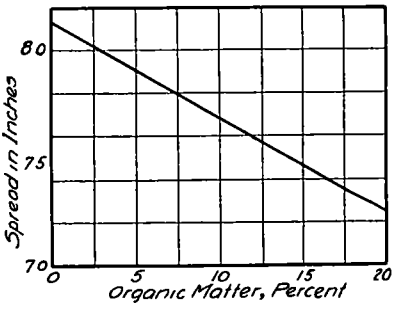

Fig. 2c Spread of the Ideal Consistency Mix upon the Flow-Table

table and the spread measured It is apparent that the spread of the ideal consistency mix decreased as the organic content increased The reduction in spread from 0 to 20 per cent organic material being about 12 per cent This means that, while two mixtures may appear to have the same visible consistency, the one that contains the higher amount of organic matter has the better flowability or that a high organic content grout may appear stiffer to the eye and spread less on the flow table and yet possess the same ability to flow as one wetter in appearance containing less organic matter.

The significance of this finding is related to the operation of the mud jacks in Michigan prior to the time when a limit was placed on the per-

centage of organic matter tolerated in the mix Unquestionably, much less mixing water could have been used in case of the higher organic content grouts

EFFECT OF SOIL TEXTURE UPON FLOWABILITY

An idea as to the effect of texture upon the ability of a grout to flow was obtained by using an almost pure silt and adding sand in increments of 10 up to 60 per cent Wet to dry mixtures were then made of each combination and tested in the viscometer The effect of sand upon amount of water necessary to create the same flowability is shown by the curves in Figure 3A As expected, adding sand up to a certain percentage decreased the amount of water necessary The 60 per cent sand

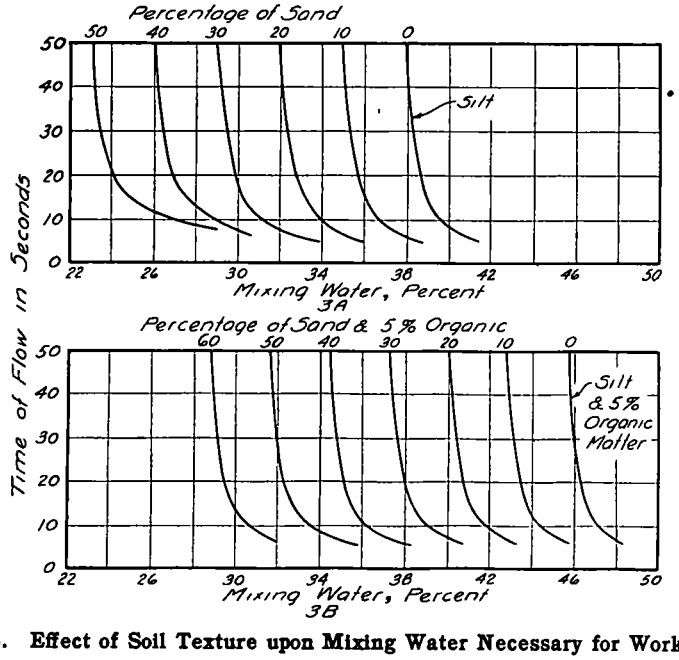

Figure 3. Effect of Soil Texture upon Mixing Water Necessary for Workability

mix failed to flow through the orifice even when extremely wet, obviously because of the high internal friction created by this amount of sand As shown by the curves in Figure 3B, the addition of five per cent of organic matter served to make the 60 per cent sand mix flowable, at the same time increasing the percentage of water necessary for the same flowability of the other mixes.

