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Synopsis

The data produced in this investigation of the causes leading to distress at the joints in concrete pavements warrant the following conclusions.

The basic cause and origin of all joint troubles, including mud pumping and faulting is the volume change of concrete arising from variations in moisture and temperature.

Concrete will expand with an increase in moisture or temperature and these two factors or conditions are rarely uniform throughout a pavement slab. As a result, the slab is curled or warped a great portion of the time so that there is nonuniformity of contact and support. At such times the slab is free to move with reference to the subgrade.

The lack of "team work" between the pavement and the subgrade soil is a factor but the principal adverse effect is the alternation of the subgrade soil is a factor but the principal adverse effect is the alteration of the subgrade support caused by the pounding of the warped slabs flexing or rocking under the passing wheel loads.

The vertical movement or "pumping action" of the slabs may cause uneven compaction or settlement of relatively dry cohesionless sands or more frequently will cause the loss of subgrade material by erosion due to "pumping" when free water accumulates beneath the end of a slab.

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MATERIALS AND RESEARCH DEPARTMENT

A REPORT OF AN INVESTIGATION TO DETERMINE CAUSES FOR DISPLACEMENT AND FAULTING AT THE JOINTS IN PORTLAND CEMENT CONCRETE PAVEMENTS

May 17, 1949

49-04

STATE OF CALIFORNIA

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

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A REPORT OF AN INVESTIGATION TO DETERMINE CAUSES FOR DISPLACEMENT AND FAULTING AT THE JOINTS IN PORTLAND CEMENT CONCRETE PAVEMENTS ON CALIFORNIA HIGHWAYS

By

F. N. Hveem
Staff Materials & Research Engineer

May 17, 1949

PREFACE

This report represents a summary and condensation of data secured during an investigation of the causes for displacement, movement and mud pumping at the joints in concrete pavements.

It was originally intended that the investigation should be conducted by a committee representing the principal Headquarters Departments concerned. As originally formed, the committee was composed of Mr. E. Withycombe, Construction Department, Mr. Clarence Woodin, Maintenance Department, and Mr. F. N. Hveem, Materials and Research Department. Later, Mr. John Meyer was designated by Mr. A. M. Nash to represent the Design Department.

The field work was undertaken in close cooperation with the Public Roads Administration and Mr. George Williams was designated by Dr. Hewes to represent the PRA. Mr. Williams accompanied the field crews and participated actively in the field observations, in the taking of samples, et cetera, for a major part of the field study. Mr. Williams also assisted in the preparation of the first progress report.

Close contact was also maintained with the west coast representatives of the Portland Cement Association and most of the findings and conclusions have been discussed with Mr. Hugh Barnes or his assistants.

As stated above it was originally intended that the final report would be a joint effort but the shifts in Headquarters Personnel and the fact that the actual details have all been carried out by the Materials and Research Department has led to a change in this procedure. Therefore, the following report as written embodies the viewpoints and conclusions of the undersigned and while most of the significant points and factors have been discussed with the other members of the original committee they may or may not be prepared to concur in all of the conclusions drawn. Therefore, each member of the committee should express his personal concurrence or disagreement with the report as written. It is not believed that there can be any question over the factual data submitted with this report. There may, however, be some difference of opinion concerning the interpretation and the significance of the various items of evidence presented.

It did not seem feasible to include in a single report all of the data accumulated. The original records and work sheets are available for inspection by anyone interested in further details.

It is desired to acknowledge the efforts and contribution of those engaged in the detailed work involved in this study. Special mention should be made of the work of James L. Beatty who had charge of the field investigation, cutting of cores, securing samples of the subgrade soil and making profilograph records of the pavements. Mr. Beatty was assisted by Mr. C. W. Clawson who has carried on the bulk of the work of preparing diagrams, tables, and photographs necessary for the compilation of this report.

It is also desired to acknowledge the assistance and advice rendered by other members of the committee and by representatives of the Public Roads Administration and the Portland Cement Association as mentioned above.

F. N. Hveem
Staff Materials & Research Engr.

SYNOPSIS

The data produced in this investigation of the causes leading to distress at the joints in concrete pavements warrant the following conclusions.

The basic cause and origin of all joint troubles, including mud pumping and faulting is the volume change of concrete arising from variations in moisture and temperature.

Concrete will expand with an increase in moisture or temperature and these two factors or conditions are rarely uniform throughout a pavement slab. As a result, the slab is curled or warped a great portion of the time so that there is non-uniformity of contact and support. At such times the slab is free to move with reference to the subgrade.

The lack of "team work" between the pavement and the subgrade soil is a factor but the principal adverse effect is the alteration of the subgrade support caused by the pounding of the warped slabs flexing or rocking under the passing wheel loads.

The vertical movement or "pumping action" of the slabs may cause uneven compaction or settlement of relatively dry cohesionless sands or more frequently will cause the loss of subgrade material by erosion due to "pumping" when free water accumulates beneath the ends of a slab.

Gross failures in the form of break up or "punching through" of a concrete pavement are not a common occurrence on California Highways. Scattered examples have been observed where there is a combination of very poor soil with slabs five inches or less in thickness that are subjected to heavy truck traffic. In general, structural weakness has not been a primary factor in producing failure or distress in Portland cement concrete pavements constructed in California since 1927.

POSSIBLE REMEDIES

A. If slab movement can be prevented, no trouble of the type mentioned will develop.

(a) Detrimental movement could not take place if all joints could be eliminated.

(b) Detrimental movement will not occur if the slabs remain at all times in uniform contact with the subgrade.

(c) If volume change of concrete is prevented or inhibited, then joints are unnecessary and the pavement will protect the subgrade.

B. If the movement of the slabs cannot be prevented, then the subgrade must be treated so as to "withstand the beating".

STEPS TO BE TAKEN

1. As an interim expedient--all subgrades should be treated to prevent expansion, shifting, compaction and erosion. (This has been done for the past three years.)

2. Studies should be continued on a laboratory scale to develop ways and means to reduce the volume change propensities of Portland cement concrete.

3. Experimental pavements should be constructed on highways subjected to heavy traffic. Experimental pavements should not be confined to variants of the stereotyped designs now in use. A definite series of types should be placed under traffic with sufficient changes and departures from current practice in order to offer some possibility of a satisfactory solution.

INDEX

I N D E X - Cont'd.

REPORT OF INVESTIGATION TO DETERMINE CAUSES FOR JOINT TROUBLES IN PORTLAND CEMENT CONCRETE PAVEMENTS IN CALIFORNIA

A. RESUME

In 1944, an investigation was authorized and funds provided under Work Order 13NN4 in order to ascertain the reasons for the increasing frequency of mud pumping and faulting at the expansion and contraction joints in concrete pavements.

Joint troubles in concrete pavements have developed in every state and have been reported from most foreign countries wherever traffic has reached a substantial volume. Extensive investigations have been carried out and reported in the Proceedings of the Highway Research Board and in independent reports issued by the Portland Cement Association and by several agencies in individual States.

A preliminary report was rendered in 1944 after a visual inspection and survey of California pavements, followed by an extensive investigation in the field and in the laboratory. A progress report was furnished July 16, 1945. Most of the tentative conclusions put forth in that report have been substantiated by further study.

Based upon the evidence available in 1945, the following recommendation was made:

(a) <u>For the Subgrade:</u> The subgrade must be solidified by achieving as much compaction as feasible and undoubtedly in many cases it will be desirable to add either granular material or artificial binders such as Portland cement or asphalt in order to create a transition zone between the concrete and the underlying soil. Such a zone is visualized as being somewhat less rigid than the present concrete pavement but more solid and less resilient than the common subsoil. This proposed treatment is believed necessary to prevent shifting and movement of the subgrade under the pumping action of pavement slabs. It is further indicated that the subgrade should be constructed or treated in a manner to prevent erosion by the action of water beneath the pavement. (For an example, an asphaltic seal on a hardened, well cemented subgrade would be one

> means for accomplishing this end.) It is not expected that an improved subgrade alone will eliminate all roughening or faulting of concrete pavements or even water pumping but such improvement should prevent mud pumping with its attendant loss of subgrade material, and should appreciably reduce the frequency and magnitude of faulting.

It was further indicated that the subgrade treatment would be unnecessary if it were possible to prevent the concrete pavement from warping or changing its shape as a result of differential temperature and moisture conditions. The following brief analysis of concrete pavement behavior was presented in 1945:

> There is unlimited proof that concrete pavements warp and curl under the influence of moisture and temperature. Since there is no positive bond between the slab and the subgrade and since there is a marked contrast between the deflection characteristics of a rigid slab and that of a more or less resilient soil, it follows that slab deformations must create temporary or even permanent spaces or openings between the concrete slab and the subgrade. This difference in movement and elevation between the under side of the pavement slab and the subgrade means that there is a constant threat that free water may accumulate beneath the slab and when the slabs are subjected to the action of traffic, the effect is to create a pumping machine in which the concrete slab serves as a movable diaphragm. The present specifications for concrete pavements are inadequate in the following respects:
>
> (a) They do not or cannot provide positive means for preventing the entrance of water between the pavement and the subgrade.
>
> (b) They do not include design features that prevent the forceful movement of surging water beneath the pavement.
>
> (c) They do not include design features which will prevent the moving water from having destructive effects.
>
> Four conditions are always found to exist where mud pumping is in evidence
>
> 1. A rigid type of pavement divided into separate slabs.

2. The accumulation of free water between the under side of the slab and the top of the subgrade.

3. A considerable volume of traffic having axle loads heavier than those of passenger cars.

4. An erosive type of subgrade soil which readily softens, loses cohesion and which can be washed away by the action of moving water.

Since the foregoing conclusions were submitted, a large mass of data has been assembled and studied in order to determine whether there is any consistent relationship between the properties of the subgrade soils and the ultimate performance of the pavement or whether variations in the design of the pavement and character of the concrete could be shown to have a consistent effect on the performance of the pavement joints.

Since 1945, virtually all concrete pavements in California have been placed on treated subgrades as a result of the preliminary study.

The completed study does not indicate any useful relationship between the type of soil and the pavement performance, with the exception that a subgrade soil which is easily eroded will definitely lead to trouble at the joints. The data do not indicate that any of the conventional slab designs have been consistently free from joint deterioration with the exception that there is less evidence of trouble in pavements having a long slab length as compared to sections built with 20 ft. or less between joints.

There are definite indications that the condition, i.e. degree of compaction, ability to stand erosion and saturation, of the subgrade is a primary factor affecting the performance of the pavement.

It appears that, where all conditions are satisfactory, there is no reasonable limit to the amount of highway traffic that can be carried by a concrete pavement. Conversely where unfavorable conditions exist, concrete pavements have shown marked distress within seven years or less under moderate traffic loads.

In preparing a report covering observations made on inspection trips and during field investigations, it becomes desirable that a few terms should be defined. Throughout this report, the following terms are used as indicated below:

Pumping Action	Displacement of air, water or mud which is in place between the relatively firm portion of subgrade and underside of pavement. Action caused by vertical movement of slabs when subjected to traffic.
Faulting	The permanent vertical displacement of a paving slab with reference to an abutting or adjoining slab (frequently called "step-off").
Curling	The tendency of concrete pavement to bend or warp, usually developing high joints.
Cracking	Refers to cracks or breaks in the slabs at points other than planned weakened plane or expansion joints.

B. TYPICAL LIFE HISTORY OF A CONCRETE PAVEMENT THAT HAS DEVELOPED JOINT TROUBLE

The mass of data secured as a result of this investigation, together with the reports of similar studies in other States, presents a somewhat difficult problem in compiling a concise and, at the same time, a comprehensive report. Therefore, in order to convey an over-all picture, the data have been analyzed and used to reconstruct a typical sequence of events or changes which take place during the life of a concrete pavement. An attempt is made to describe the steps by which a typically faulted pavement has become altered from a smooth-riding satisfactory surface as indicated by the original constructed profile, until it becomes rough with marked faulting at the joints, often but not always accompanied by evidence of mud pumping.

The typical pavement constructed by the California Division of Highways during the years 1927 to 1937 was placed upon a subgrade constructed of soil materials having the following average sieve analysis:

Typical Grading of Subgrade Material
(Average sieve analysis of 317 samples.)

Screen Size	% Passing
1"	96
#4	87
10	82
40	62
200	31
270	28
5 microns	10

A study of both good and bad sections throughout the State does not indicate any consistent relationship between performance of a Portland cement concrete pavement and the subgrade soil characteristics. (29, 30, 31) The compaction of the subgrade soil was found to be generally good ranging from a low of 75% to a high of 112%, with an average for all locations studied of 91% of standard maximum density at optimum moisture. The pavements generally were constructed with a fairly smooth profile and with a few exceptions the riding qualities of the new pavement were good.

Shortly after construction however - probably within a period ranging from 30 to 60 days - certainly within the first year - the individual pavement slabs began to undergo a daily alteration in shape. This daily change is clearly indicated by Profilograph records taken over a number of pavements (7, 8) and indicates that the pavement departs from the planned surface profile of the slabs by curling upward at the edges and at the corners, resulting in an elevation of the pavement at the expansion and weakened plane joints.

It is evident that the upward curling of the slab ends is most marked in the early morning, usually between five and seven o'clock, and may vary, depending upon the recent weather and climatic conditions. This upward curling at the joints is probably most pronounced during the hot weather in late spring or early summer and becomes least pronounced during the winter months of January, February and March.

The contour of the curled slabs has been studied both by means of the Profilograph and by the use of a piano wire stretched to form a datum line from which direct measurements could be made (6). From a study of the curling characteristics of the slabs of various lengths, it becomes evident that each end of the slab departs from the original plane. These portions range from four to seven feet in length with an average of about six feet, (1, 6) and the shape of the curled slab is indicated in the sketches on Reference No. 1. There are some indications that this warping or curling of the slabs does not become manifest until a certain degree of strength is attained. (7)

In any event, it is quite certain that shortly after construction the individual slabs of the concrete pavement tend to curl and warp, and, as this movement follows a definite cycle throughout the 24 hours, it is obvious that the immediate cause is variation

(The numbers in parentheses are reference numbers identifying tabulations, charts, graphs or photographs in the attached Appendices containing the detailed data.)

in temperature. However, the Profilographic studies further indicate that the warping is rarely reversed; that is, the daily cycle does not often produce a perceptible depression at the joints and there is little indication that slabs are often convex upward or lifted off the subgrade in the center. Such shapes have been observed but the condition appears to be relatively uncommon, at least in California. In fact, the only time when most pavement slabs are flat, or restored to a profile contour similar to the original construction, is in the middle of a warm afternoon when the surface of the concrete is at a higher temperature than is the underside in contact with the subgrade. This indicates that concrete pavement slabs in a state of uniform temperature throughout must be normally curled, presumably from the expansive effects of moisture on the underside of the slab. (10)

Therefore, it would appear to be a sound generalization to state that the warping in the slab induced by temperature on a hot day is, in the majority of cases, approximately equal to that caused by moisture alone and on a hot day the profile may revert to the same plane as constructed. (7) This comparative magnitude of expansion due to moisture and temperature has been demonstrated by measurement in the laboratory. (24, 25) When the surface of the pavement is cooler than the underside, then the curling due to temperature differential is added to that caused by moisture, and at such times the warping of the slabs becomes most pronounced.

The existence of expansive forces in concrete pavements has long been recognized and the widespread adoption of expansion joints, contraction joints, load transfer devices, etc., stemmed from the desire on the part of engineers to reduce the stresses in the concrete and to discipline the inevitable cracking into straight lines with an orderly uniform spacing. In order to prevent troubles at the expansion joints, load transfer devices were soon provided.

In spite of such devices and precautions, concrete pavements have given a great deal of trouble and it appears that the principles governing the performance of rigid pavements have not been too well understood. For example, it may be pointed out that both moisture and temperature are prone to vary throughout the depth of the slab and it is inevitable that the expansion or shrinkage of a concrete pavement will rarely be confined to simple horizontal movement alone; i.e., in a direction parallel to the surface of the pavement. It is almost certain that the expansion or contraction will be greater either on the surface or on the underside of the slab with the result that any over-all expansion is invariably accompanied by warping or curling of the slabs.

As proven by Profilograph records, direct measurements from a steel wire, and by deflection measurements taken at various times of the day (6,7,8,17,18) the pavement slabs are, during a great portion of the 24 hours, curled upward at the ends and when the slabs are relatively short the inevitable result is that the slab takes on the shape and characteristics of a rocker. The evidence is clear-cut and incontrovertible that the length of slab that departs from the plane of the pavement ranges from 4 ft. to 7 ft. in length. This means that the elastic yield of the average concrete will not sustain a load in excess of the moment created by a cantilever approximately 7 ft. in length. Therefore, pavement slabs 20 ft. in length may have no more than 6 ft. of the center section resting upon the subgrade when the slabs are curled to the greatest extent. A 15 ft. slab may have no "flat" section in the center and therefore it has the least mechanical stability against rocking movement.

For a considerable portion of the day, concrete pavement slabs represent a series of more or less flexible "rockers" and the motion of these slabs becomes a somewhat complex matter under the rapid passage of multiple axle trucks. (2) The continual working of these slabs under traffic and the constant differential movement at the joints has made it virtually impossible to maintain any sort of joint seal by means of the usual asphalt filling material. The slabs develop the greatest movement when the upper surface is cold and under these conditions an asphalt is hard and brittle and least able to withstand any movement whatsoever.

An inspection of California pavements points to the conclusion that when the movement at the joints is prevented, then even a hard asphalt filling material will last indefinitely. (12 - V-Mon-2-a) On the other hand, the conclusion is inescapable that is has never been possible to seal the cracks in the average concrete pavement with air or steam refined asphalt for more than a few weeks at a time so long as there was any movement of the slabs due to a curled or warped condition. Furthermore. even though the joints can be tightly sealed, it is still virtually impossible to prevent water from entering from the shoulders. A tight seal between a concrete slab and the adjacent shoulder material is extremely difficult to achieve and to maintain. Also, as the ends of the slabs alternately depress under the wheel loads and spring back to their slightly elevated position, a suction will be created which tends to draw water into the space beneath the slab. Sooner or later the subgrade beneath the ends of the pavement slabs becomes saturated either by capillary moisture, by moisture from condensation, or by water entering through the joints in the pavement or from openings along the edges. Inasmuch as the pavement slabs are lifted off the subgrade over an area represented by the full width of the pavement and for a distance of 4 ft. to 7 ft. on either side of the joints, it is clear that the unloaded subgrade soil is free to expand to the greatest possible extent and, having thus expanded, the capacity for water is correspondingly increased. Therefore, there is nothing to prevent an expansive soil from reaching the limits of swell characteristic of the unrestrained state and if water is available, sooner or later the soil will reach a moisture content representing complete saturation in this expanded condition.

When the slabs are forced into contact with the subgrade during the passage of heavy vehicles or when the upward curling is reversed during the middle of a hot day, pressure on the subgrade will not be sufficient to compact the soil while in a saturated state. Instead, the continual movement of the slabs tends to churn up and plasticize the surface of the subgrade. The slabs will continue to work with greater facility with the passage of time because of the inevitable reduction of resistance at the joints, either caused by the grinding up of the concrete or by the deterioration and breakdown of the load transfer devices. (1, 20 a,b,c,d)

It is not possible to illustrate the rapid sequence of the forces which are brought to bear upon a concrete pavement slab during the passing of a heavily loaded truck and trailer unit. Sketches (2) illustrate typical joint spacing and the relative spacing of the axles of one of the most frequently used truck trailer units. From the viewpoint of an observer standing on the roadside with traffic proceeding from left to right, it is evident that when the front wheels of a truck have reached the right hand end of a given slab, the rear wheels of most trucks are already upon the left or receiving end of the same slab. Therefore, the depression of the ends or rocking of the slab is somewhat inhibited by the fact that at this particular instant the truck load is fairly well distributed over the slab. However, when the front wheels pass from one slab to the next, the left end of the slab receiving the front wheels is free to depress with the least amount of restraint, while, at the same moment, the right end of the adjacent slab just abandoned is free to rebound when relieved of the load. This rebound is partly due to the elasticity of the concrete and probably is facilitated by the weight of the rear truck wheels which are usually beyond the center point or near the left end of the slab. Therefore, at the monent the front wheels of a truck have crossed a joint in the pavement, the tendency is for any water to be expelled violently from beneath the forward end of the slab and this expulsion occurs at the moment when the end of the adjacent slab is springing upward, thus creating a suction and inviting the transfer of muddy water.

It is, therefore, evident that the combination of forces and sequence of movements tends to cause the violent movement of any water beneath the slab with the consequent erosion of the subgrade material when sufficient water is available. The hydraulic pressure forces the water, with the suspended soil, upward through the joints in the pavement and at times along the edges adjacent to the shoulder. While the bulk of the eroded material is washed out on the surface of the pavement, a certain amount is probably transported across the joint and redeposited beneath the adjoining slab. This deposition would tend to occur only with the coarser sand grains and during the pavement investigation the presence of a layer of coarse sand was noted in several instances and always on the "high" side of a faulted joint.

After a sufficient amount of the material has been pumped from beneath the pavement slab, the unsupported slab ends can be deflected sufficiently under wheel loads to cause a transverse break, usually occurring from 6 to 7 ft. from the joint. The end of the slab then drops down into the depression creating a marked fault at the joint. (1) In some cases slabs may be broken on either side of the joint resulting in a dip at each planned joint in the pavement. (13)

As indicated by the foregoing statements and deductions supported by evidence set forth in the attached appendices, it seems clear that the origin of all joint troubles in concrete pavements lies in the propensity of the concrete to expand or contract in a non-uniform manner, resulting in the warping or curling of the individual slabs. The curled slabs with the unsupported ends represent a structure that will move or flex under the action of traffic and with the consistent repetition of slight movements which may be described as a sort of pumping action, the condition and shape of the subgrade is definitely altered in the course of time.

Examples of concrete pavements which are breaking through or showing definite evidence of insufficient strength or thickness required to carry the loads, even over poor subgrade soils, are comparatively rare. In fact, it can be stated that with the exception of internal destruction or of alkali attack, all concrete pavements which are giving an unsatisfactory appearance have reached this condition only after a prolonged period of moving, warping and deflecting under traffic loads. If joint troubles are absent there are few evidences of weakness or of "breaking through" even over unquestionably poor subgrades.

The accompanying sketch (1) shows diagrammatically the development or progression of typical "joint troubles" occurring in Portland cement concrete pavements.