The question as to why high sanded mixes can not be made workable by the addition of silt is explained by the curves shown in Figure 3A. While the use of small amounts of clay might improve the flowability factor of high sanded mixes, its use in the field has not proven satisfactory due to difficulty experienced in dispersing this material and

attaining a homogenous mixture It is quite evident that small amounts of organic matter such as exist in the majority of black top soils in Michigan has a most unusual effect upon the workability of sandy grouts Apparently the colloidal properties of this material serve to lubricate the soil particles and thereby reduce their resistance to flow. This is substantiated by the fact that the average soil used at the present time in the air type jacks contains from 75 to 80 per cent sand and from 3 to 6 per cent organic matter

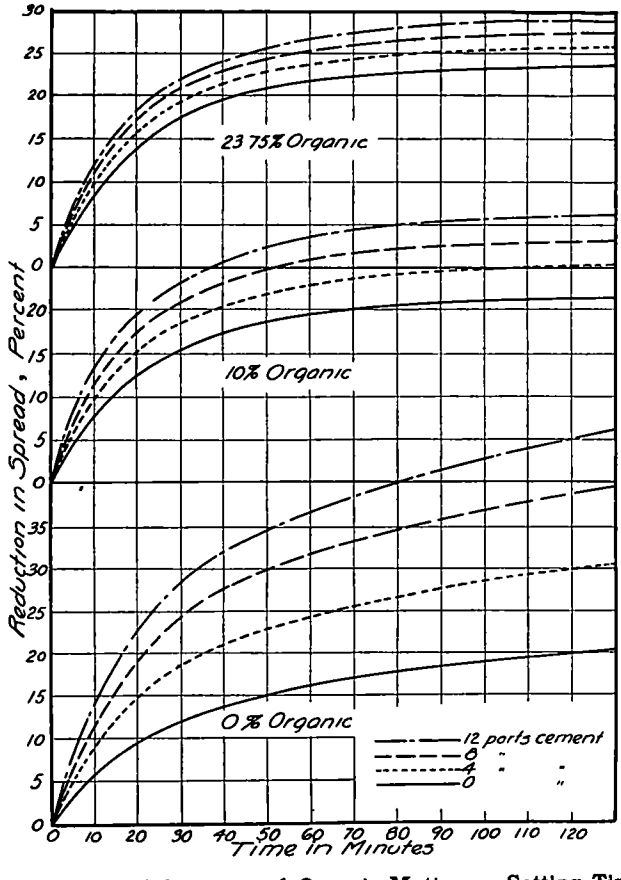

Figure 4. Influence of Cement and Organic Matter on Setting Time of Ideal Consistency Mix

SETTING TIME

The use of cement in mud jack soils serves two distinct purposes, that of reducing shrinkage and of accelerating the stiffening or setting up of the mixture. The latter action lessens the tendency of wet grout to flow out beneath and along the edge of the slab

With the use of the flow-table, an attempt was made to determine the rate of setting of various grouts. A series of six cones was made up of

a number of soil cement mixtures having an ideal consistency They were kept in a special moist compartment until time of test to prevent undue loss of moisture At the end of 15, 30, 45, 60, 90 and 120 minutes one of the cones of each mixture was subjected to 75 drops of the flow-table, the mean diameter or spread being measured at 25, 50 and 75 drops The three values obtained were then averaged and the percentage of reduction in spread over the spread at zero time computed From these data, a family of curves was developed, Figure 4, which show the influence of organic matter and cement upon the rate of set-