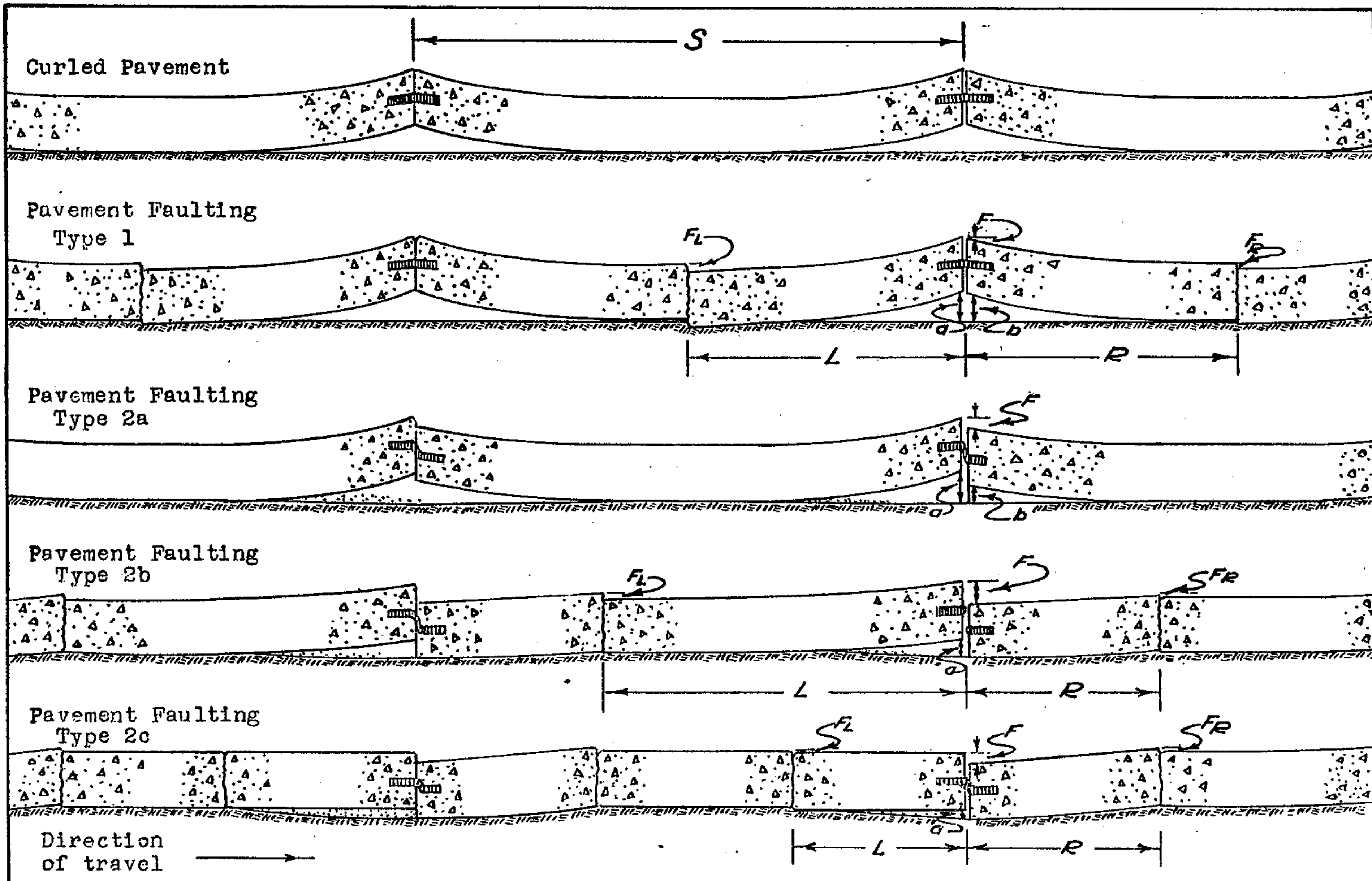
In heavily doweled pavements, type 1 faulting usually occurs. As the pavement curls, the joint and a section of pavement on either side of it are lifted clear of the subgrade. A heavy external load, such as a loaded truck, tends to force the pavement back down on the subgrade. The heavily doweled joints are generally more than adequate to keep the adjacent slabs in alignment; consequently when the stresses set up in the slabs by the load exceed the strength of the concrete, the slab will crack at a point approximately midway between the joints. Further repetition of heavy wheel loads will often cause the pavement to "fault" at the transverse crack, particularly if the subgrade soil is saturated.

Type 2 faulting is a progressive type and generally occurs when the joint has only a few dowels or none at all. Heavy external loads on the curled pavement joints act to force the pavement down, bending and eventually breaking the few dowels. (2) When the ends of the slab are repeatedly forced down on a subgrade that is saturated with water, a gradual loss of material will result. As soon as the dowels are broken, the action of the slab ends is much more severe under each passing truck load.

In the course of this investigation, pavements in various stages of this progressive faulting were encountered. To adequately identify and classify the stages, the designation as shown on the sketch (1) were adopted. On this sketch designations are made by letters as shown below:

- "S" indicates the original slab length
- "L" indicates the distance from the joint to the first crack to the left of the joint
- "R" indicates the distance from the joint to the first crack to the right of the joint
- "F" refers to faulting at a planned joint
- "F_1" refers to the faulting of the first crack to the left of the joint
- "F_r" refers to the faulting of the first **crack** to the right of the joint
- "a" refers to the space beneath the slab on the left side of the joint
- "b" refers to the space beneath the slab on the right side of the joint.

Detailed field measurements of these items are given in the appendix tabulation headed "Pavement Details", (26).



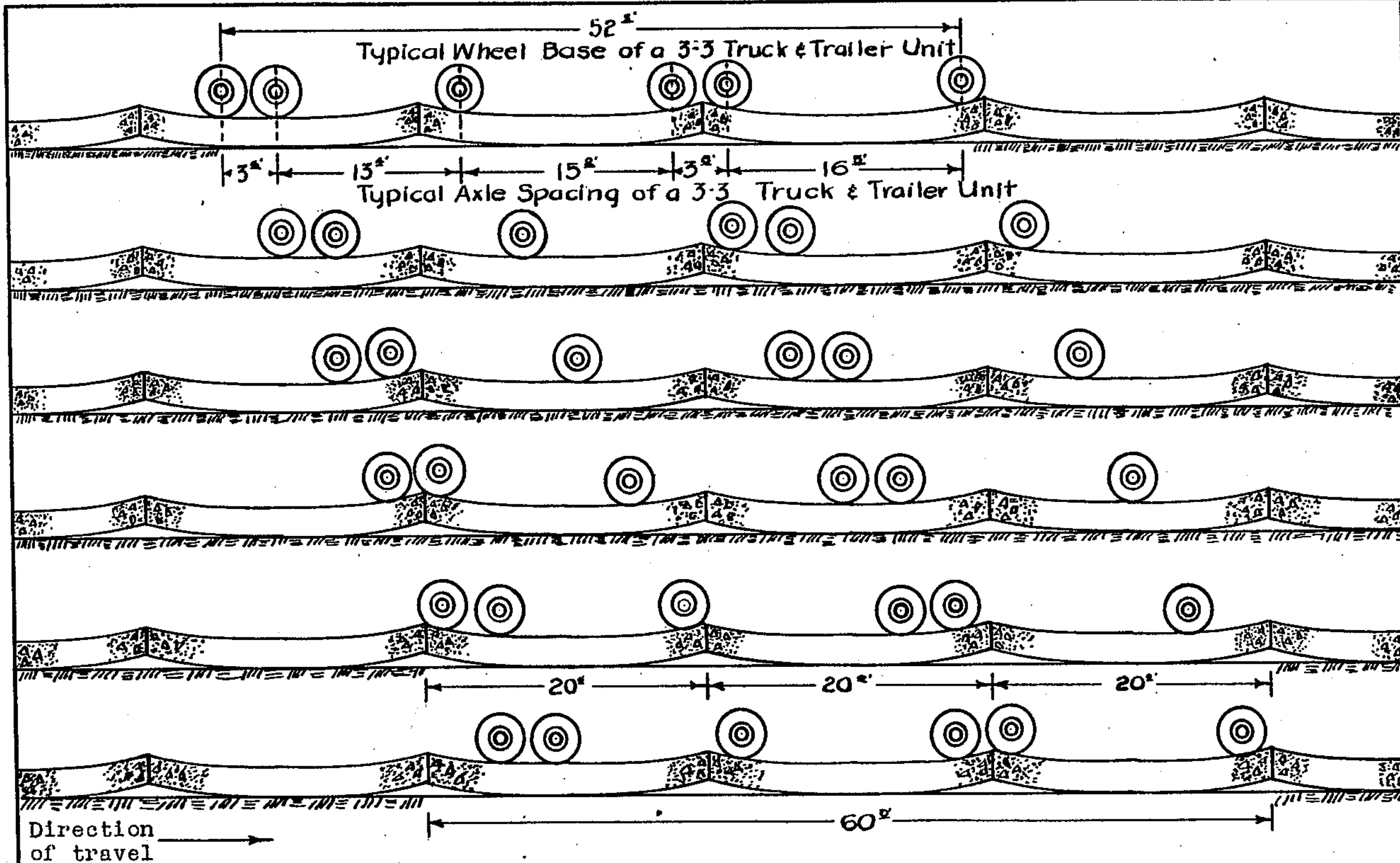
Development of "Joint Troubles" in P.C.C. Pavements

The accompanying drawing (2) is a diagrammatic sketch showing the progress of a 3-3 truck and trailer unit across a series of curled P.C.C. pavement slabs, each 20 ft. in length. Axle spacings are to scale for one of the many combinations encountered on California highways.

The rapid progress of such a truck and trailer unit across each slab from left to right produces many very complicated stresses and reaction in the slab. This subject is considered in detail in the preceding text.

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 2



Relative Positions of Axles of a 3-3 Truck and Trailer Unit Passing Over Curled 20 ft. P.C.C. Slabs

REMEDY

There seems to be little, if any, evidence to sustain an opinion that concrete pavement troubles are ordinarily due to a lack of strength or to a lack of thickness. The question of remedy for troubles at the joints would seem to subdivide into two phases. First, if the concrete pavement can be prevented from undergoing any change in shape which would prevent an intimate contact with the subgrade, then it is difficult to see how the present type of joint trouble could develop. Secondly, if it is not possible to prevent the concrete from expanding and contracting, a second remedy would be the construction of a subgrade which would resist the erosive action and which could not expand or swell, even when unprotected by the direct contact of the pavement and would, therefore, never permit an amount of deflection sufficient to break the pavement slabs. The feasibility of this latter solution is indicated by numerous bits of evidence that concrete pavements constructed directly over old traveled ways, whether of bituminous mixtures, macadam or old concrete pavements have given excellent performances for a great many years.

It, therefore, seems that the simplest definition of an adequate subgrade for the modern concrete pavement is "one which has undergone any process or treatment which renders it capable of serving as an all-weather road for light traffic." The subgrade for a concrete pavement apparently need not possess high unit supporting power but must be so treated as to resist erosion under the action of rapidly moving streams of water.

In the light of the foregoing analysis of the causes and results of "joint troubles", the following recommendations are made:

1. As an interim expedient--all subgrades should be treated to prevent expansion, shifting, compaction and erosion.

2. Studies should be continued on a laboratory scale to develop ways and means to reduce the volume change propensities of Portland cement concrete.

3. Experimental pavements should be constructed and subjected to heavy traffic. Experimental pavements should not be confined to variants of the stereotyped designs now in use. A definite series of types should be placed under traffic with sufficient changes and departures from current practice in order to offer some possibility of a satisfactory solution.

The Analysis Chart (3) is an attempt to classify the most important causes and factors which contribute to joint failures in concrete pavements. This chart is developed on the principle of subdividing each major item into its primary factors indicating the secondary and tertiary elements or variables that are involved. This chart indicates that for a satisfactory concrete pavement, the following items ought to be limited or controlled by the engineer. These items, marked on the chart by asterisks, are as follows:

1. Volume change of the concrete
2. Erosion and loss of Subgrade Material
3. Consolidation or Settlement in Localized Areas
4. Resilience of the Underlying Soil

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 3

ANALYSIS CHART INDICATING THE CAUSES OF JOINT FAILURES IN PORTLAND CEMENT CONCRETE PAVEMENTS

PROBLEM	Primary Cause	Secondary Cause	Tertiary Cause	Primary Factor	Secondary Factor	Tertiary Factor
Joint failures in P.C. Concrete Pavements	Excessive Movement of pavement slabs	Subgrade Flexure or elastic rebound	⊛ Resiliency of soils	Characteristics of subgrade soils	Characteristics of particles	Shape of Particles
						Compressibility or porosity of particles
					Size of soil particles	
					Original Degree of Compaction	Amount of rolling (compactive effort)
						Type of compaction equipment
						Moisture Content at Compaction
		Slab Deflection when not supported by the subgrade	Departure of subgrade from original plane	⊛ Settlement or Expansion in localized areas	Amount of Moisture	
					Vibration from traffic	Cohesive Soil
					Type of Soil	Cohesionless Sand
				⊛ Erosion of subgrade (can occur only if slab curls upward)	Presence of water	Particle size Distribution
					Granulometry	Particle Size
					Cohesion	Specific Gravity
			Lifting of pavement slab from subgrade (Curling or warping)	⊛ Volume Change of Concrete	Chemical Interaction	Nature and behavior of aggregates and cements
					Temperature	
					Moisture	

NOTE:
Items marked thus:
⊛ are properties which should be meaured by laboratory tests and controlled during construction.

II

PERTINENT OBSERVATIONS

The foregoing reconstruction of the sequence of events which accompany or characterize the development of joint troubles in concrete pavements leads to certain conclusions. Also the examination of the pavements in the field and the laboratory test data warrant a series of definite statements which may assist in bringing the picture into proper focus.

1. Concrete pavements are in existence which have given excellent service with moderate maintenance costs and which have not required resurfacing until a period of more than twenty years has elapsed. These examples prove that it is possible to develop a combination of adequate subgrade together with characteristics in the design of the pavement which will give little or no trouble under heavy traffic.

2. No type of soil or imported borrow material was found which was consistently associated with freedom from joint troubles in the concrete pavements. In other words, a wide variety of soils was found to exist under pavements giving marked evidence of joint trouble and a very similar range has been found under pavements giving little or no trouble. (29,30,31)

3. Faulting and misalignment of the joints may occur without evidence of mud pumping and mud pumping has occurred at joints which have given no evidence of faulting.

4. There is no evidence that increasing slab thickness up to ten and eleven inches for example, will eliminate either joint troubles or intermediate cracks in the slabs. (8,9) The Pennsylvania Turnpike section is 11"-9"-11" and is showing extensive mud pumping after eight years service.

5. Individual projects where the pavement is known to be growing or expanding for any reason are virtually free from the common joint troubles. (12) This same observation has been made in areas outside of California.

6. Steel dowels placed at 15" centers or less have been effective in preventing faulting or "stepping off" at the joints. However, this construction has not prevented large intermediate cracks in the slabs and in many cases the intermediate cracks have developed faulting and give evidence of mud pumping. New Jersey has devoted intensive effort toward experimentation with many types of metal load transfer devices--so far none have proved to remedy or prevent joint troubles.

7. There is consistent evidence both in California and elsewhere which shows that pavements constructed over subgrades which had carried traffic before the concrete was placed are almost

universally in good condition compared to adjoining sections constructed over new subgrade. Joint troubles are not common where the subgrade consists of old bituminous macadam, bituminous surface treatments or old Portland cement concrete. (11)

8. There is no evidence that high "bearing value", stability or supporting power of the subgrade soil is essential for the successful performance of a modern concrete pavement and there is no reason to believe that any of the prevalent joint troubles can be ascribed to a basic lack of supporting power in the subgrade (29,30,31) or to lack of strength and slab thickness in the pavement. (26,28)

9. It appears that the volume change characteristics of concrete show a greater variation with respect to the effects of moisture than to changes in temperature. However, it also appears that the magnitude of expansion or contraction of California concrete under field conditions is approximately the same for temperature as compared to moisture considering the normal range in both cases. (25) The Corps of Engineers reports that expansion of concrete due to moisture may be three times the expansion from temperature.

10. The general beneficial results of asphalt subsealing is proof that preventing the erosion of subgrade material is an important factor and furthermore demonstrates that low bearing capacity or stability of the material beneath the pavement is a minor consideration in view of the fact that asphalts have practically zero "bearing power" or "stability" as the term is ordinarily construed. Further evidence on the beneficial results of subsealing is given in the report by the Corps of Engineers published in Civil Engineering in June, 1948.

APPENDIX A--GENERAL

(1) Extent of Investigation

Before any field sampling work was begun, an inspection of concrete pavements throughout the State was carried out by Materials & Research Department personnel, accompanied whenever possible by District Maintenance and Construction Engineers in the respective districts. This inspection trip covered approximately 2,130 miles of P.C.C. pavements representing some 385 separate projects built prior to 1940. These pavements were classified, by inspection, into six groups taking into account their appearance smoothness, frequency and severity of joint faulting, and evidence of mud pumping.

The percentage distribution among the six groups was as follows:

Poor	10%	Good	29%
Fair	16%	Very Good	15%
Fairly Good	22%	Excellent	8%

Careful study of all inspection reports subsequent to the inspection trip narrowed the choice of projects to be covered by a detailed field investigation to the accompanying tabulation. (4) It will be noted that many of the "projects" include more than one contract. In many cases a significant difference in performance was noted between adjacent or adjoining contracts and it was thought desirable to investigate some of the most outstanding cases.

As noted on the tabulation, field investigations covered 20 projects designated in this report by letters of the alphabet. These projects in turn included 66 separate contracts. A total of 119 locations were sampled, 380 cores and 2,811 soil samples being taken. All tables of data, faulting classification, etc., in this report are based on the projects listed.

(2) Field Investigation

For each project listed the entire area included within the limits of the contracts specified was evaluated and representative areas for sampling were decided upon.

Field investigations consisted of cutting cores, sampling subgrade materials for density and moisture (generally in 6" layers) to a total depth of 24" below the underside of the pavement, obtaining profilograph records of stretches of pavement representative of the project, measuring and drawing sketches of the slabs near the sampled area, showing faulting, cracking and other pertinent data.

Materials & Research Dept.
Research No. 00204

P.C.C. Joint Investigation
Reference No. 4 (a)

PROJECT DESIGNATIONS SHOWING COUNTIES, ROUTES, SECTIONS, LIMITS AND CONTRACTS COVERED BY THE INVESTIGATION

Project Letter	Dist. Co. Rte. Sec.	Limits	Contracts Covered Contr. No.	Year Comp.
A	X-Sol-7-B	½ Mi. West of Cordelia to Fairfield	410CN2	1932
B	IV-Mrn-1-A	San Rafael to Ignacio	208 94EC7 24EC5 04TC6	1918 1929 1930 1939
C	X-SJ-4-C,D	Lodi to Dry Creek Bridge (East of Galt)	256 210EC3 410CN1 010TC3	1919 1930 1931 1938
D	IV-SM,SCl-68-A,B	South C/L San Francisco to Jct. Rte. 5 near San Jose	44TC4 44TC6 44TC8 44CN2 64TC1, 64TC4 84TC11	1932 1933 1933 1933 1934 1937
E	IV-Ala,SCl-5-C,A	Warm Springs to Milpitas	89 230 94EC3	1918 1918 1928
F	V-Mon-2-A,J	Salinas to North Co. Line	95EC2 45EC1 45TC2	1928 1932 1943
G	V-SB-2-C,L,M	Los Alamos to Santa Maria (Solomon Canyon Cutoff)	45CS1 45CS2	1932 1932
H	VI-Fre-4-C	Belmont Circle to Herndon	86TC3 86TC4	1937 1937
I	VII-LA-4-J,D	Piru Cr. to Holland Summit	47FC5 47FC13	1933 1933
K	VII-LA-26-A,Elm,BC	El Monte through West Covina	County 47XC1 47XC3 67XC1 87XC17	1929 1933 1933 1934 1937

PROJECT DESIGNATIONS (CONT'D)

Project Letter	Dist. Co. Rte. Sec.	Limits	Contracts Covered Contr. No.	Year Comp.
M	VII-Ora-2-C	Irvine - Tustin	98 370 (M20) 47VC14	1914 1922 1933
N	VII-Ora-60-Lg.Bch.C	Laguna Bch to Dana Pt.	27CS1 47VC24	1933 1935
O	XI-SD-12-C,D,EFGH	Bostonia to Mountain Springs Grade	07CS1 27VC6 47CS1 47CS4 47CS9 07VC7 47CS2 47CS7 47CS10 27VC11	1929 1931 1932 1932 1933 1930 1932 1932 1933 1931
P	XI-Riv-26-G	Avenue 62 to Imperial County Line	48CS2 48FC2	1933 1933
R	V-SB-2-D,E	Gaviota to Zaca Station	279 25CS2 25FC4 25FC5 65VC8 65VC13 25VC1	1922 1930 1931 1931 1935 1939 1940
S	VII-Ora-171-A VII-Ora-184-A	Coast Blvd-Garfield Ave. Rte. 43, near Santa Ana Airport to Santa Ana	07XC3 County	1937 1929
T	VIII-SBd-26-D	Ontario to Colton	48CS3 68XC4 08XC1	1933 1934 1938
V	VII-LA-Alameda St.		County County	1921 1923
W	VII-LA-Beverly Blvd.		County	1929
X	VII-LA-Pico Blvd.		City	1926

Total Number of Projects 20
Total Number of Contracts 66

Total Number of Locations sampled 119
Total Number of cores taken 380
Total Number of Soil Samples 2811

In cutting cores, both diamond set and calyx bits were used. Chilled steel shot was used as a cutting medium with the calyx bits.

Profilograph records were obtained covering long stretches of the pavement in each project, using the Profilograph designed and constructed in the Materials & Research Department.

Faulting at individual joints was measured by a straight edge and steel scale graduated in 100ths of an inch.

Sketches were drawn of each area sampled to show the pattern of cracking, joint spacing, direction of traffic, and joint and crack faulting as well as the type of subgrade material encountered under the pavement.

More detailed description of sampling and testing methods are given in the sections devoted to pavement, subgrade, etc.

(3) Office Work, Records and Tabulation of Data.

(a) As field work got well under way and samples arrived at the Laboratory, test data began to accumulate in considerable quantity.

Standard Soil Survey sheets were adopted as the most expedient way of tabulating test data from each core hole sampled. At first, location sketches showing joints, cracks, core holes, etc. were drawn directly on the Soil Survey sheets but after a short time location sketches were made up in the field and later were attached to the Soil Survey sheets.

Test data recorded for each layer of subgrade soil included CBR tests, both at optimum and at field conditions, expansion during soaking, field moisture and density figures, liquid limit, plasticity index, specific gravity of fine and coarse fractions. Water capacity, percent saturation and relative compaction of subgrade material in place were calculated from recorded data and entered on the sheets.

Field density and moisture in place, water capacity of soil, percent saturation in place, plasticity index, optimum density and relative compaction were also shown graphically. Grading curves were drawn for each layer of soil and were attached to the Soil Survey sheets.

The data on the Soil Survey sheets were transferred to record cards made up to cover all locations sampled. At each location sampled where the results of tests of the subgrade soil from several sample holes indicated the materials to be the same or similar, the sample holes were grouped toghether on one record card. Test results that were characteristic of the material were listed for the group. When the results of tests of subgrade soils from one or more of the sample holes at the same location indicated the material to be considerably different than material from adjacent holes, a separate grouping was made and a separate record card made up. Consequently, for any particular section of pavement sampled, there may be two or more record cards in the series.

(b) With field investigations progressing towards completion, great masses of notes, sample sheets and test results began to accumulate and the need for some system of classification became pressing.

Several conferences were held and various ideas considered. It was agreed that a system of classification based on total joint faulting, measured in inches, per mile of pavement, would best serve the purposes of the investigation.

In arriving at figures indicating total accumulated faulting per mile, the profilograph records were reviewed and a 300' section of pavement, which appeared typical of the area sampled, was selected for detailed study. In nearly all cases the section selected had been cored and sampled in the course of the field investigations. In a few instances, however, the 300' section was adjacent to a sampled area.

In analyzing each 300' section of pavement, the faulting in 100ths of an inch at each joint was scaled from the profilograph record and a total of the faulting for the section summarized. Also, a count was made of all cracks appearing in the section. If any of these cracks were faulted, the amount of faulting was scaled and noted. The general condition of the pavement in the section was noted as to appearance, riding quality and whether curling was or was not evident.

The total number of joints and cracks and the total faulting figures, both for joints and cracks were then projected to a per mile basis.

The faulting at joints and cracks was tabulated for all lanes of pavement in the 300' section analyzed. However, in the tabulating and classification process, the faulting at the planned joints in inches per mile, for the lane sampled was the figure used to determine the relative position of a given section of pavement in the tabulated results.

As explained previously, for any particular section of pavement, there may be two or more record cards and each of these will have the same classification, so far as joint faulting is concerned. When several card representing the same magnitude of joint faulting were encountered, they were classified in the order series by other pavement characteristics, such as appearance and curling.

On each record card of the series, field test results and laboratory test results on subgrade soils, laboratory test results on the concrete, construction details of pavement cross section, reinforcing, joint spacing, number and size of dowels, number of lanes and construction date, data on total traffic carried and joint and crack faulting data were listed.

The entire card series - a total of 274 - was then arranged in order of increasing joint faulting in inches per mile and a sequence number assigned to each card.

All data listed on the record cards were tabulated on Summary Sheets. This tabulation was then separated into groups by order of increasing joint faulting, group number 1 having the least joint faulting and group number 9 having the greatest joint faulting. Joint faulting limits for each group are listed below:

Group Number	Joint Faulting, inches per mile Minimum	Maximum
1	0.00	1.00
2	1.00	2.00
3	2.00	4.00
4	4.00	8.00
5	8.00	16.00
6	16.00	32.00
7	32.00	64.00
8	64.00	100.00
9	100.00+	

It will be noted that the limits on group No. 8 do not follow the same pattern as do the groups preceding it. It seemed advisable to break the upper limit at a total joint faulting of 100.00 inches per mile and establish a ninth group to cover the last two tabulated results, joint faulting of which were so extreme as to demand special classification.

APPENDIX B - TRAFFIC

The amount of traffic of various classes, particularly truck traffic, that a pavement has carried from the time it was constructed until it was investigated must obviously be one of the primary factors to be considered in evaluating the performance of any section of pavement. Traffic loads must also be a primary factor considered in comparing any one section of pavement with other sections throughout the State.

Many of the projects studied in the investigation were carrying traffic several years prior to the dates when the practice of taken regular traffic counts was established throughout the State. In estimating total traffic volumes for these projects, it was necessary to make many assumptions. The methods outlined below were used for all projects covered in the investigation.

Before undertaking to develop figures representing the relative amount of traffic carried by the various sections, a classification system was set up to tabulate traffic in three groups; namely, passenger cars (axle loads up to 2000#), light trucks (axle loads of from 2000# to 5000#) and heavy trucks (axle loads over 5000#). This classification corresponds in some degree to the system formerly used by the State in making traffic counts.

Traffic census stations selected were those which were located nearest to the sections sampled. Regular traffic census figures were obtained for all years shown on the records of the Planning Survey. The Maintenance Department and other sources furnished additional census figures for a number of stations covering several years prior to the records of the Planning Survey. On many of the projects it was necessary to take available figures and make interpolations and extrapolations for the years previous to those in which counts were made, or in some cases for intervening years where records were incomplete. The Planning Survey furnished factors for converting the Sunday and Monday counts to a daily and yearly basis.

The Planning Survey, State Railroad Commission and other sources furnished information from which axle count tables were compiled. Using these tables, an average number of axles per truck and trailer unit for different locations was computed. In all cases, buses and passenger cars were considered as two axle vehicles. For those years prior to the start of actual counts, an approximate figure was obtained by decreasing the last count a small amount for each intervening year so as to arrive at a figure representing the number of axles per vehicle for the year required. From the tabulated traffic census and the average number of axles per vehicle, the total axle count at each census station was computed and entered on a diagrammatic sketch of the project concerned. A weighted average was then calculated for each sampled section, the respective distances from adjacent census stations and the incidence of any major side roads being taken into consideration. Percentages of total traffic volume for each lane in the sampled section was then calculated from the weighted figures above. Using factors furnished by the Design Department and the total axle count for each lane, the traffic load was converted to equivalent 5000# wheel loads.

The percentages used for various lanes on each project are shown in the accompanying tabulation. (5) This division is, of necessity, a purely arbitrary one but has been based upon best available evidence.

Considering all pavements studied; there is no consistent correlation between the amount of traffic carried and the degree of faulting or other evidence of displacement at the joints (26,31). However, on individual sections it is quite evident that there are differences depending on the amount of traffic. For example, on a four or three lane pavement the outer lanes generally show more evidience of faulting than the inner lanes (16).

However, in spite of the fact that heavy wheel loads are undoubtedly one of the factors it is true that some of the best pavements have also been subjected to the heaviest traffic.

ASSUMED TRAFFIC DISTRIBUTION BY LANES

Project		Portion of Project	Date of Const.	No. of Lanes	Type Traffic & percent of total traffic used in computing traffic volumes and EWL Figures				
Letter	Designation				Type of Traffic	Lane: Left Outer	Left Inner	Right Inner	Right Outer
A	X-Sol-7-B	All	1932	2	Mixed		50%	50%	
B	IV-Mrn-1-A	All	1929	2	Mixed		50	50	
			1,1939	3	Mixed	40%	20	40	
C	X-SJ-4-C,D	All	1919 1930 1937	2	Mixed		50	50	
D	IV-SM-68-A	S.F. to So. San Francisco	1931-1933	4	Heavy Light	40 30	10 20	10 20	40 30
	IV-SCl-68-B,C	Palo Alto to San Jose	1932-1936	4	Heavy Light	40 35	10 15	10 15	40 35
E	IV-Ala-SCl-5-C,A	All	1914 1918 1928	3	Mixed	Lt. 45	Center 10	Rt. 45	
F	V-Mon-2-A	Salinas to Santa Rita	1928	3	Mixed		50	50	
	J		1943	3	Mixed	40	10	10	40
	J	Santa Rita to Co. Line	1932	2	Mixed		50	50	
G	V-SB-2-C, L,M	Las Alamos to 1-1/2 Mi. So. of Santa Maria	1932	2	Mixed		50	50	
						Note: Traffic counts 'north on SB-2-M' increased by 10% for town of Los Alamos as indicated by 1944, 1945 traffic count			
H	VI-Fre-4-C	All	1937	3	Mixed	Left 45	Center 10	Right 45	
I	VII-LA-4-I,J	All	1933	3	Mixed	Left 40	Center 20	Right 40	
K	VII-LA-26-A,El.M	West of Valley Blvd.	1929	2-15'	Mixed	Lt. 15' Ft. 50%		Rt. 15 Ft. 50%	
			1937	4	Mixed	Widen Strip 35%	35%	35%	Widen Strip 35%
	VII-LA-26-B,C	East of Valley Blvd.	1933	3	Mixed	Left 45	Center 10	Right 45	
			1937	4	Mixed	40	10	10	40
M	VII-Ora-2-C	Irvine to Culver's Corner	1922	2	Mixed		50	50	
			1933	3	Mixed		Left 45	Center 10	Right 45
		Culver's Corner to Tustin	1933	3	Mixed	Left 45	Center 10	Right 45	
						Note: Heavy truck count in West (left) lane increased by 10% of average count for 1942, '43 and 1/2 for 1944 due to construction trucking into El Toro Marine Base			

ASSUMED
TRAFFIC DISTRIBUTION BY LANES

Project Letter	Project Designation	Portion of Project	Date of Constr	No. of Lanes	Type of Traffic	Left Outer	Left Inner	Right Inner	Right Outer
N	VII-Ora-60-C	Dana Point to So. C/L Laguna Beach	1933	3	Mixed		Left 45	Center 10	Right 45
N	VII-Ora-60-Lga Bch	in Laguna Beach	1935	4	Mixed	35	15	15	35
O	XI-SD-12-C D,E,F,G	All	1929 to 1933	2	Mixed		50	50	
P	VIII-Riv-26-G	All	1933	2	Mixed		50	50	
R	V-SB-2-D,E	All	1930 to 1940	2	Mixed		50	50	
S	VII-Ora-171-A	All	1937	2	Mixed		50	50	
S	VII-Ora-184-A	All	1929	2	Mixed		50	50	
T	VIII-SBd-26-D	All	1933 1934	2	Mixed		50	50	
T	VIII-SBd-26-D	All	1938	3	Mixed		Left 45	Center 10	Right 45
V	VII-LA-Alameda St.	Dominguez St. to So. City Limits of Compton	1923	2	Mixed		50	50	
V	VII-LA-Alameda St.	Dominguez St. to So. City Limits of Compton	1935	4	Mixed	Not Used	35	35	Not Used
V	VII-LA-Alameda St.	North City Limits of Compton to South City Limits of Los Angeles	1921	2	Mixed	Not Used	Not Used	50	50
V	VII-LA-Alameda St.	North City Limits of Compton to South City Limits of Los Angeles	1926	3	Mixed	Not Used	Not Used	35	50
V	VII-LA-Alameda St.	North City Limits of Compton to South City Limits of Los Angeles	1943	4	Mixed	Not Used	Not Used	20	40

Note: Lane columns are headed "Type Traffic & percent of total traffic used in computing traffic volumes and EWL Figures — Lane".

APPENDIX C. EVIDENCES OF SLAB MOVEMENT

As previously noted, the system adopted for comparative evaluation of P. C. C. pavement performance was based on the magnitude of joint faulting, expressed in inches per mile of pavement, as scaled from profilograph records.

The profilograph was built by the Laboratory some years ago and is believed to be by far the most accurate and economical means for comparing various sections of pavement throughout an entire Highway System. However, a correlation between the profilograph records and some other means of measurement of pavement surfaces appeared desirable in order to furnish evidence as to the accuracy of the record obtained by use of the machine.

The first of the accompanying sketches, (6), was made up of profiles of several sections of pavement as translated directly from the profilograph records and also as measured by scaling from a straight edge in the field.

In making the field scale measurements, a piano wire was stretched over several slabs and subjected to considerable tension. The wire was blocked up at each joint with a short piece of steel pipe to eliminate any sag insofar as possible. Measurements from the wire to the pavement surface were made at one foot intervals by means of a steel scale rule. Profilograph records of the same sections of pavement were made just before or soon after the scale readings were made.

The profilograph records were laid off as accurately as possible at one foot intervals and measurements from a base line were scaled to the profile.

Results have been plotted and superimposed in the accompanying drawing (6). Due to limitations that are inherent in the profilograph as built, some deviation in pavement surfaces between joints is apparent. However, it is felt that the two methods show a satisfactory degree of correlation and that the important and significant effects of faulting and curling are accurately reproduced by the profilograph.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

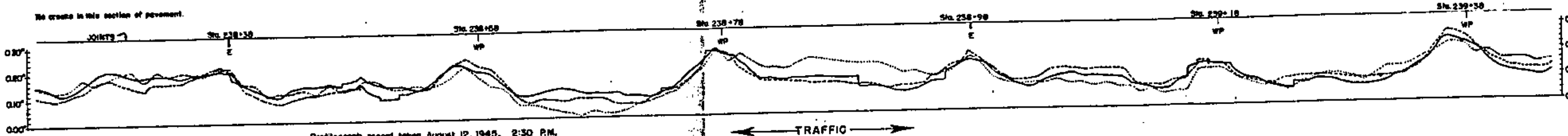
RESEARCH NO. 00204

REFERENCE NO. 6

SKETCH NO. ______

RELATIVE ACCURACY OF PROFILOGRAPH RECORDS COMPARED WITH PROFILE OBTAINED BY STRETCHING A PIANO WIRE & SCALING OFFSET TO PAVEMENT SUFACE.

VII-Ora-60-G - Job Letter (N). South of Laguna Beach, Center Lane. Readings taken 30" from longitudinal joint between east and center lanes. Pavement showing medium curl.

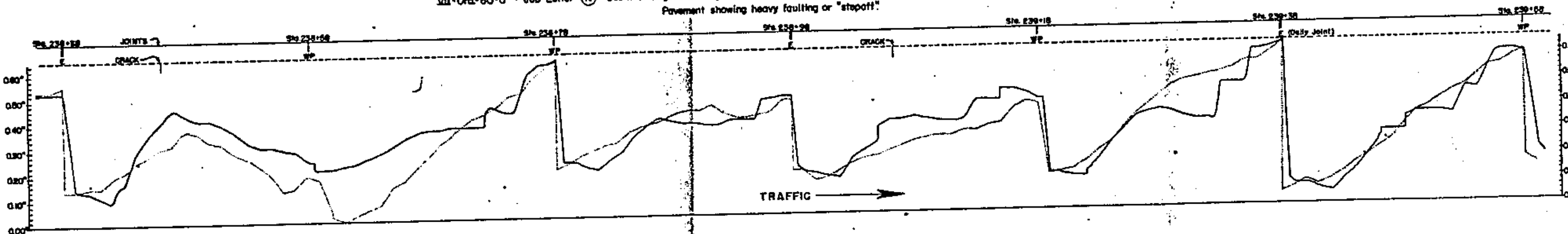


Profilograph record taken August 12, 1945, 2:30 P.M.

Profilograph record taken August 12, 1945, 4:30 P.M.

Profile scaled from piano wire to pavement surface, taken August 13, 1945, P.M.

VII-Ora-60-C - Job Letter (N) South of Laguna Beach, West Lane. Readings taken 30" west of longitudinal joint between center and west lanes. Pavement showing heavy faulting or "stepoff".

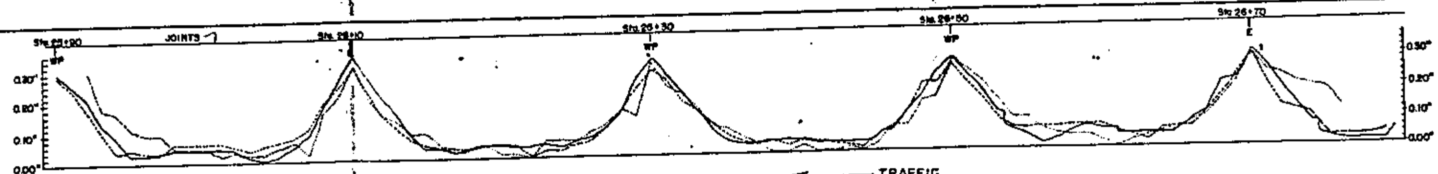


Profilograph record taken August 12, 1945, 4:30 P.M.

Profile scaled from piano wire to pavement surface, taken August 13, 1945, P.M.

VII-Ora-171-A - Job Letter (S). Hampshire Avenue – West Lane.

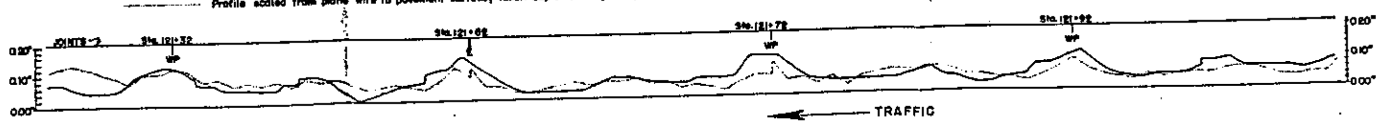
Profiles from different sections of pavement, both placed under Contract No. 07XC3 in 1937. Pavement was smoothest P.C.C. pavement constructed in state in 1937. Surrounding country flooded by heavy rains in early 1938 and pavement curled soon after. At present time pavement has no cracks and is still in excellent condition except for permanent curl. Profiles taken 30" west of longitudinal joint.



Profilograph record taken August 1, 1945, 3:15 P.M.

Profilograph record taken March 26, 1946, 3:30 P.M.

Profile scaled from piano wire to pavement surface, taken September 4, 1945, 10:00 A.M.



Profilograph record taken August 1, 1945, 11:30 A.M.

Profile scaled from piano wire to pavement surface, taken September 4, 1945, 11:15 A.M.

The following sketches are tracings of several of the numerous pavement profilograph records obtained during the course of the investigation.

The first of these tracings (7), represents several profiles of the same section of concrete pavement. The first profiles were obtained the day that the concrete was placed, the second was run 24 hours after pouring and the third was run one week after pouring. The succeeding profiles were taken at intervals of 1 month, 2 months, 1 year and 2 years from the date of pouring of the pavement. In each case, a profile was taken in the early morning and another in the middle of the afternoon. These profiles demonstrate very clearly the almost immediate appearance of curling movement in the pavement. Even at the end of one week a small amount of curl is noticeable in the morning profile, and this increases as the pavement ages. Also, even though with increasing age an increase in surface roughness is apparent in both morning and afternoon profiles, the pavement loses most of its curl and virtually reverts to its original contour in the hot afternoon.

REFERENCE NO. 7
SKETCH NO. ____

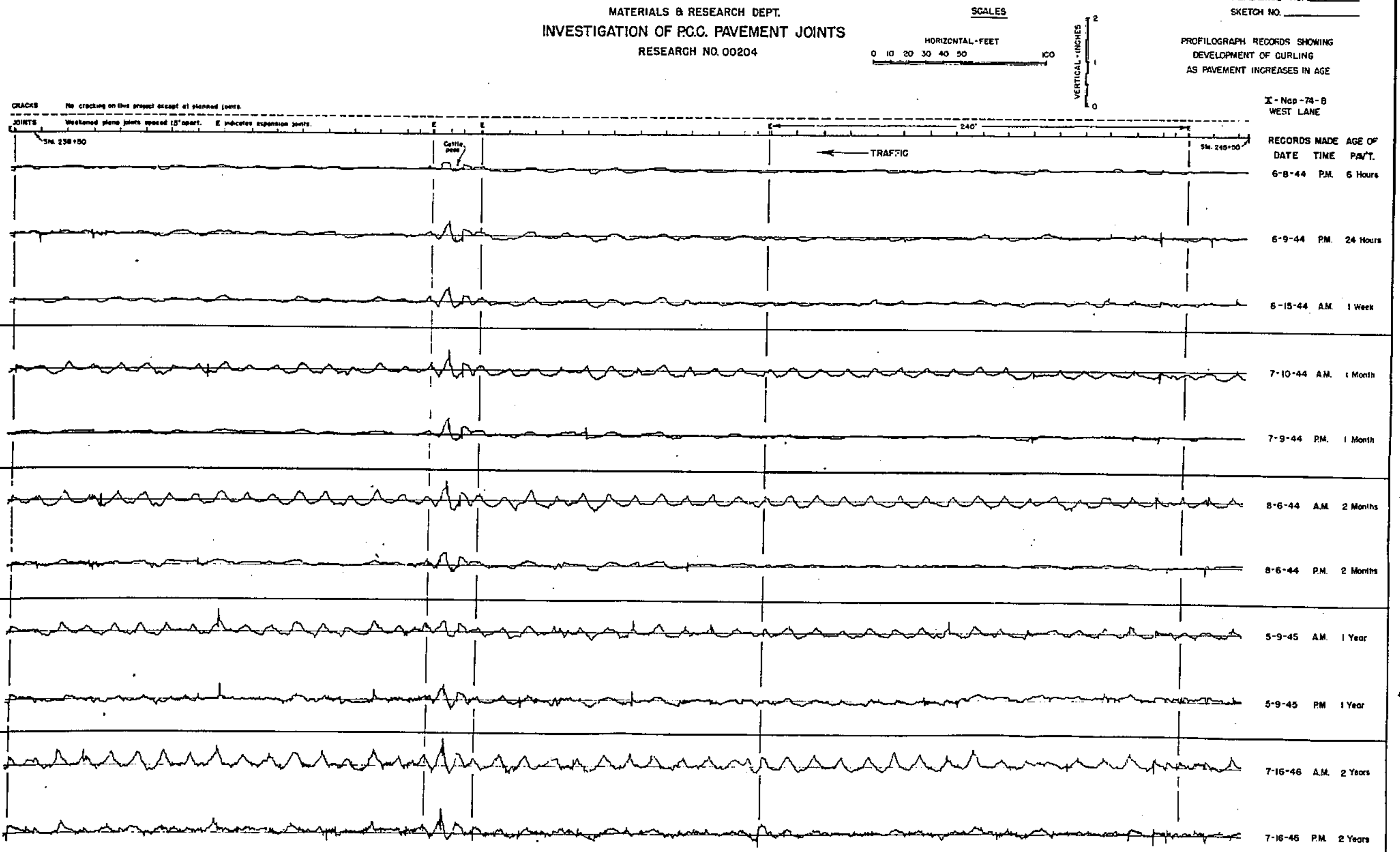
MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

PROFILOGRAPH RECORDS SHOWING DEVELOPMENT OF CURLING AS PAVEMENT INCREASES IN AGE

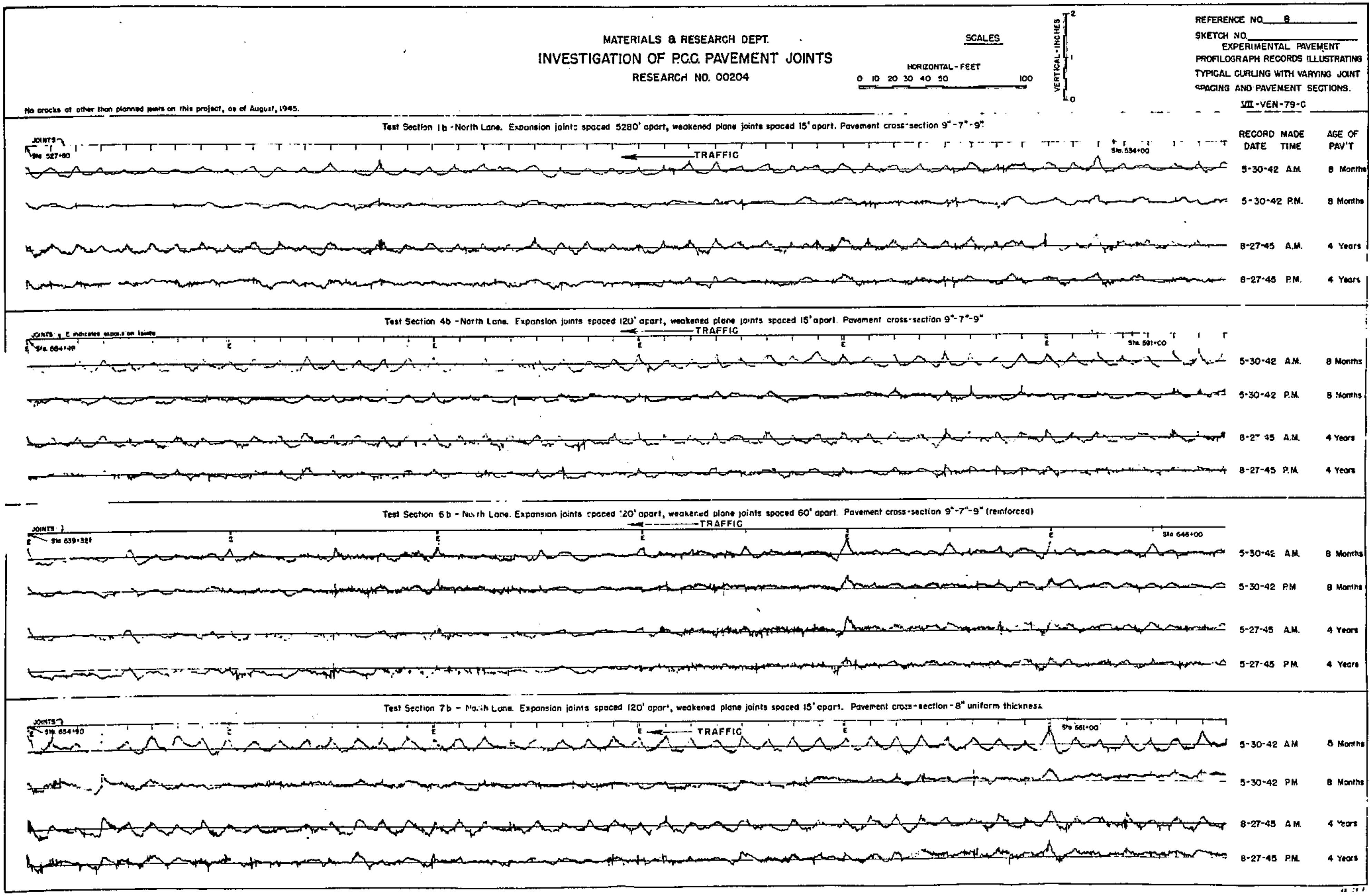
X - Nap - 74 - B
WEST LANE



The second of the profile sheets (8), was made up of profiles taken over different test sections of pavement constructed in 1941 on the Piru Experimental Pavement, VII-Ven-79-C. The first profile was secured at the age of 8 months and the second after 4 years. This experimental pavement was constructed primarily to compare different expansion and weakened plane joint spacing although varying pavement cross sections were also used.