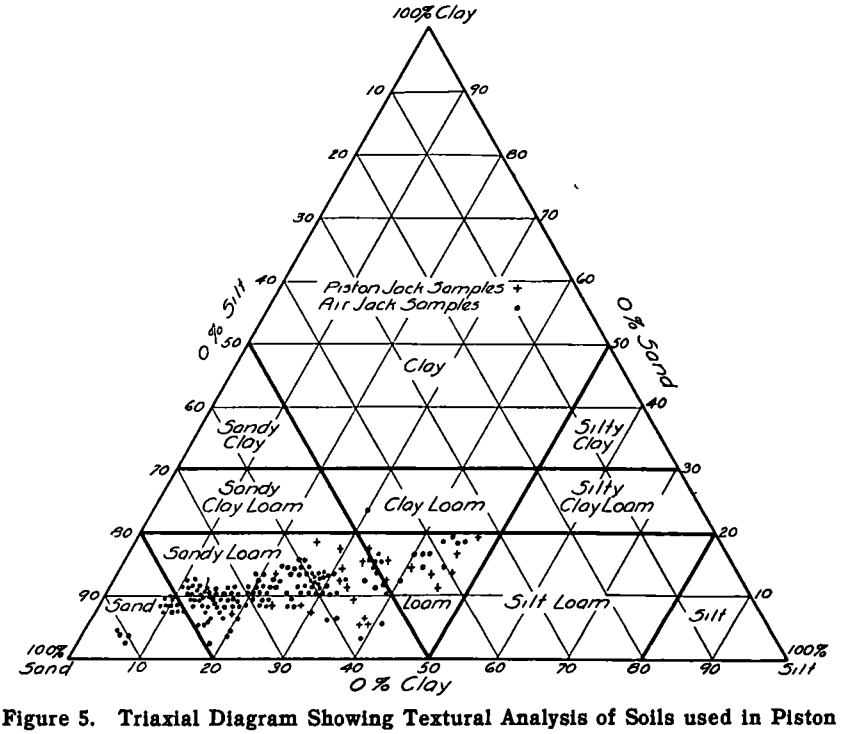

Figure 5. Triaxial Diagram Showing Textural Analysis of Soils used in Piston and Air Type Jacks

ting, assuming of course that the spread of the mixture upon the flow-table is a measure of this factor

It is clearly evident from a study of these curves that, as the organic content of this typical mud jack soil was increased, the effect of cement on setting of the mixture was greatly diminished Only five per cent reduction in cone diameter resulted in two hours from the use of 12 per cent cement in the 23 75 per cent organic soil mixture whereas approximately twice the reduction occurred in the 10 per cent mixture. About 26 per cent reduction resulted from the use of the same amount of cement in the soil containing zero per cent organic matter.

As previously stated, high organic content mixes, having the same

degree of flowability as low organic mixes, spread to a less extent under the flow-table test This is verified by the data obtained in this study. Less reduction in spread is shown for the 0 and 10 per cent than for the 23 75 per cent organic content mix.

It is also of interest to note in connection with these data that the rate of setting is more pronounced during the first 30 minutes The curves, particularly in case of the 10 and 23 75 per cent organic content mixes,

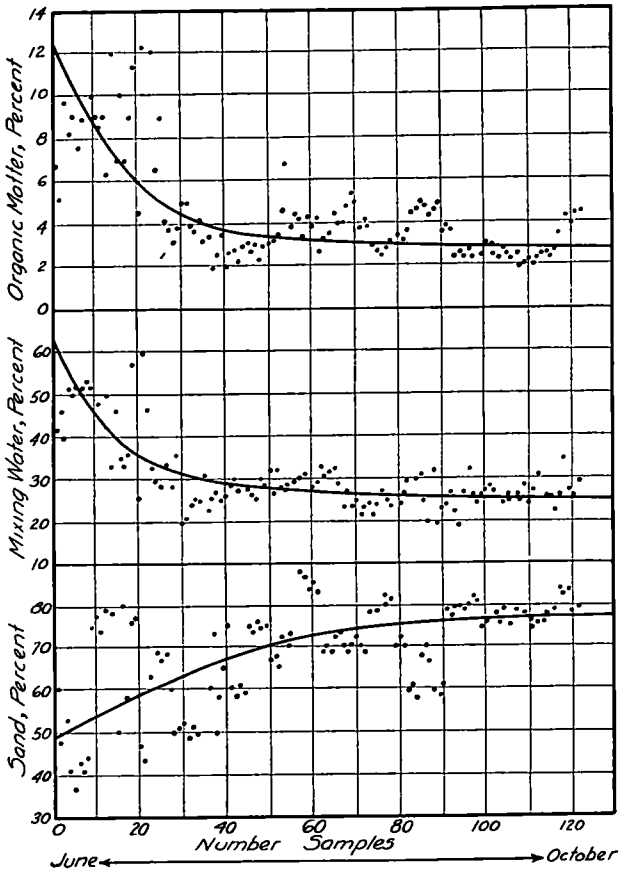

Figure 6. Percentage of Organic Matter, Sand and Mixing Water in Material Used in Air Type Jack

flatten out after this time. This is of practical significance because in case of a shoulder blow-out, a delay of a half hour or so should result in sufficient stiffening of the grout to enable a resumption of operations.