It is of interest to note that by the time the pavement was 8 months old as much curl was in evidence in the early morning as was recorded later at the age of 4 years.

Also of interest is the evident fact that the spacing or elimination of expansion joints alone is not the controlling factor in the amount of curl but that curling also occurs at the weakened plane joints. The three profiles from sections with weakened plane joints spaced at 15 feet intervals all show about the same amount of curl per joint regardless of expansion joint spacing. On the other hand, the section with expansion joints spaced 120 feet apart with only one weakened plane joint between expansion joints giving a slab length of 60 feet shows about the same curl per joint but the total roughness is less on account of the fewer joints.


MATERIALS & RESEARCH DEPT.
INVESTIGATION OF P.C.C. PAVEMENT JOINTS
RESEARCH NO. 00204
SCALES
HORIZONTAL - FEET
0 10 20 30 40 50 100
VERTICAL - INCHES
2
1
0
REFERENCE NO. 8
SKETCH NO.
EXPERIMENTAL PAVEMENT
PROFILOGRAPH RECORDS ILLUSTRATING
TYPICAL CURLING WITH VARYING JOINT
SPACING AND PAVEMENT SECTIONS.
VII-VEN-79-C
No cracks at other than planned joints on this project, as of August, 1945.
RECORD MADE
DATE TIME
AGE OF PAV'T
Test Section 1b - North Lane. Expansion joints spaced 5280' apart, weakened plane joints spaced 15' apart. Pavement cross-section 9"-7"-9"
JOINTS
Sta. 527+60
Sta. 534+00
TRAFFIC
5-30-42 A.M. 8 Months
5-30-42 P.M. 8 Months
8-27-45 A.M. 4 Years
8-27-45 P.M. 4 Years
Test Section 4b - North Lane. Expansion joints spaced 120' apart, weakened plane joints spaced 15' apart. Pavement cross-section 9"-7"-9"
JOINTS E indicates expansion joints
Sta. 584+40
Sta. 591+00
TRAFFIC
5-30-42 A.M. 8 Months
5-30-42 P.M. 8 Months
8-27-45 A.M. 4 Years
8-27-45 P.M. 4 Years
Test Section 6b - North Lane. Expansion joints spaced 120' apart, weakened plane joints spaced 60' apart. Pavement cross-section 9"-7"-9" (reinforced)
JOINTS
Sta. 639+32
Sta. 646+00
TRAFFIC
5-30-42 A.M. 8 Months
5-30-42 P.M. 8 Months
5-27-45 A.M. 4 Years
5-27-45 P.M. 4 Years
Test Section 7b - North Lane. Expansion joints spaced 120' apart, weakened plane joints spaced 15' apart. Pavement cross-section - 8" uniform thickness
JOINTS
Sta. 654+90
Sta. 661+00
TRAFFIC
5-30-42 A.M. 8 Months
5-30-42 P.M. 8 Months
8-27-45 A.M. 4 Years
8-27-45 P.M. 4 Years

The conditions noted previously for the second profile sheet are further borne out by the third sheet (9). The sections which have 15 feet and 20 feet spacing between weakened plane joints show curl at every joint regardless of expansion joint spacing. The pavement with longer spacing between joints (30 feet to 60 feet) show curl at each joint and also at most cracks but the spacing of expansion joints seems to have little effect. As noted above, the longer slab length results in a pavement that is smoother over all than is the case with the shorter joint spacing.

It should be further noted that, so far as smoothness or incidence of cracking is concerned, the thickness of a concrete pavement slab seems to have little, if any, direct effect.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

SCALES

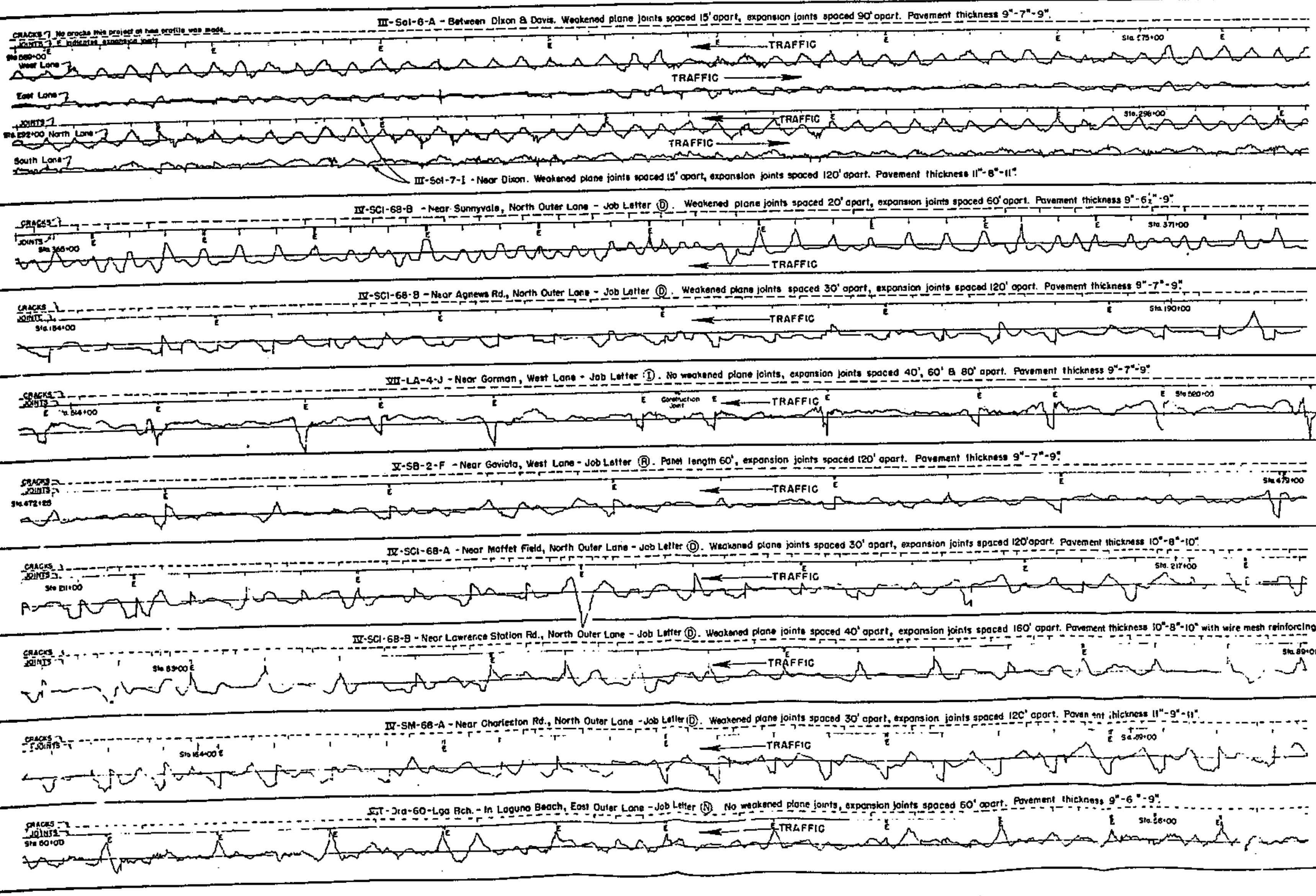
HORIZONTAL – FEET 0 10 20 30 40 50 100

VERTICAL – INCHES 0 1 2

REFERENCE NO. 9

SKETCH NO.

PROFILOGRAPH RECORDS ILLUSTRATING COMPARISON OF DIFFERENT SLAB LENGTHS AND PAVEMENT THICKNESSES.



RECORDS DATE	MADE TIME	AGE OF PAV'T
9-1-43	A.M.	1 Year
8-31-43	P.M.	1 Year
9-1-43	A.M.	1 Year
8-31-43	P.M.	1 Year
10-25-44	A.M.	7½ Years
10-25-44	A.M.	10½ Years
4-17-45	P.M.	12 Years
4-10-45	P.M.	11 Years
10-25-44	P.M.	11 Years
10-25-44	P.M.	11 Years
11-4-44	A.M.	11 Years
3-26-45	P.M.	10 Years

The fourth profile sheet (10), was made up from records of pavement which have curled to a greater extent than any of the other sections observed. Apparently, most of these pavement slabs have under gone some form of permanent change for they do not smooth out completely in the afternoon.

At the time it was constructed and finished (1937), the pavement on VII-Ora-171-A was considered to be the smoothest pavement that had been constructed in the State for that year. During the following winter (1937-38) the surrounding country was completely flooded. The pavement curl became noticeable shortly thereafter and the first section of pavement has not smoothed out since. A section of this pavement is also used in the first tracing of this series (6), on the exaggerated scale. This drawing was made to illustrate other relationships but shows the extreme curl very clearly. The section illustrated between Station 24+00 and 30+00 is laid on a low fill of silty, clayey sand over low-lying, more or less swampy ground. On the other hand, the section illustrated between Station 117+00 and Station 123+00 is on higher, better drained ground. Note that this latter section smooths out and becomes practically flat in a hot afternoon.

The second pavement shown, VI-Ora-184-A, was built by Orange County in 1928-29 and according to the Orange County Engineer's Office became curled the first winter after construction. It has a somewhat higher elevation than VII-Ora-171-A and it is laid over black adobe soil.

The third pavement shown, VII-Ora-60-C, is between Laguna Beach and Dana Point. All profiles were run in the afternoon and all three lanes show considerable curl. The west lane shows heavy faulting at some joints and the curling is not so general as in the other two lanes. Causes for the permanent curl in this pavement are not readily apparent. Subgrade soil in this area is a dark sandy clay material and the soil in place had a moisture content ranging from 85 to 95% of its theoretical moisture capacity.

The fourth pavement on this sheet is included to show the wide variation in curling observed within a relatively short distance. The two sections shown are only 700 feet apart but there is considerable difference in the curling. It should also be noted that in one section, joint spacing is 30 feet while in the other it is only 20 feet. The shorter slab lengths are obviously the rougher of the two sections.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

SCALES

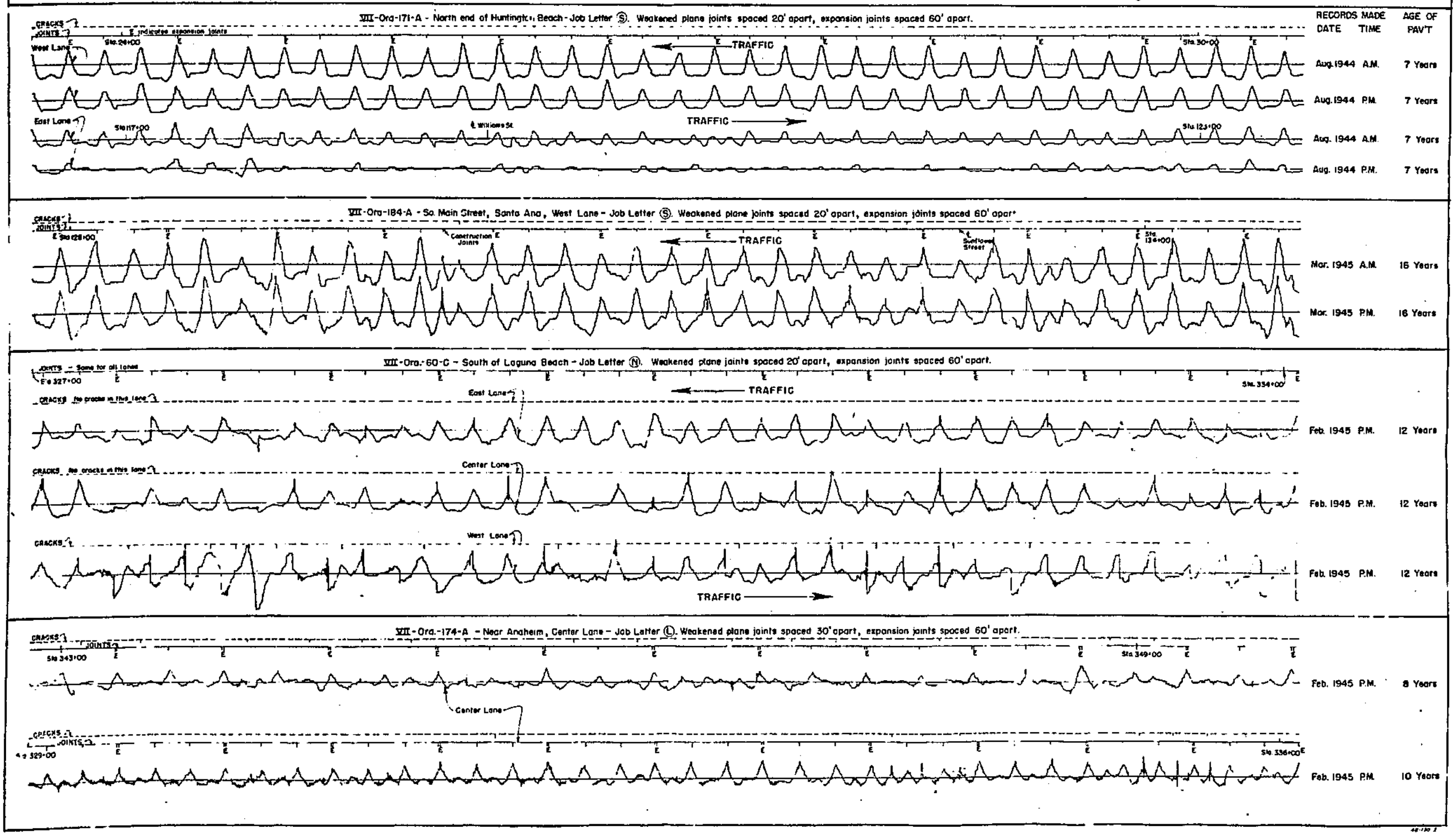
HORIZONTAL - FEET 0 10 20 30 40 50 100

VERTICAL - INCHES 0 1 2

REFERENCE NO. 10

SKETCH NO.

PROFILOGRAPH RECORDS ILLUSTRATING PAVEMENTS WITH EXTREME CURL AND ALSO WITH PERMANENT CURL.



The fifth sheet of profiles (11), is made up entirely of pavements which show practically no evidence of daily change in their surfaces in the form of warping or curling. Surfaces on all projects illustrated with the exception of XI-SD-12-G are comparatively rough but little, if any, curl is apparent in any of them. The pavement on VII-LA-Alameda Street is in excellent condition considering the age and amount of traffic that it has carried since construction. This pavement was laid over 6" of D. G. which was placed, oil treated and maintained under traffic for a year before the concrete was placed. At time of sampling, the 24 year old pavement was in much better condition than some of the newer pavement widening that has been placed along side of it.

The section at Hermosa Beach, VII-LA-60-LA, was not cored or sampled during the investigation so construction or material details are not known.

The third pavement on this sheet, from X-SJ-4-D, is one of considerable interest. The original 5", 15' monolithic slab (Sta. 59+00 to 65+00) was of a 5 inch uniform cross section, and the only joints were placed at the end of the morning and afternoon runs. This pavement was placed directly over the old "dirt road" which had been traveled for many years previously. While the pavement has some transverse cracks and is comparatively rough judged by modern standards, it was in good condition when sampled. Flush concrete widening strips were added in 1930 to bring the width to 20 ft. and subgrade soil under these widening strips is apparently the same as under the old pavement. However, the field notes at time of sampling mention the fact that subgrade under the widening strips was not nearly so compact as that under the old pavement. The 1931 section of the pavement, Lodi to Houston School, Sta. 20+00 to 26+00, was placed with weakened plane joints 20' apart and expansion joints 60' apart. Subgrade soil is practically identical to that found under the older section. The heavy faulting of expansion joints and lesser faulting at weakened plane joints developed several years ago. While the 1931 pavement has a cross section of 9"-7"-9", it has required much greater maintenance expenditure than the older pavement of thinner section constructed 12 years before.

The fourth pavement shown, XI-SD-12-G, is in a section of the State that is generally fairly dry and is on a D. G. subgrade. There is no significant change in profilograph record between morning and afternoon. The traffic is not heavy on this route.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

REFERENCE NO. 11

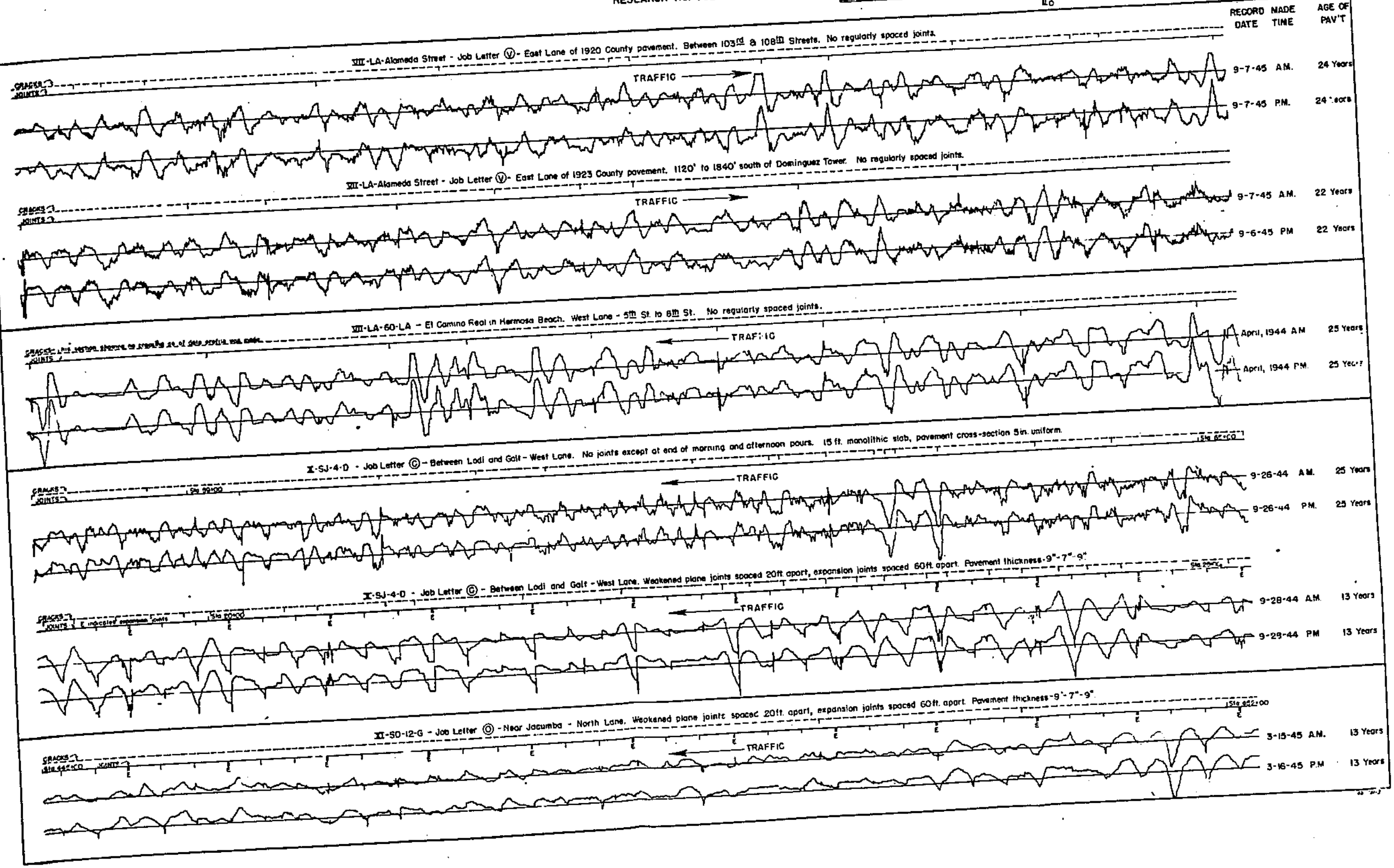
SKETCH NO.

PROFILOGRAPH RECORDS OF PAVEMENT ILLUSTRATING SLIGHT OR NO DAILY CHANGE DUE TO WARPING OR CURLING.

SCALES

HORIZONTAL - FEET 0 10 20 30 40 50 100

VERTICAL - INCHES 0 1 2



The sixth sheet of profiles (12), is made up of profiles from sections of pavement which show definite evidences of expanding concrete generally due to "reactive" aggregates. One exception to the above was included to illustrate the difference in profiles between sections which show "reactive" aggregates and sections in the same area which do not show reactions. This exception is on VI-Fre-4-C and the differences in appearance of the pavement are very apparent from visual inspection. It was noted that wherever evidences of "reactive" aggregates are seen the joints are invariably in good condition and very tight.

Profiles from V-Mon-2-A,J represent the lanes of the road which until 1943, carried the entire traffic load. This load, plus evidences of considerable moisture in the subgrade, probably accounts for the comparative roughness of this section.