TEXTURAL ANALYSIS OF FIELD SAMPLES

Approximately 300 samples of the material used in the different mud jacks during the past summer were analyzed in the laboratory The

tests were limited to the determination of organic matter and grading. On the triaxial diagram, Figure 5, the texture of the various samples analyzed is indicated It is evident that practically all the material used is classified according to the diagram as being loam or sandy loam, also that the material used or usable in the air type jack is of a coarser texture than that used in the piston jack

An interesting study of data obtained by determining the moisture content as well as the mechanical analysis of the grout used throughout the 1932 working season in one of the air type machines is shown in Figure 6 It can be noted that, at the beginning of the season, a material high in organic matter and relatively low in percentage of sand was utilized. This required, as shown, an excessive amount of water to produce workability Following the preliminary experiments on shrinkage, a special effort was made to select a material as low in organic matter and as coarse as possible and yet which was workable for use in this machine It can be seen from the curves that a great deal of improvement in the uniformity and quality of the material resulted Moreover, a reduction in amount of mixing water necessary, for proper workability, to the extent of about 20 per cent was made possible It should be obvious that slabs raised during the latter part of the season not only rest upon a material subject to less shrinkage but upon one which most certainly offers firmer support than in case of the slabs raised earlier in the season

The above is substantiated by the level observations made to date Slabs raised, using the high organic content material, show from 20 to 35 per cent settlement as against 10 to 15 per cent for those raised later in the season Moreover, samples of the grout obtained from beneath the slab at various locations show, as anticipated, only about half as great a moisture loss in case of the slabs raised since utilizing the better grade of material

SUMMARY

While this investigation has furnished considerable information relative to the type and grading of soil best adapted for use in mud jacks, it is felt that the knowledge gained is particularly revelant to the problem and conditions existing in Michigan Black top soils prevailing in other states utilized for this class of work may have decidedly different characteristics As mentioned previously, the factor of economy enters into the use of such material in Michigan Ease in handling and mixing, ready availability and ideal plasticity or flowability are desirable properties which it possesses On the other hand, in accordance with the findings of this investigation, it is dangerous material to use unless special care is exercised in its selection The organic content should be held as low as is consistent with good workability The fact that the use of a material high in organic matter is apt to result in (a) detrimental

shrinkage, (b) nullifying the beneficial effect of cement, (c) slow setting and (d) unstable support is reason for the above statement.

In future work, black top soil available for use in a given area, will be inspected and, if necessary, analyzed in the laboratory to insure the use of a material having satisfactory workability as well as textural characteristics. Mixing of two or more materials will be resorted to if necessary. An attempt will be made to hold the organic content between 3 and 6 per cent and sand content as high as 70 to 80 per cent in case of material used in the air type machine Likewise, as coarse a soil as possible containing sufficient fine material and organic matter to give workability and that will produce a minimum of wear upon the pump will be used in the piston type machine

THE DANA AUTOMATIC RECORDING ROUGHOMETER FOR MEASURING HIGHWAY ROUGHNESS

By Homer J Dana, *Assistant Director*

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SYNOPSIS

Description of an instrument devised at the Engineering Experiment Station, State College of Washington The essential features are (1) The record paper runs five inches per mile with a faster speed of three inches per one hundred feet available for special roughness study, (2) A pencil operated through a pantograph system connected to a front wheel gives a continuous visible picture of the roughness of the road surface, (3) An automatic stamping device prints the mileage on the record every half mile or oftener as required, (4) The same stamping device prints the integrated roughness along with the mileage

During the past nine years, the Engineering Experiment Station of the State College of Washington has carried forward continuously certain studies in the field of Highway Research

The first was a determination of the relative tire wear on various kinds of highway surfaces Tire wear was measured on smooth and on rough surfaces and the excess wear on the latter was determined [1]

The second study was an outgrowth of the first Rough roads were observed frequently to be washboarded, and therefore an attempt was made to determine the cause and to discover the possible control, of washboards [2]

[1] Fifth Annual Proceedings, Highway Research Board, p 30 Bulletins 16, 17, 18, Eng Exp Sta State College of Washington

[2] Ninth Annual Proceedings, Highway Research Board, p 186 Bulletin 31, Eng Exp Sta State College of Washington