The other two sections are in fairly dry regions of the State and in the case of XI-SD-12-G, the traffic load is quite light.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

SCALES

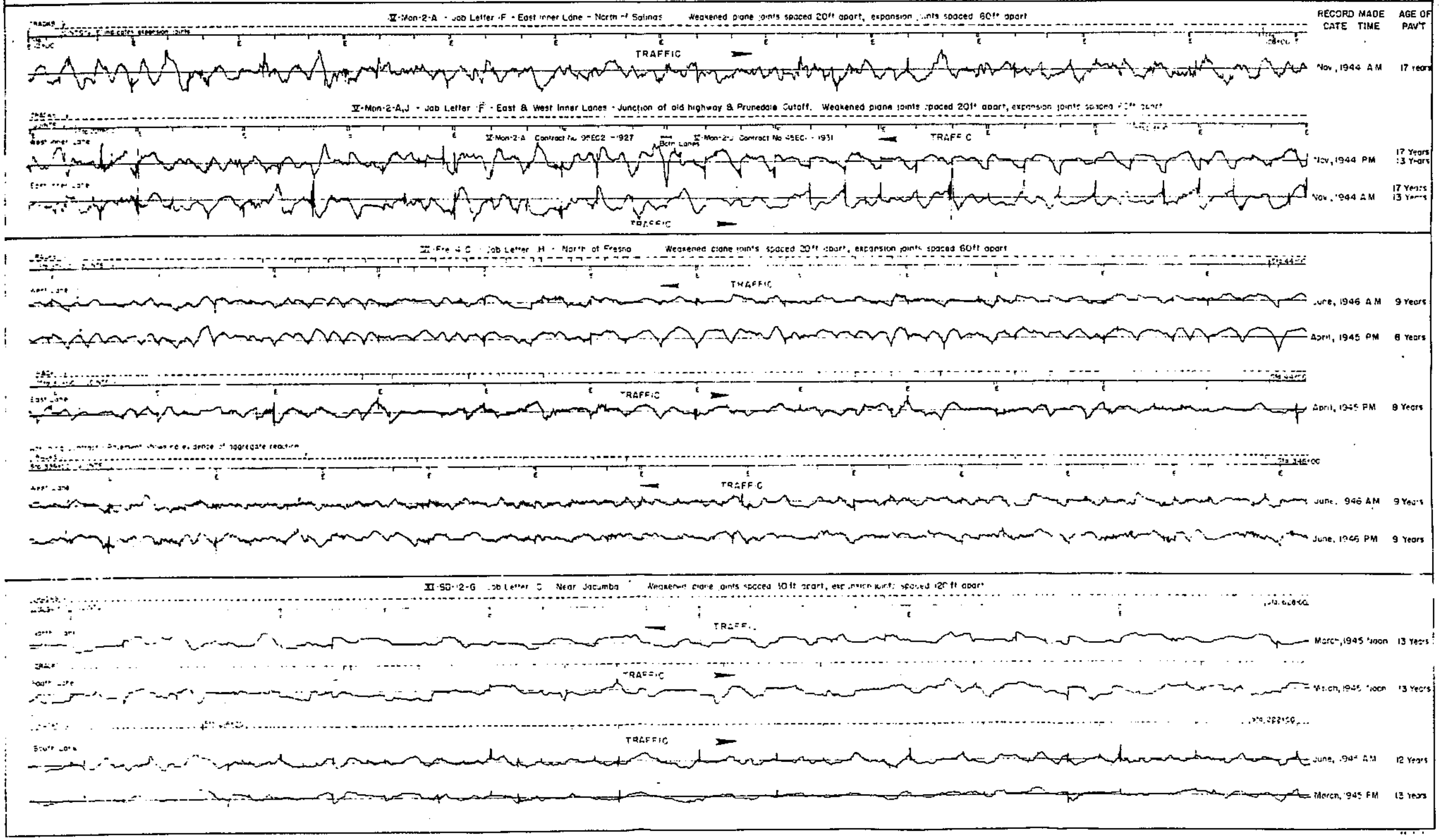
HORIZONTAL - FEET: 0 10 20 30 40 50 100

VERTICAL - INCHES: 0 1 2

REFERENCE NO. 12

SKETCH NO. ____

PROFILOGRAPH RECORDS ILLUSTRATING PAVEMENTS SHOWING EVIDENCE OF AGGREGATE REACTION.



The seventh sheet of pavement profiles (13), was included because of the rather marked difference noted in second story P.C.C. pavement through the State.

The three sections of pavement illustrated from XI-Riv-26-G were taken from a job which improved an old typical concrete paved desert road that was constructed with numerous "dips" at water courses. The new pavement was placed as "second story" over the old pavement but with gravel fills in the depressions. A course of imported material consisting of coarse sand and gravel was placed through the "low spots" or dips. A 3" to 4" blanket of "cushion material" was placed over the old P.C.C. pavement and the new pavement placed over the "cushion". The cushion course material was of two distinct types, on the northerly portion a silty sand was used and on the southerly a clean coarse sand. The profilograph records, after twelve years of traffic over this pavement, show a marked contrast in condition of the pavement over the two types of cushion material. In every case it is evident that the pavement is in much worse condition over the silty sand cushion and it is easy to distinguish the points where the coarse sand and gravel material ended and the silt cushion began and vice versa. Where coarse sandy gravel was used there are no appreciable differences between the construction over new subgrade and the second story construction.

The pavement section on XI-SD-12-C is laid on a 4" to 5" cushion course of disintegrated granite over an old P.C.C. pavement. The new pavement has not cracked but is fairly rough and shows no better performance than the adjoining pavement which is not second story. This section shows somewhat more surface roughness than do most of the sections to the eastward on Route 12. However, it compares favorably with the state average.

IV-Mrn-1-A was included in the study primarily because there was a contrast between the newer lane constructed in 1938 and the older second story concrete placed in 1928. While faulting or other evidence of joint displacement was not evident on either portion the newer lane shows extensive cracking compared to the older second story section.

MATERIALS & RESEARCH DEPT.

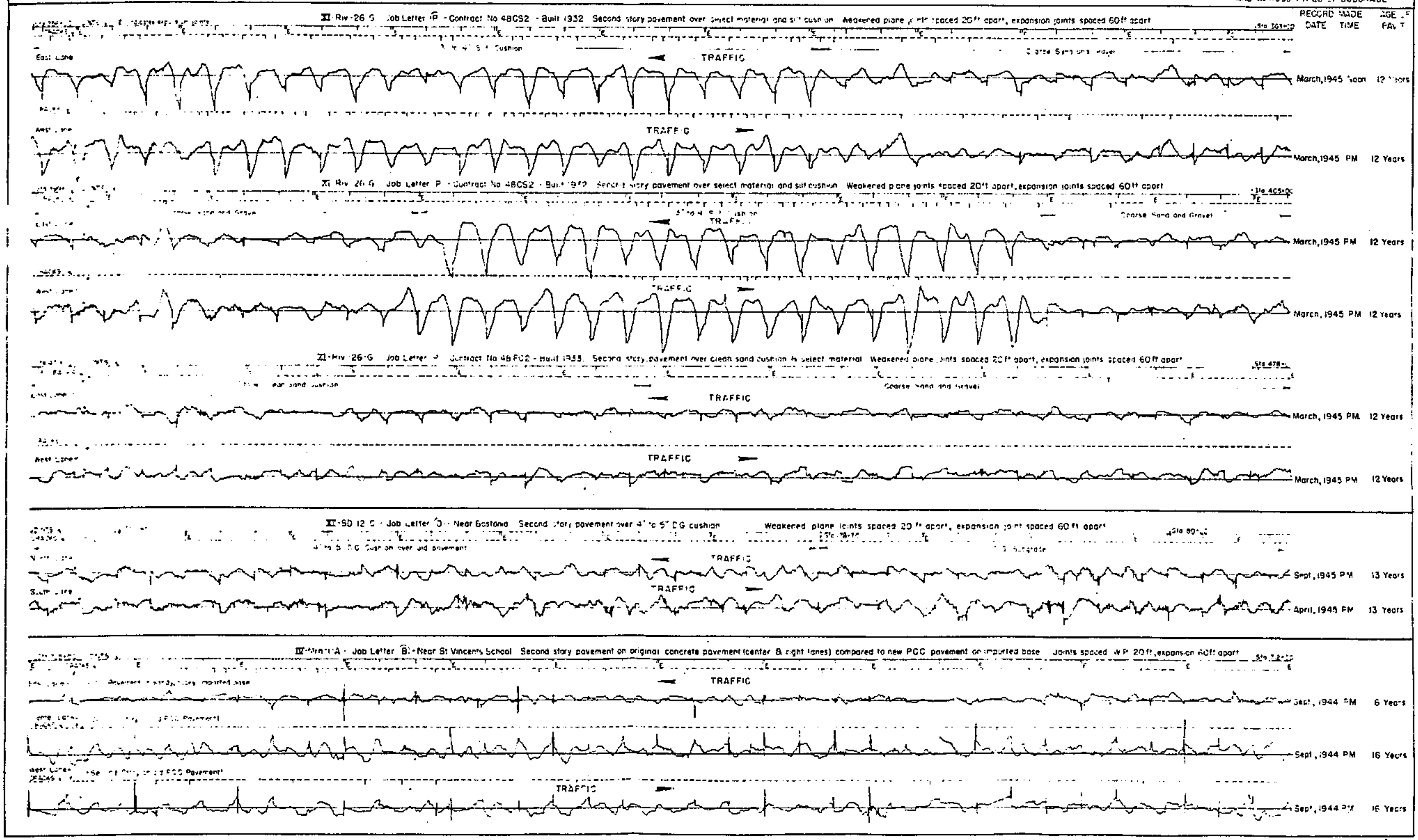
INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

REFERENCE NO. 13

SKETCH NO.

PROFILOGRAPH RECORDS ILLUSTRATING SECOND STORY PAVEMENTS PLACED DIRECTLY OVER ORIGINAL CONCRETE AND VARIOUS TYPES OF SUBGRADE



The next two sheets of profile tracings (14 &15), represent some marked contrasts between pavements on the same section laid over ~~different~~ types of subgrade soils and in some cases over subgrades with a wide variation in degree of saturation.

The examples from VII-LA-26-B,C (14) are all taken from the same lane of traffic, at various locations, over various types of subgrade material. All subgrade material in place on this particular section was comparatively dry but there was a variation in moisture content within the limits of the section. The clean sand subgrade in the first section (Sta. 32+00 to Sta. 38+00) contained only 14-1/2%, the clayey silt subgrade (Sta. 223+00 to 230+00) contained 55% and the clayey silt subgrade (Sta. 63+00 to 70+00) contained 69% of the theoretical amount of moisture necessary for saturation. This variation may account for the marked faulting in the last section as compared to second. However, in the first section the sand subgrade was very loose and apparently has compacted under the vibration of traffic with the result that faulting at the joints is quite evident.

The two sections of pavement on VII-Ora-2-C are both over the same type of soil. The west lane is bordered by a heavy planting of eucalyptus trees south of Station 156 whereas on the section north of Station 156 and along the east lane there are no trees planted close to the roadway. The difference in degree of saturation in the subgrade soil between the strip bordered by trees and the adjoining section that has no trees is noted on the profilograph sheet. This difference in moisture content possibly accounts for the difference in pavement appearance between the two sections for no differences appear in character of the subgrade soil itself.

The three sections of pavement on XI-SD-12-C,F are over disintegrated granite subgrade but as shown, there are differences in surface smoothness. The section on XI-SD-12-F (near Tecate Divide) and the section on XI-SD-12-C (3-1/2 miles west of Alpine) have subgrade material that is considerably more granular than the third section. However, the pavement subgrade in section "F" has 68%, in the section west of Alpine has 48% and in the section east of El Cajon has 60% of the theoretical amount of moisture necessary for saturation. Traffic loads increase from east to west on this route so that the Tecate Divide section has the least traffic and the section east of El Cajon has the most.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

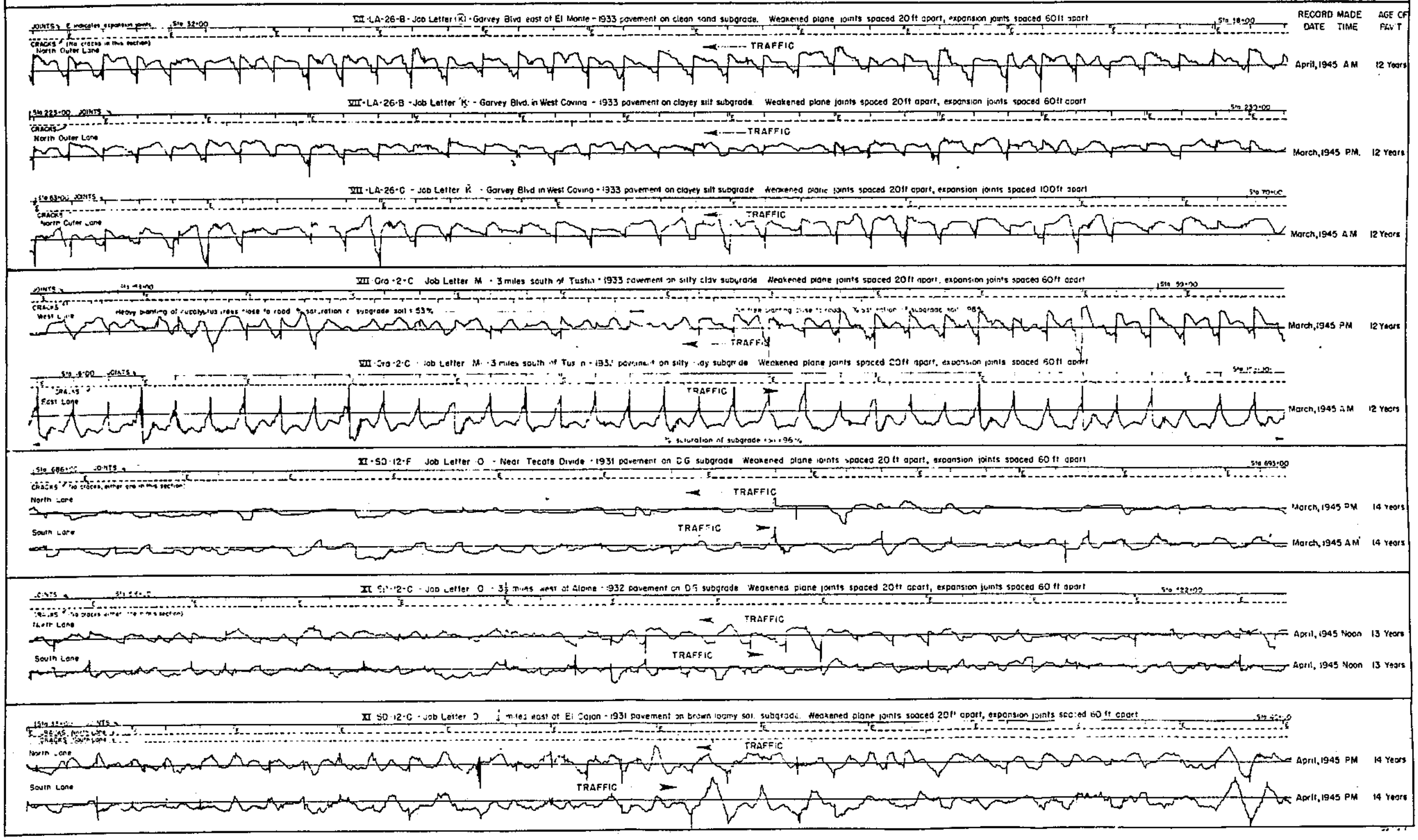
REFERENCE NO. 14
SKETCH NO.

PROFILOGRAPH RECORDS ILLUSTRATING PAVEMENTS PLACED ON DIFFERENT TYPES OF SUBGRADE SOILS

SCALES

HORIZONTAL - FEET: 0 10 20 30 40 50 100

VERTICAL INCHES: 0 1 2



The two sections of concrete pavement on IV-Ala-5-C and one IV-SCl-5-C (15) are both on very similar imported borrow subgrade material over adobe basement soil. However, the amount of moisture varies widely, the Alameda County section having 95% and the Santa Clara County section averaging 77% of the theoretical amount of moisture necessary for saturation. It will be noted that the Santa Clara section is in the better condition.

Subgrade material under X-Sol-7-B is the same for both lanes shown - a tufa material. The amount of moisture in the subgrade varied from 90% - 100% of the theoretical amount required for saturation. However, the portion illustrated did not show the degree of faulting and mud pumping that was evident farther eastward on this route.

Profiles from V-Mon-2-J are over two sections of pavement laid on very similar subgrade material. In one section, subgrade soil in place contained 52% and in the other section contained from 90-100% of the theoretical amount of moisture necessary for saturation. As all conditions including type of subgrade materials are quite similar on the two sections, it is evident that the character of subgrade soil alone does not decide pavement performance.

The subgrade material under the pavement on V-SB-2-L is a cohesionless loose sand and contained approximately 25% of the theoretical amount of moisture necessary for saturation. This section shows definite faulting.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

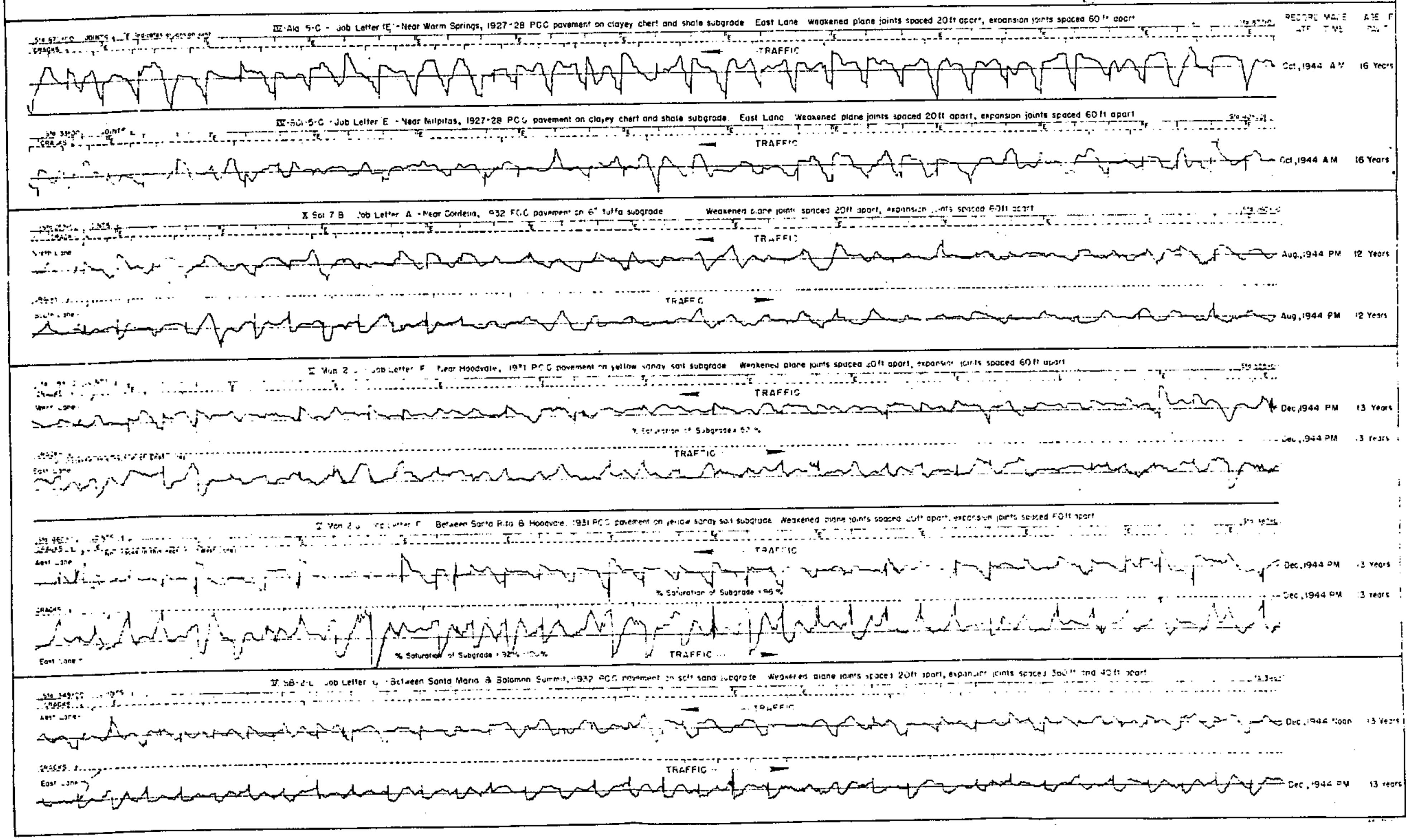
SCALES

HORIZONTAL - FEET

REFERENCE NO. 13

SKETCH NO. ______

PROFILOGRAPH RECORDS COMPARING PAVEMENTS PLACED ON DIFFERENT TYPES OF SUBGRADE SOILS



The profiles on the tenth and last sheet (16) were selected to illustrate the part played by traffic in causing faulting of P.C.C. pavements where all other conditions are similar.

The first profiles from VII-Ora-60-C show the two outside lanes of pavement with the joints heavily faulted in the normal manner (the end of the slab that is first loaded by vehicle wheels being one that become depressed.) The center lane, on the other hand, which carried fewer heavy axle loads and in which traffic moves in both directions shows definite curl but no serious faulting. This indicates that curling is a precursor to faulting, and faulting develops only when traffic reaches a certain magnitude.

The profiles from VII-LA-4-D (Ridge Route) are further evidence of the effect of heavy traffic on the joints of P.C.C. pavement. The two outside lanes which carry practically all of the large number of heavy trucks on this section of highway are badly faulted. The center lane, generally speaking, carries only a small percentage of the heavy truck load and the center lane is subjected to traffic moving in either direction. This is also one of the very few sections of California pavement in which a "reverse" curl has been noted.

Profiles on VII-LA-26-B, east of El Monte, not only illustrate the effect of heavy traffic in producing faulted joints and cracks but show rather clearly the tilting effect on entire slabs. This effect is noticeable in profiles of VII-Ora-60-C but is much more pronounced in these profiles. Again, the absence of faulting in the inner lanes is apparent.

The profile from VII-LA-26-C, at West Covina, further illustrates the contrasting effects of light and heavy traffic on joints in P.C.C. pavement. Considerable difference in displacement is evident, however, between this section and the section on VII-LA-20-B, east of El Monte, (14). Little or no "tilting" of the slabs which was so evident east of El Monte is apparent on the West Covina section. Inner lane profiles are also considerably smoother at West Covina than the inner lane on the previous section.

MATERIALS & RESEARCH DEPT.

INVESTIGATION OF P.C.C. PAVEMENT JOINTS

RESEARCH NO. 00204

SCALES

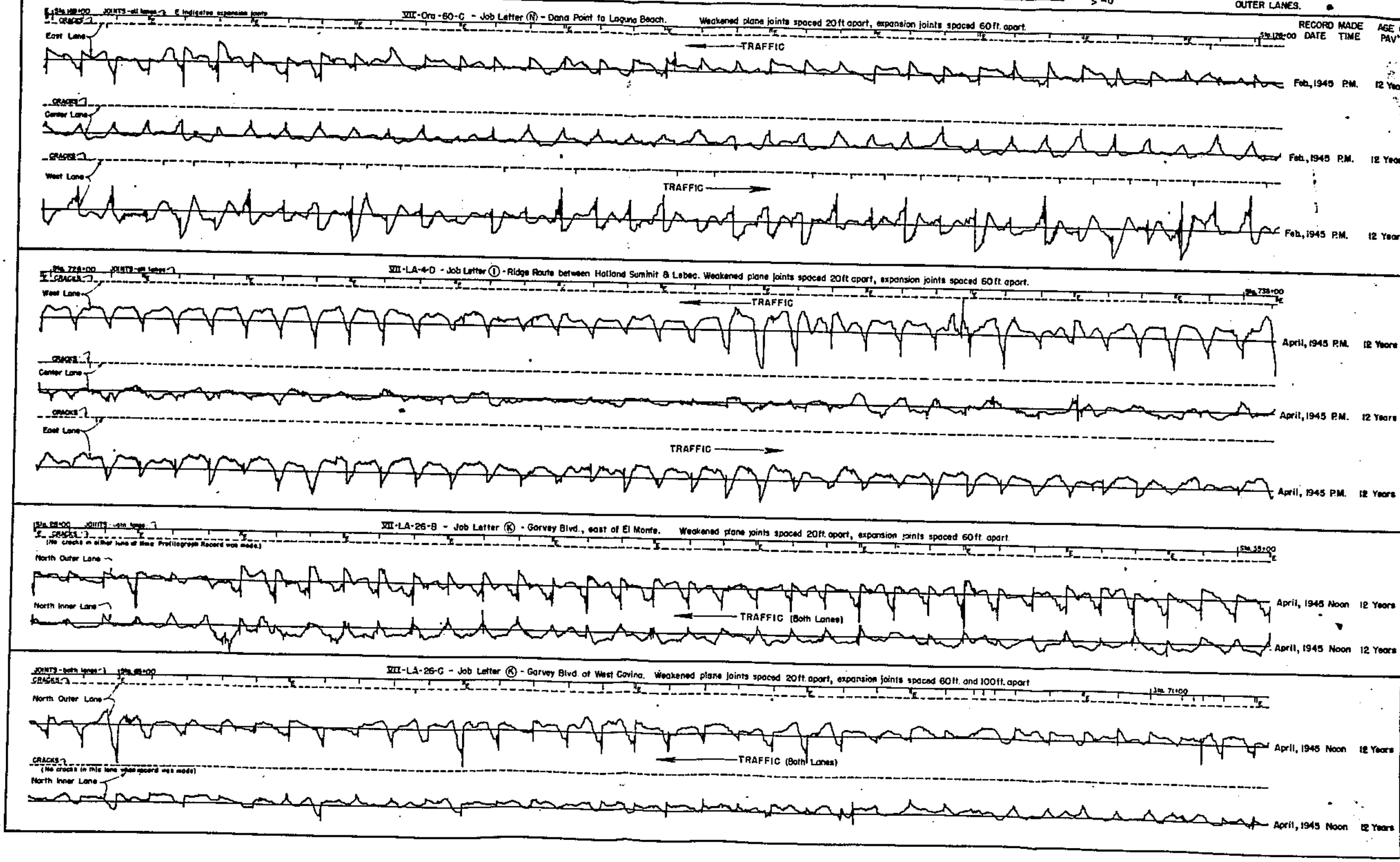
HORIZONTAL - FEET: 0 10 20 30 40 50 100

VERTICAL - INCHES

REFERENCE NO. 16

SKETCH NO.

PROFILOGRAPH RECORDS ILLUSTRATI[NG] DIFFERENCE BETWEEN INNER AND OUTER LANES.



COMPARISON OF DEFLECTION MEASUREMENTS AND PROFILOGRAPH RECORDS

The accompanying sketches (17 & 18) were made from records on two experimental projects. Deflection measurements under static load were made at the ends, quarter point and midpoint of the slab, by means of electric gauges, both in the morning and afternoon. Morning and afternoon profilograph records were made at the same time deflections were measured. These records for the particular weakened plane joint involved have been expanded to a scale equivalent to twice the scale used in plotting the deflections.

The curled pavement slab is clearly indicated by the morning profiles, with the ends lifted off the subgrade and the approximate center section remaining in position on the subgrade.

A very definite correlation between the amount of curling and the magnitude of the measured deflection is readily apparent in both the morning and afternoon records. In the morning, when the curling is greatest, the deflection at the end is greatest, and decreases towards the quarter point, where the amount of curling (and hence the amount of "lift" off the subgrade) is definitely less than at the ends of the slab. At the midpoint of the slab the deflection and curl are both negligible.

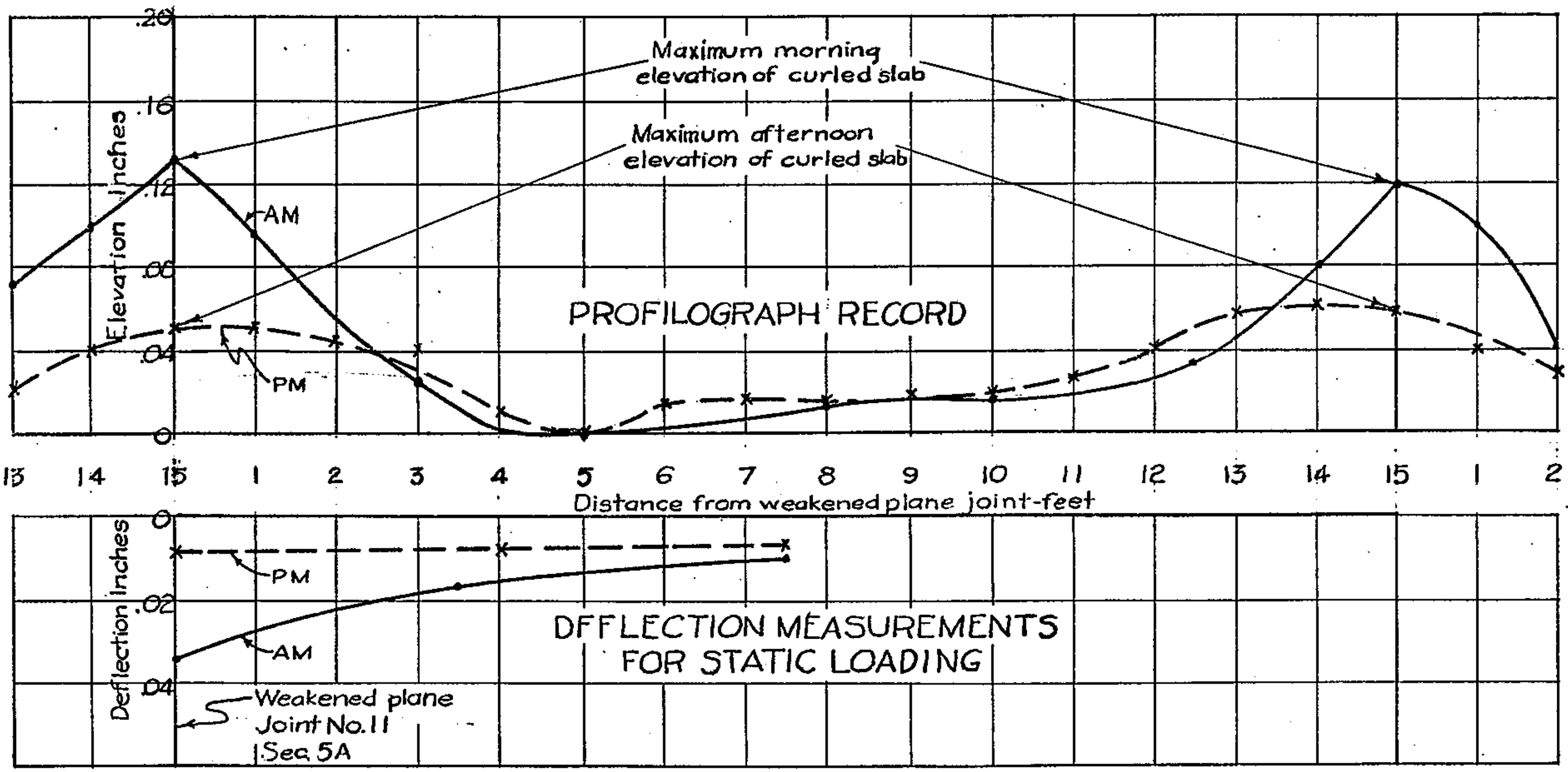
The afternoon records show only a slight amount of curl in the slab, but the deflection measurements follow the same pattern as the morning to a lesser degree. The greatest amount of deflection occurs at the end of the slab which is slightly curled. The magnitude of the deflections decreases progressively towards the mid-point of the slab.

MATERIALS & RESEARCH DEPARTMENT
RESEARCH NO. 00204

PCC JOINT INVESTIGATION
REFERENCE NO. 17

COMPARISON OF PROFILOGRAPH RECORD AND DEFLECTION OF SLAB DUE TO STATIC LOAD

VII-VEN-79-C   CONT. 27XC7-P



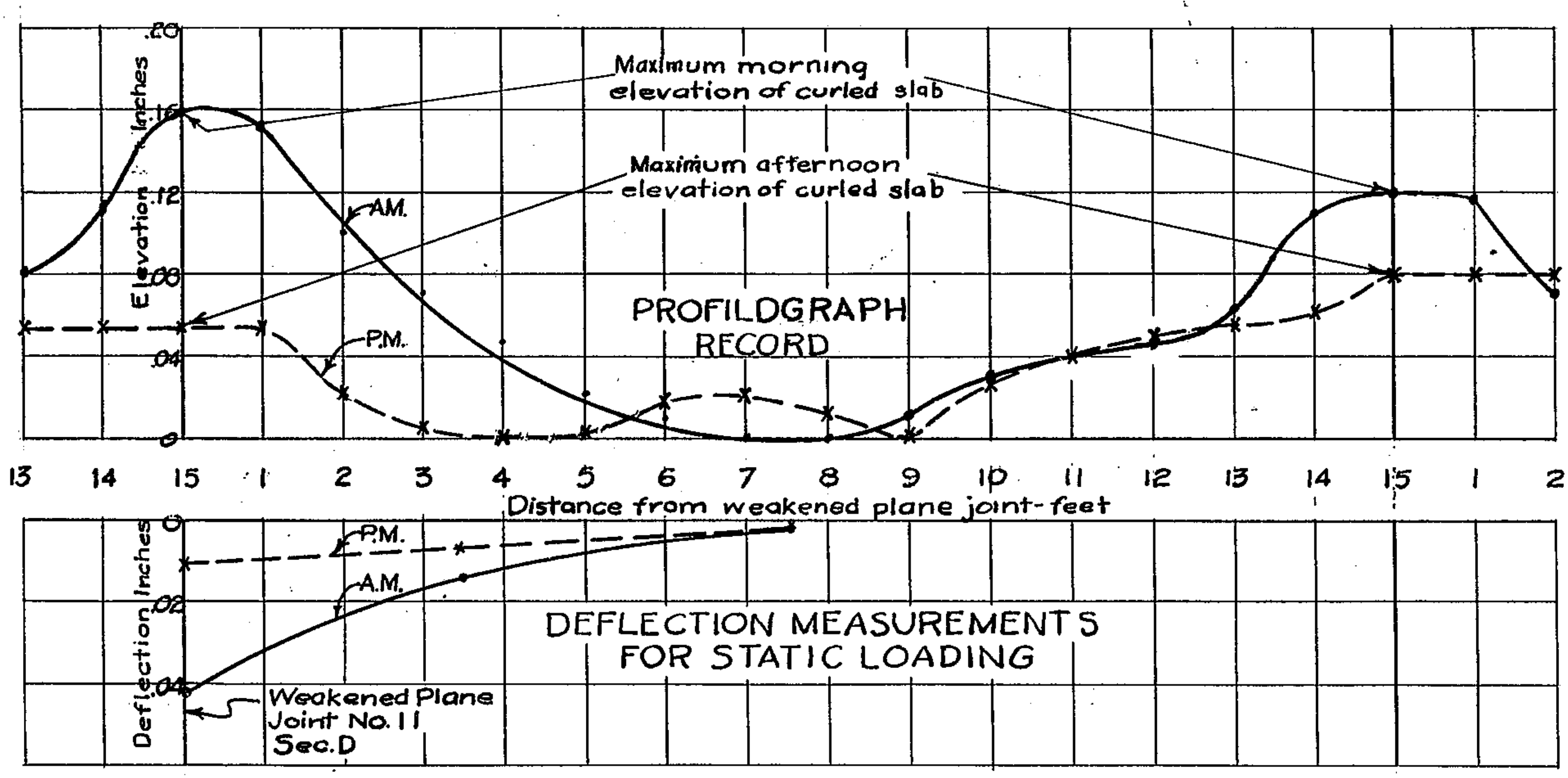
MATERIALS & RESEARCH DEPARTMENT
RESEARCH NO. 00204

PGC JOINT INVESTIGATION
REFERENCE NO. 18

COMPARISON OF PROFILOGRAPH RECORD AND DEFLECTION OF SLAB DUE TO STATIC LOAD

XI-SD-2-D

CONT. 11VC5



Measurement of extent of opening under ends of a pavement slab

The sketch which appears opposite (19) is a graphic representation of an attempt to measure the area of opening under the slabs, adjacent to a faulted weakened plane joint.

As noted, plaster of paris of quite thin consistency was introduced into core hole K-35. By means of tight fitting wooden discs, pressure was applied to this material at hole K-35, forcing it into any open space under the ends of the two slabs. After the plaster had hardened several additional cores were cut as indicated on the sketch, to check the extent of the flow of the plaster.

Results are noted for each core hole on the sketch and from these notes, the approximate extent of the opening is estimated to be as shown.

Materials & Research Dept.
Research No. 00204

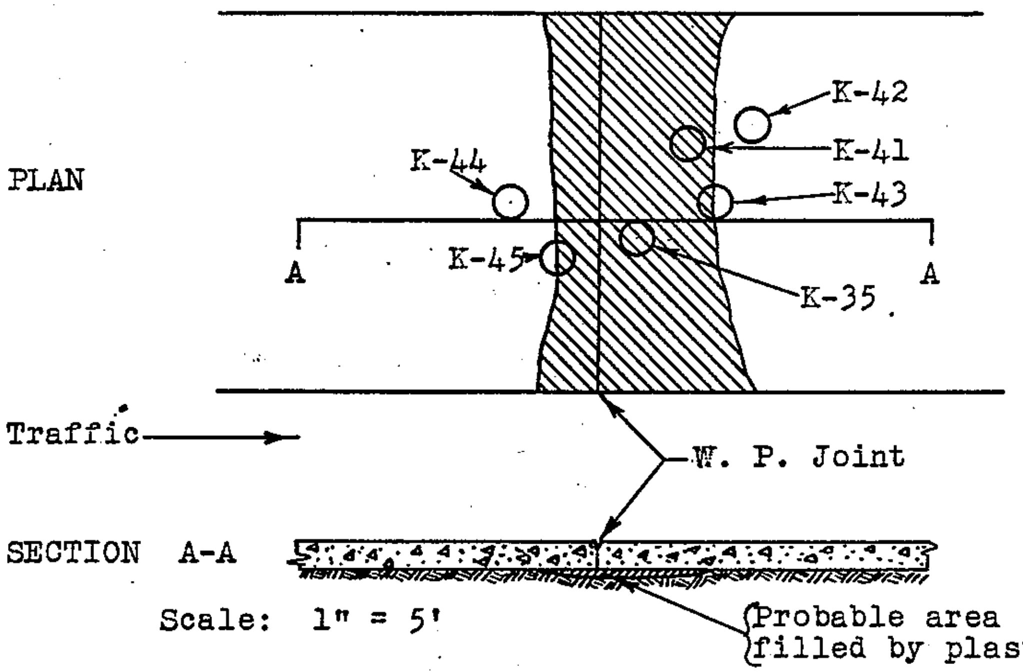
P.C.C. Joint Investigation
Reference No. 19

SKETCH SHOWING THE APPROXIMATE EXTENT OF VOID SPACE BENEATH A PAVEMENT SLAB AS INDICATED BY PLASTER OF PARIS PUMPED UNDER THE SLAB AT A CORE HOLE

Project 'K', VII-LA-26-B
North Outer Lane
Sta. 226+12

Weakened Plane Joint

Cross hatched area corresponds to space filled by plaster



Scale: 1" = 5'

Core No.	Remarks
K-35	1' from joint. 1/16" to 1/4" opening all around hole. 1/4" on side towards joint. Plaster forced under slab from here.
K-41	33" c. to c. from K-35. Plaster was from 3/16" to 5/16" thick here.
K-42	48" from joint to center of hole. No trace of plaster.
K-43	36" from joint, 28" c. to c. from K-35. Thin plaster on one side of hole and on bottom of core. Approximately 34" from joint, plaster was 1/32" to 1/16" thick.
K-44	28" east of joint. No plaster.
K-45	26" from K-35. Thin layer of plaster on 1/2 of core next to joint. Plaster extends 14" to 15" from joint.

APPENDIX D

Pavement Design, Construction Details Including Characteristics of Concrete

(1) Field Work

All coring of pavement was done with a Concore drill machine, using both calyx bits with chilled steel shot and diamond set bits. At all locations at which samples of the subgrade were to be taken, cores were 8" in diameter. Generally, several additional cores 5" in diameter were also taken. Cores were labeled for identification and forwarded to Sacramento for testing.

(2) Laboratory Work

All 5" diameter concrete cores were tested in Sacramento for determination of weight per cu. ft., modulus of elasticity, and compressive strength. The table "Test Results on Concrete Core Specimen" (28) is a summary of test data on all pavements sampled.

Certain of the 8" diameter cores were used to obtain additional 5" diameter cores for testing. These 5" diameter cores were cut from the original 8" diameter cores at the Laboratory in Sacramento.

Some of the 8" diameter cores were cut through cracked sections of pavement or at faulted joints and, of course, could be used only for observation and photographs. (20 - a, b, c, d)

From most of the remainder of the sound, 8" diameter cores, thin discs were cut, (22 - a, b, c, d) using a diamond saw. These discs varied from 3/16" to 5/16" in thickness and were used in measuring expansion caused by moisture and temperature variations.

Pictures of one of two "spiders" used in making the thermal and moisture expansion tests are included with core and disc photographs (21). One spider was made of brass and the other of invar steel. It will be noted that the two gauges are so located that readings were obtained simultaneously at two points on the circumference 90° apart.

All discs were dried in an oven maintained at 140°F. for several days prior to testing for expansion due to absorption of moisture.

In the actual test for expansion due to absorption of moisture, the disc to be tested was placed in the bronze spider, firmly seated, and the 2 Ames dials were read. The spider and disc were then placed in a water bath in which the water was at room temperature. The disc was completely immersed with the upper arms of the spider and the Ames dials being above the water level. The readings were immediately checked so as to be sure that the disc had not been disturbed.

It was discovered soon after starting the tests that the greatest expansion takes place in the first two or three hours after the concrete comes in contact with moisture (24). Accordingly readings were taken every 5 minutes for the first 30 minutes, then every 30 minutes for the first 4 hours, the every hour for the next 4 hours. After the first 7-1/2 or 8 hours, readings were taken each morning, noon and evening for a total period of 7 days.

The disc was then removed and placed in a soaking tank prior to being tested for thermal expansion.

The invar steel spider was used in measuring thermal expansion. Discs were saturated before being tested. After placing the disc in the spider, it was immersed in a controlled temperature water bath. The starting temperature in this bath was 40°F. The disc was placed in bath and allowed to come to the temperature of the bath before reading. The disc was then left at starting temperature for 4 hours and the readings again made. Temperature of the bath was then advanced to 50°F., readings were taken and temperature maintained at 50°F. for 4 hours. This process was continued, while stepping up the temperature in ten degree increments, until the disc had been held at 130°F. for four hours.

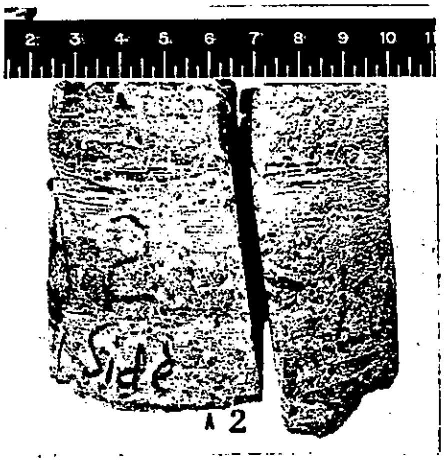
Reference No. 20 - a   Cores cut through joints

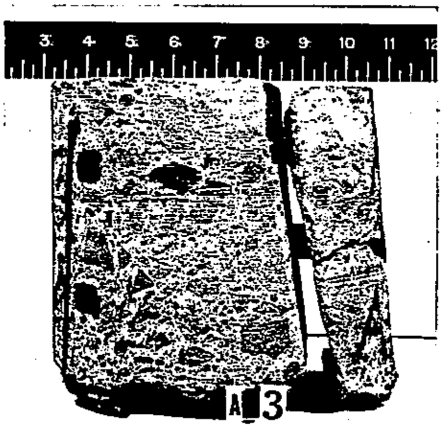
Core No.	Remarks
A-2	From X-Sol-7-B, Contract No. 410CN2, constructed in 1932. Core was cut from an expansion joint that was faulted 3/16". Joint filler was in good condition with most of the top 2" still in place. Below 2", only a thin coat of filler was left. The dowel was sheared off about 3/4" from joint in high side. Dowel was originally 3/4" but had corroded and worn down to 5/8" at sheared end. Sheared end of dowel showed evidence of vertical movement. In the high side of core, hole left by dowel has been worn into an oval shape, approximately 1-1/4" in vertical measurement. In the second photograph there is an apparent worn place on the face of the core, which is actually a place at which the filler material has eroded away completely. Mortar from mudjacking operations is adhering to the bottom of the core on the high side of the joint.
A-3	From X-Sol-7-B, Contract No. 410CN2, constructed in 1932. Core was cut from same joint as A-2 above, 5' from A-2. Top 2" of filler was in good condition; below 2" there was only a very thin coating which had many sand grains in it. This core was offset in order to avoid transverse steel, so that the joint was not in the center. A section of the dowel "chair" was encountered however. Mudjack mortar is plainly evident in all three photographs of this core. The smaller section of core broke at the dowel while the core was being removed from the slab. This section contained the dowel sleeve in which the dowel was solidly "frozen" by rust and corrosion. Originally a 3/4" dowel, pitting, wear and corrosion had reduced it to 9/16" at the sheared end. The projecting section of dowel 7/8" long shows a definite upward bending and the hole opposite to it has been worn oval shaped (with the vertical measurement being 1-1/4").

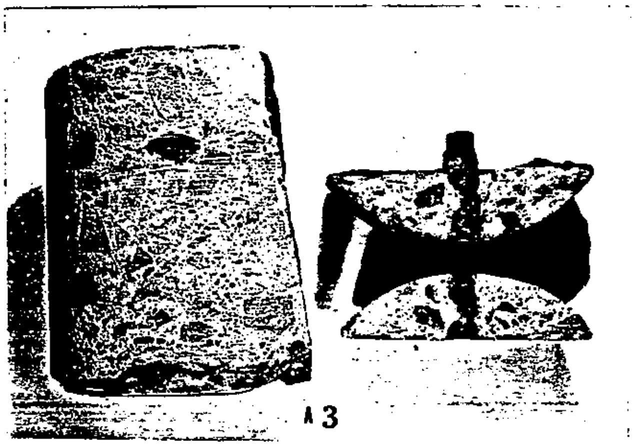
Materials & Research Dept.
Research No. 00204

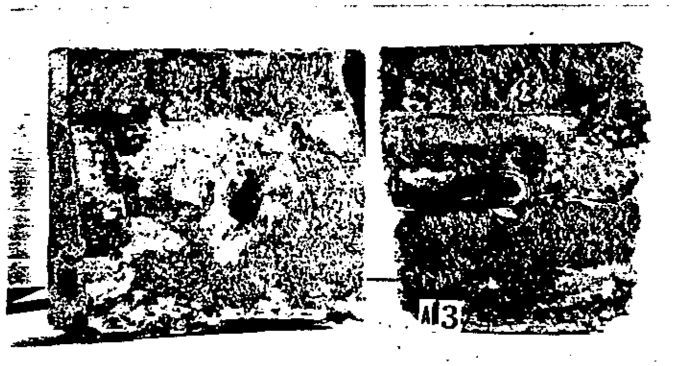
P.C.C. Joint Investigation
Reference No. 20 (a)

CONDITIONS OF DOWELS AND JOINT ALIGNMENT AS INDICATED BY CORE SPECIMENS









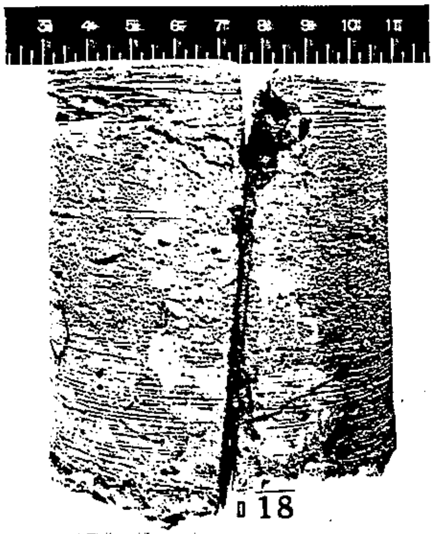
Reference No. 20 - b   Cores cut through joints

Core No.	Remarks
D-18	From IV-SM-68-A, Contract No. 44TC8, constructed in 1933. This core was cut from an expansion joint that was faulted 3/16". Pavement was constructed with gravel drain under the joints and some of this rock is evident in the first two photographs. The dowel was intact and free in the sleeve. The dowel itself was slightlv bent but showed small evidence of wear. It was remarkably free of rust, although the lower part was pitted and somewhat eroded at the joint itself. The sleeve was very rusty and the lower section was rusted completely away. The third photograph is a close-up of the sleeve and the dowel hole on the outer surface of the core. Note that the lower right hand section of the sleeve is completely gone. This is probably due to corrosion and rust, since the dowel did not bear on this section of the sleeve at the time the core was cut. Filler material was in good condition. In the first two photographs, there is some honeycomb showing in the upper section of the core. However, most of the evenly space horizontal lines which appear to be defects in the pavement are actually grooves cut in the core surface by the Calyx bit and chilled steel shot.

Materials & Research Dept.
Research No. 00204

P.C.C. Joint Investigation
Reference No. 20 (b)

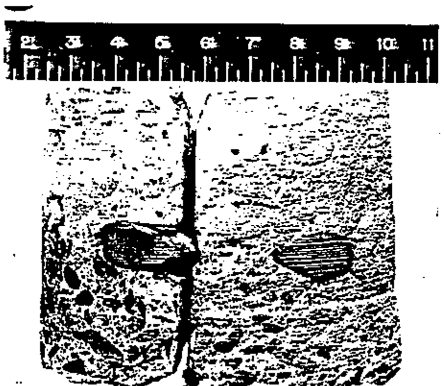
CONDITIONS OF DOWELS AND JOINT ALIGNMENT
AS INDICATED BY CORE SPECIMENS



Reference No. 20 - c Cores cut through joints

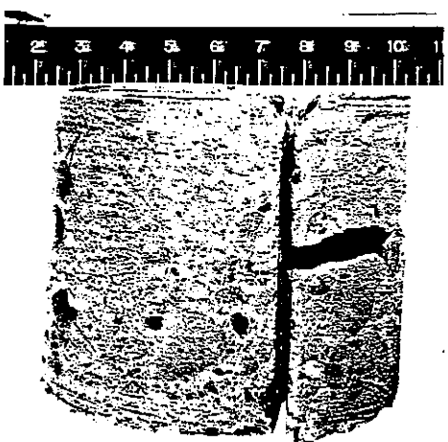
Core No.	Remarks
E-3	From IV-SC1-5-A, Contract No. 94EC3 constructed in 1928, the core was cut from an expansion joint that was faulted 1/8". The dowel was cut in the edge of the core and was intact. The sleeve was badly rusted and many small pieces had broken away and fallen down around the dowel. The dowel itself was rusted and pitted, particularly close to the joint face. Filler material was quite hard and about 1/8" thick and had been extruded about 1" into the subgrade. There was considerable sand and small gravel in the filler material.
E-4	From IV-SC1-5-A, Contract No. 94EC3 constructed in 1928, This core was cut from an expansion joint that had faulted 1/8" and was 60 ft. from joint of which E-3 was cut. There was a horizontal crack in the concrete at the dowel on the side opposite to the sleeve. The dowel was badly corroded and pitted on the lower side near the joint but the balance was in good condition. Rust stains are evident for approximately 3/4" into concrete on the side opposite to sleeve in the third photograph. The dowel is rusted into the sleeve side of core for 1/4". Filler material was in fairly good condition but contained many sand grains and small gravel particles.

CONDITIONS OF DOWELS AND JOINT ALIGNMENT
AS INDICATED BY CORE SPECIMENS

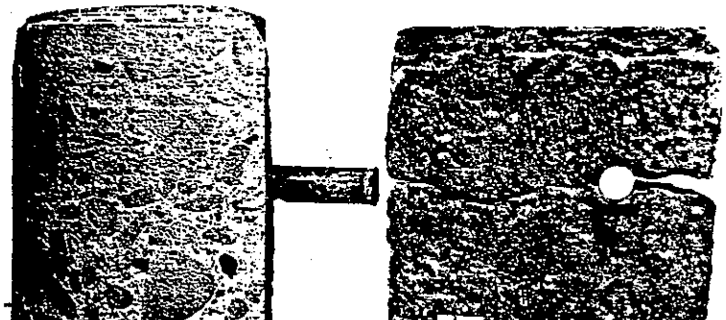


E 3

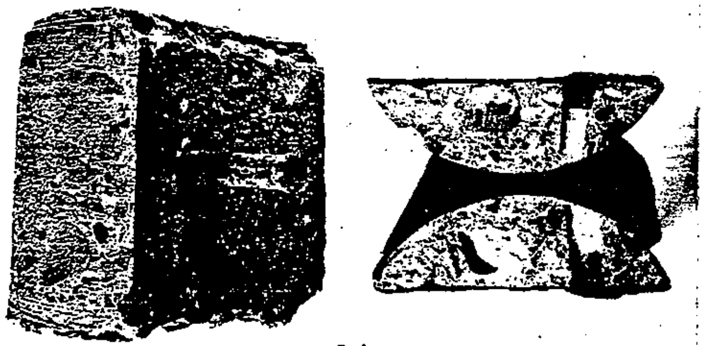
E 3



E 4



E 4



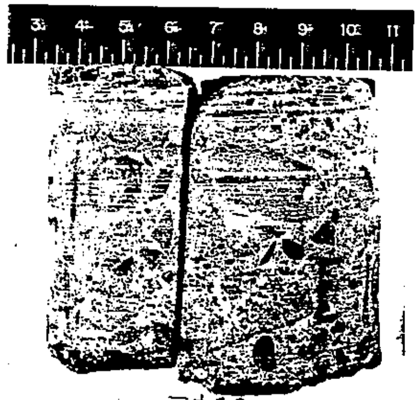
E 4

Reference No. 20 - d Cores cut through joints

Core No.	Remarks
E-10	From IV-Ala-5-C, Contract No. 94EC3, constructed 1928. Expansion joint that had faulted 3/16". The dowel was intact and loose in its sleeve which was on the high side of the joint. Both sleeve and dowel were corroded, the lower half of the sleeve being entirely gone. At time core was taken, the dowel was tight against the residue from the sleeve, in the bottom of the hole, with a space of 1/8" above the dowel. Hole in concrete formed by sleeve and dowel had become oval shaped, as shown in the second photograph and some evidence of movement of the dowel was noted. Pitting and corrosion were worst on lower side of dowel and sleeve, and extended into the concrete for 3/8". There was very little filler material left in the joint. Considerable foreign material was found in the filler material that remained, as indicated by the large sand grains visible in the third photograph.
G-25	From V-SB-2-L, Contract No. 45CS2, constructed 1932. Expansion joint that had practically no faulting. The dowel is intact and solid in the sleeve. Severe hammering produced no movement of the dowel. This joint is in excellent condition. Filler material tight in place.

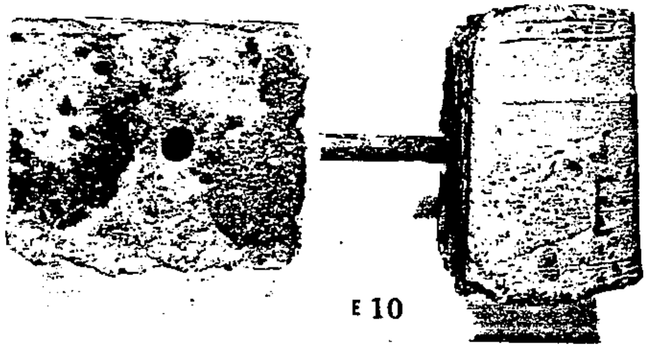
Materials & Research Dept. P.C.C. Joint Investigation
Research No. 00204 Reference No. 20 (d)

CONDITIONS OF DOWELS AND JOINT ALIGNMENT
AS INDICATED BY CORE SPECIMENS



E 10

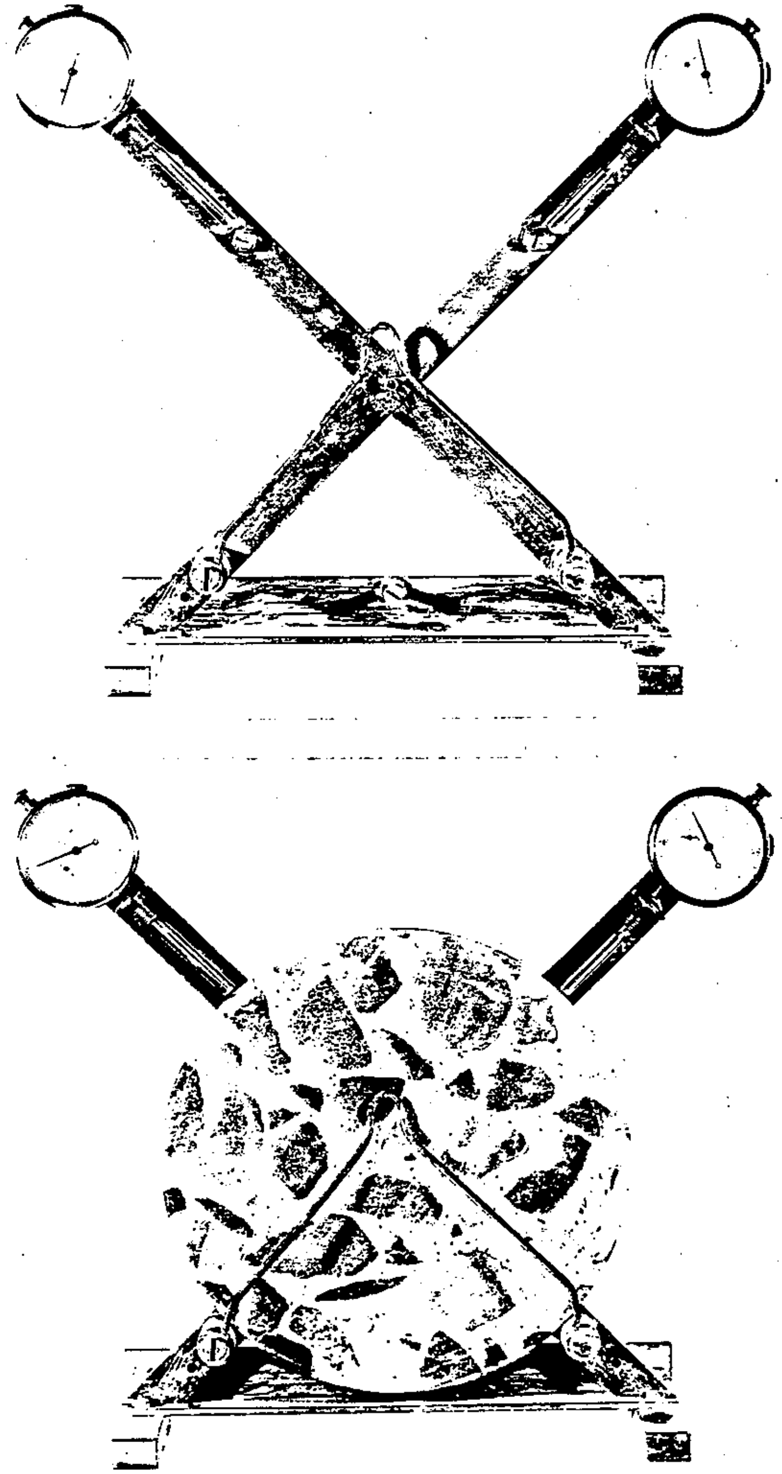
E 10



E 10

G 25

"SPIDER" USED IN MEASURING THERMAL
AND MOISTURE EXPANSION OF CONCRETE



Core No. C-13 From X-SJ-4-C

Contract No. 256-Completed 1919

Coarse aggregate from Fair Oaks, fine aggregate was Marysville muck sand. Proportioned: 55% coarse, 45% fine. Note the apparent absence of any pea gravel. Pavement was poured without joints, except at end of morning and afternoon runs. Occasional cracking was noted, but no faulting. Pavement was in good condition, although rough due to hand finishing. Still carrying traffic in 1944.

Core No. R-2 From V-SP-2-D

Contract No. 279-Completed 1922.

Coarse aggregates from Gates, Sisquoc and Dougherty, San Luis Obispo. Fine aggregates from Gates, Sisquoc. Pavement in fair condition. Placed with joints only at end of morning and afternoon runs. Fairly heavy cracking with faulted construction joints.

Core No. F-2 From V-Mon-2-A

Contract No. 95EC2-Completed 1928.

Coarse and fine aggregates from Granite Rock, Logan. Pavement in this area has much crazed cracking but no faulting Concrete shows definite "growth" due to reactive aggregates. All joints are tight and well sealed. Pavement is in good condition and has carried a heavy traffic load. Classified in Joint Faulting Group No. 4.

Core No. C-4 From X-SJ-4-C

Contract No. 010TC3 - Completed 1938.

Coarse and fine aggregates from Kaiser, Radum. Pavement is cracked in many places and joints are faulted. Pavement is breaking up and quite rough. Classified in Joint Faulting Group No. 4.

Core No. A-1 From X-Sol-7-B

Contract 410CN2 - Completed September 1932.

Coarse aggregate from Thomasson-Cordelia quarry. Fine aggregate from Basalt Rock, Healdsburg. Pavement in this area shows definite mud pumping and joints are slightly faulted (3/16"+). Pavement has been mudjacked. Some cracking observed. Pavement classified in Faulting Group No. 4.

Core No. F-9 From V-Mon-2-A

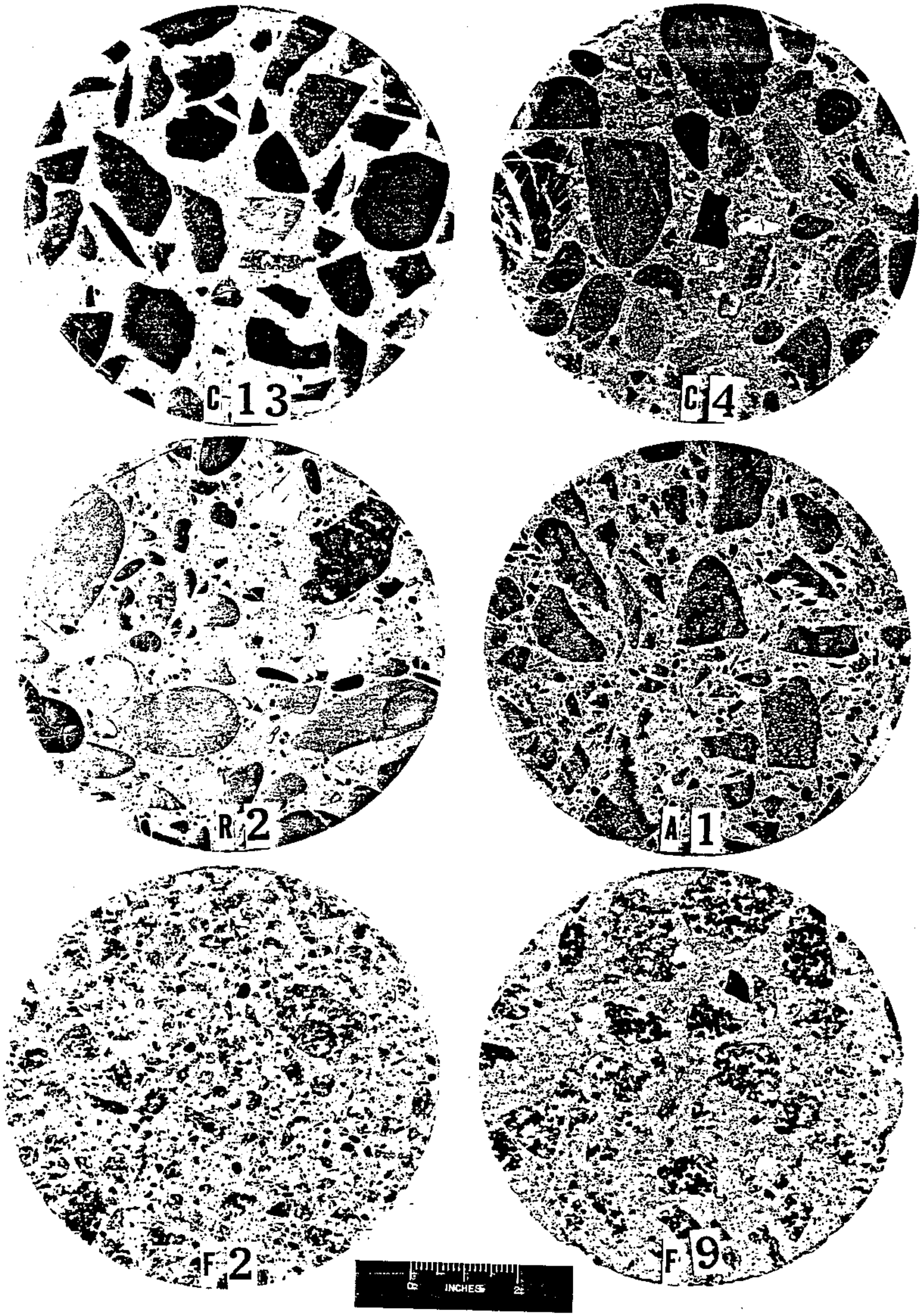
Contract No. 45TC2-Completed 1943.

Coarse aggregate from Granite Rock, Logan. Fine aggregate from Kaiser, Olympia. Pavement less than two years old when sampled, with no cracking or faulting. Pavement placed to convert 1928 pavement to 4 lane divided highway. Classified in Joint Faulting Group No. 4.

Materials & Research Dept.
Research No. 00204

P.C.C. Joint Investigation
Reference No. 22 (a)

CROSS SECTIONS OF CONCRETE CORES



Core No. M-8 From VII-Ora-2-C

Contract No. 370(M20)
Completed September 1922.

Coarse and fine aggregates from Yaeger Rock and Sand and Orange Co. Sand and Gravel. Second story pavement over 1914 base, placed with no joints. Pavement shows heavy frequent cracking but no faulting.

Core No. B-6 From IV-Mrn-1-A

Contract No. 94EC7-Completed April, 1942.

Coarse and fine aggregates from Grant Rock, Healdsburg. Second story pavement over 1915 pavement. No cracking or faulting in slab from which this core was cut.
Pavement classified in Faulting Group No. 5

Core No. S-13 From VII-Ora-184-A

Built by Orange County in 1928-29.

Coarse and fine aggregates from Olive. Pavement was considered quite good at time it was constructed, but curled during the first winter after construction. Now has heavy permanent curl but otherwise is in good condition. Some joint faulting.
Classified in Joint Faulting Group No. 4.

Core No. V-1 From VII-LA-Alameda St.

Built by L.A.Co. in 1923. Source of materials not known. Pavement was placed over D.G. subgrade that had been oiled & maintained under traffic for a year previous to paving. There are no weakened plane joints & expansion joints are not regularly spaced. Very moderate joint faulting, and a few cracks noted. Has carried the heaviest traffic load of any pavement investigated. In excellent condition. Classified in Joint Faulting Group No. 2.

Core No. N-20 From VII-Ora-60-Lga. Bch.

Contract No. 47VC24
Completed June, 1935.

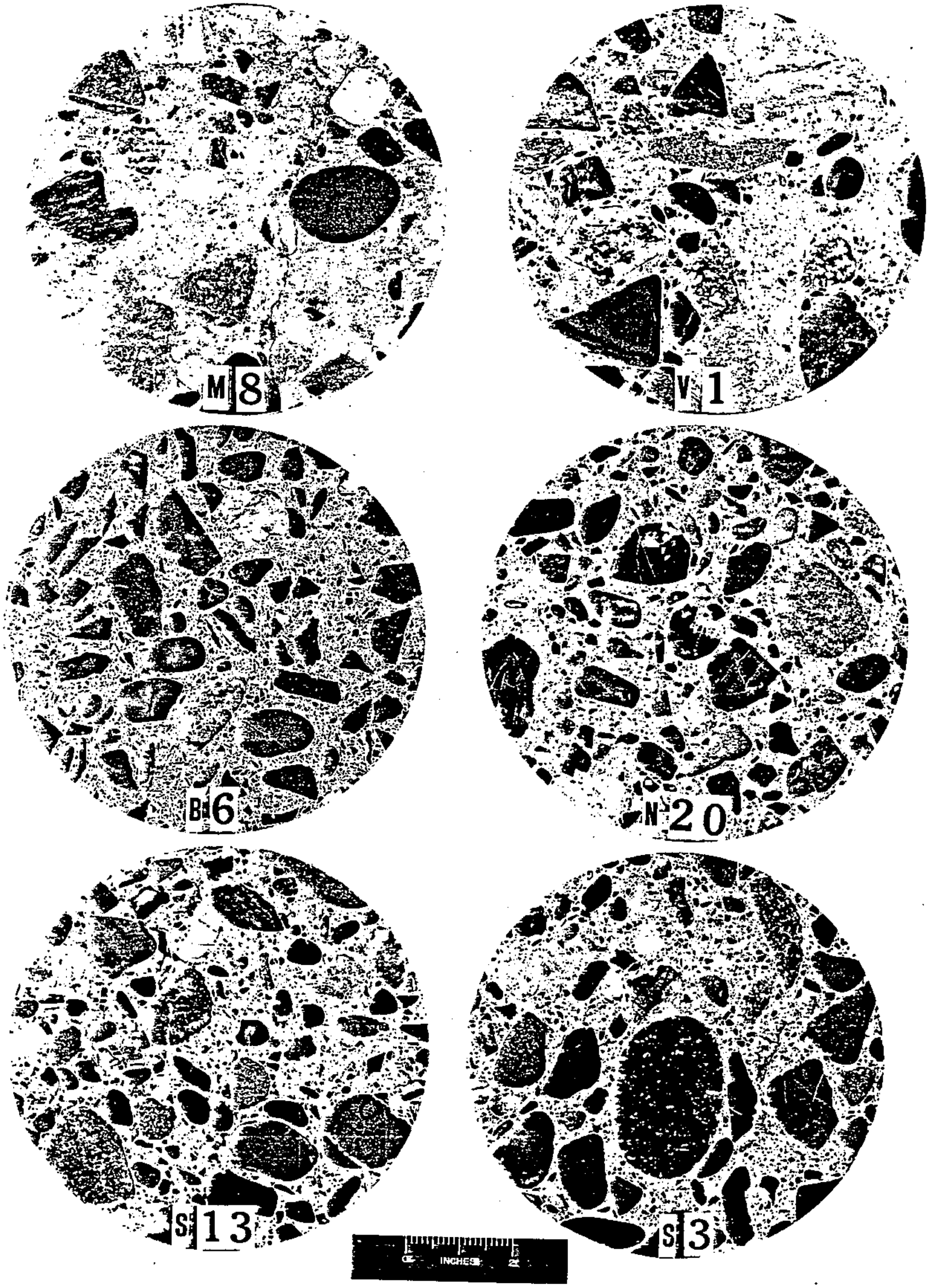
Coarse and fine aggregate from So. Coast Rock Co., San Juan Capistrano. Pavement is in good condition but shows slight faulting at the joints. Classified in Joint Faulting Group No. 4.

Core No. S-3 From VII-Ora-171-A

Contract No. 07XC3-Completed November 1937.

Coarse and fine aggregates from Graham, Orange Co. & Consolidated, Orange Co. This pavement was considered the smoothest laid in California in 1937. Area was flooded during winter of 1937-38 and pavement curled soon after. Now has very severe permanent curl. (6,10) Pavement in good condition otherwise with very little faulting. Classified in Joint Faulting Group No. 2.

CROSS SECTIONS OF CONCRETE CORES



Core No. M-9 From VII-Ora-2-C

Contract No. 370(M20)
Completed September 1922.

Coarse and fine aggregates from Yaeger Rock & Sand, and Orange Co. Sand & Gravel. Second story pavement over 1914 base, placed with no joints. Pavement shows heavy, frequent cracking but no faulting.

Core No. B-4 From IV-Mrn-1-A

Contract No. 94EC7
Completed April, 1929.

Coarse and fine aggregates from Grant Rock, Healdsburg. Second story pavement over 1915 pavement. No cracking or faulting in slab from which core was cut. Pavement classified in Faulting Group No. 5.

Core No. R-11 From V-SB-2-E

Contract No. 25FC5
Completed July, 1931.

Coarse aggregate from Honda, fine aggregate from Saticoy Rock Co. Pavement in very poor condition, with heavy cracking and joint faulting. Classified in Joint Faulting Group No. 7.

Core No. C-8 From X-SJ-4-D

Contract No. 210EC3
Completed 1930.

Coarse and fine aggregates from Atlas Rock, Oakdale. Core cut from widening strip which was placed along 1919 pavement. There are no joints in this widening strip but it is badly cracked and quite rough.

Core No. B-3 From IV-Mrn-1-A

Contract No. 94EC7
Completed April, 1929.

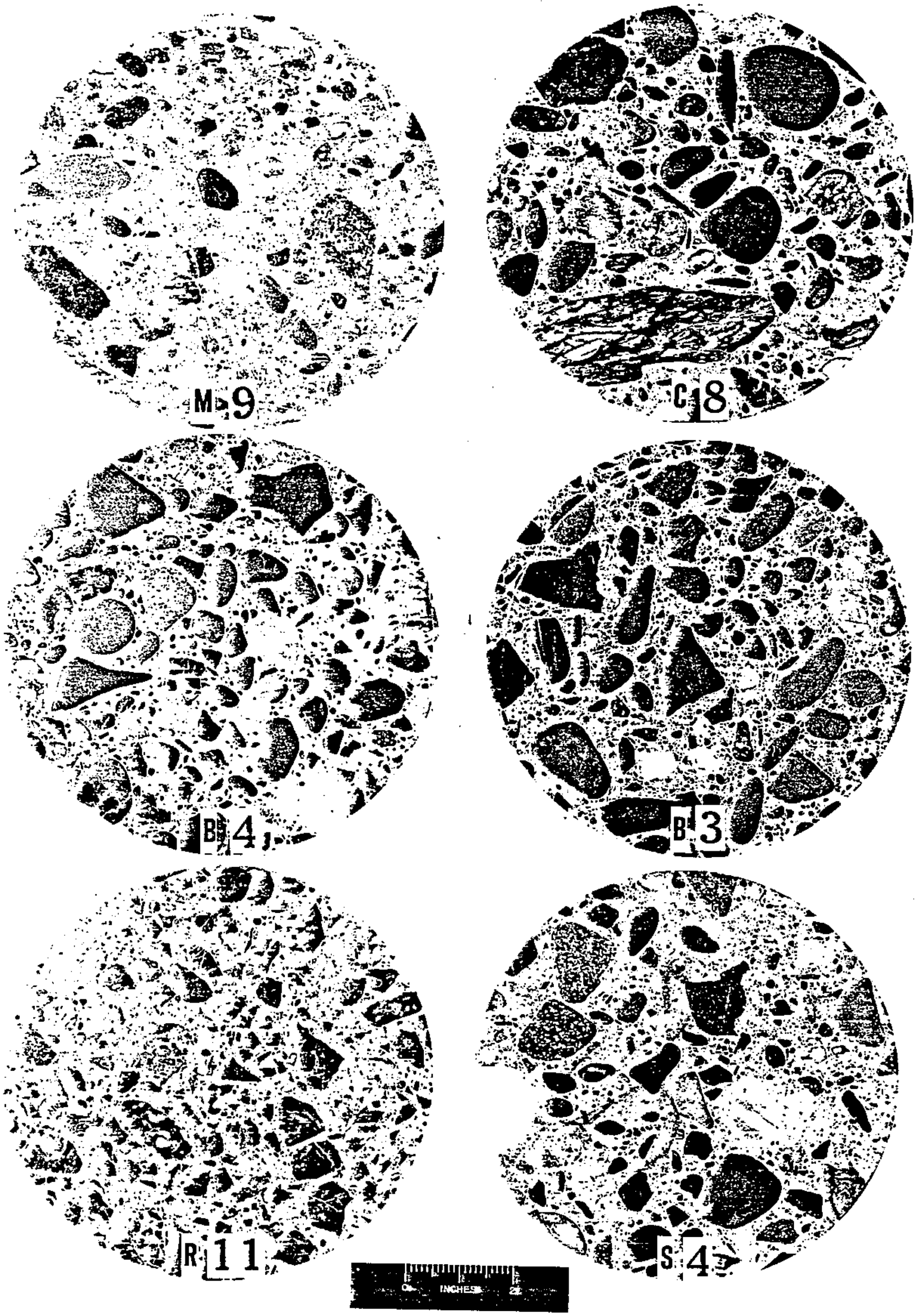
Coarse and fine aggregates from Grant Rock, Healdsburg. Second story pavement over 1915 pavement. No cracking or faulting in the slab from which this core was cut. Pavement in this area classified in Faulting Group No. 4.

Core No. S-4 From VII-Ora-171-A

Contract No. 07XC3
Completed November, 1937.

Coarse and fine aggregates from Graham, Orange Co. & Consolidated, Orange Co. Pavement was considered the smoothest laid in State in 1937. Area was flooded during winter of 1937-38 and pavement curled soon after. Now has very severe permanent curl (6,10). Pavement in good condition otherwise with very little joint faulting. Classified in Joint Faulting Group No. 2.

CROSS SECTIONS OF CONCRETE CORES



Core No. G-11 From V-SB-2-L

Contract No. 45CS1
Completed July, 1932.

Coarse and fine aggregates from Gates, Sisquoc. Pavement is cracked and there is considerable joint faulting.
Pavement classified in Joint Faulting Group No. 6.

Core No. K-11 From VII-LA-26-B

Contract No. 47XC3
Completed April, 1933.

Coarse and fine aggregates from San Gabriel Wash, 25% Graham Bros., 25% Blue Diamond, 50% Consolidated, Irwindale. Pavement shows very little cracking but joints are faulted. There is noticeable movement at the joints under traffic action.
Classified in Joint Faulting Group No. 6.

Core No. P-2 From XI-Riv-26-G

Contract No. 48CS2
Completed January, 1933.

Coarse and fine aggregates from local pits 600 ft. right of center line. Pavement is in fair condition. There is slight joint faulting and occasional cracking.
Classified in Joint Faulting Group No. 6.

Core No. O-5 From XI-SD-12-G

Contract 47CS4
Completed October, 1932.

Coarse and fine aggregates from Imperial Rock Co., Rainey Pit, local. Pavement is in good condition, although there is some cracking. No joints are faulted.
Classified in Joint Faulting Group No. 2.

Core No. O-8 From XI-SD-12-F

Contract No. 27VC11
Completed July, 1931.

Coarse and fine aggregates from Fenton Materials, Otay Plant. Pavement is in good condition, with no cracking. There is an occasional weakened plant joint that has faulted.
Classified in Joint Faulting Group No. 4.

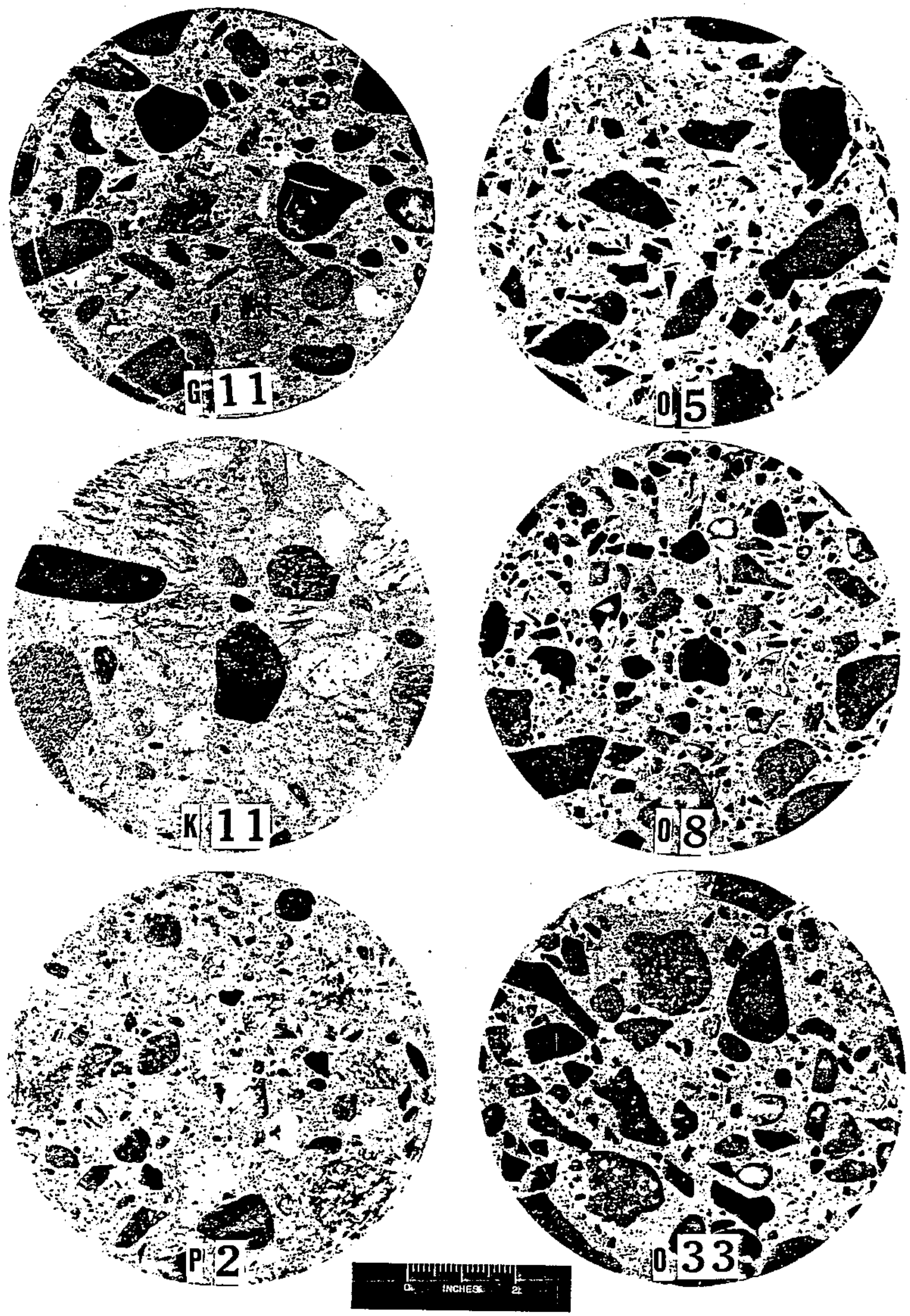
Core No. O-33 From XI-SD-12-D

Contract No. 47CS10
Completed August, 1933.

Coarse aggregate from Lakeside, San Diego River. Fine aggregate from Fenton Materials, Otay Plant. Pavement is in good condition, with no cracking. There is some slight joint faulting.
Classified in Joint Faulting Group No. 5.

Materials & Research Dept. P.C.C. Joint Investigation
Research No. 00204 Reference No. 22 (d)

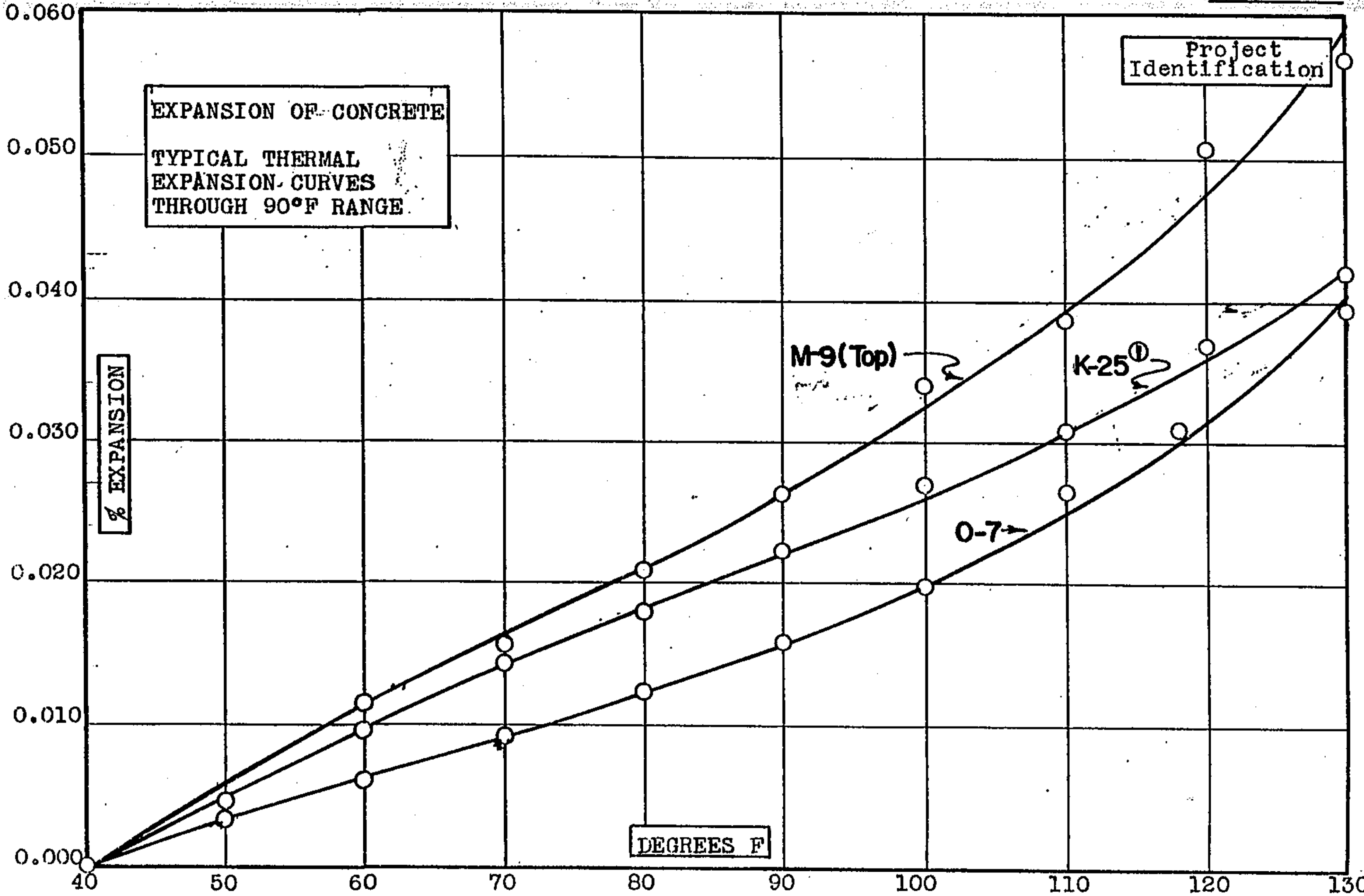
CROSS SECTIONS OF CONCRETE CORES



Reference Nos. 23, 24, and 25 are graphic representations of some of the thermal and moisture expansion test results obtained. Note that in Reference 25 with the exception of a very few cases, the expansion due to temperature and that due to moisture are approximately equal. This fact would seem to substantiate the observed conditions of "curled" pavement, namely that the greatest curl occurs in the early morning when expansion due to moisture (lower part of slab) is greatest and expansion due to temperature (upper surface) is least. Conversely, the pavement becomes smoothest in mid-afternoon when the expansion of the upper surface due to temperature is approximately equal to the expansion of the under side due to moisture - the pavement tends to return to the "normal" contour with surfaces again straight.

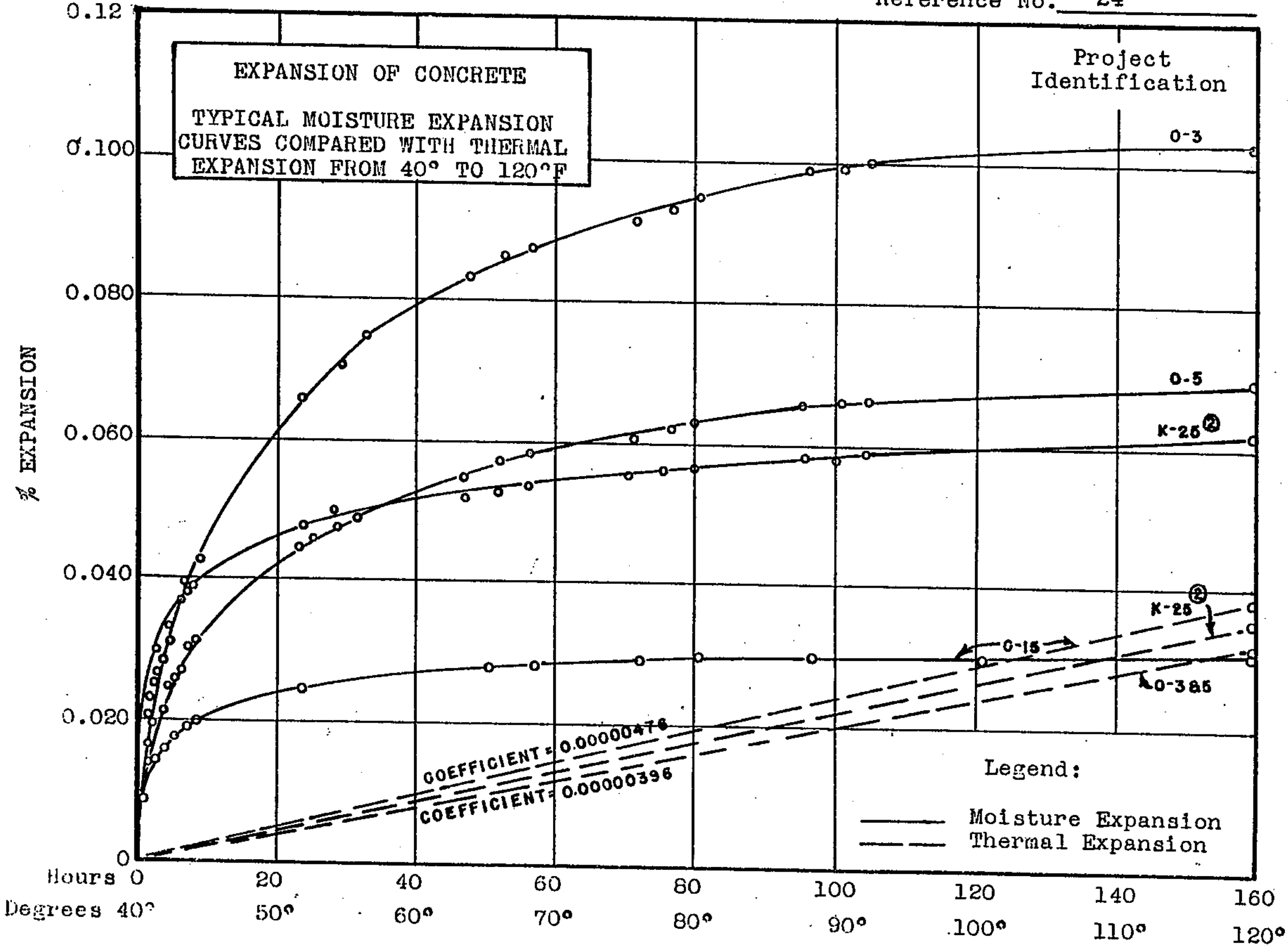
Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 23



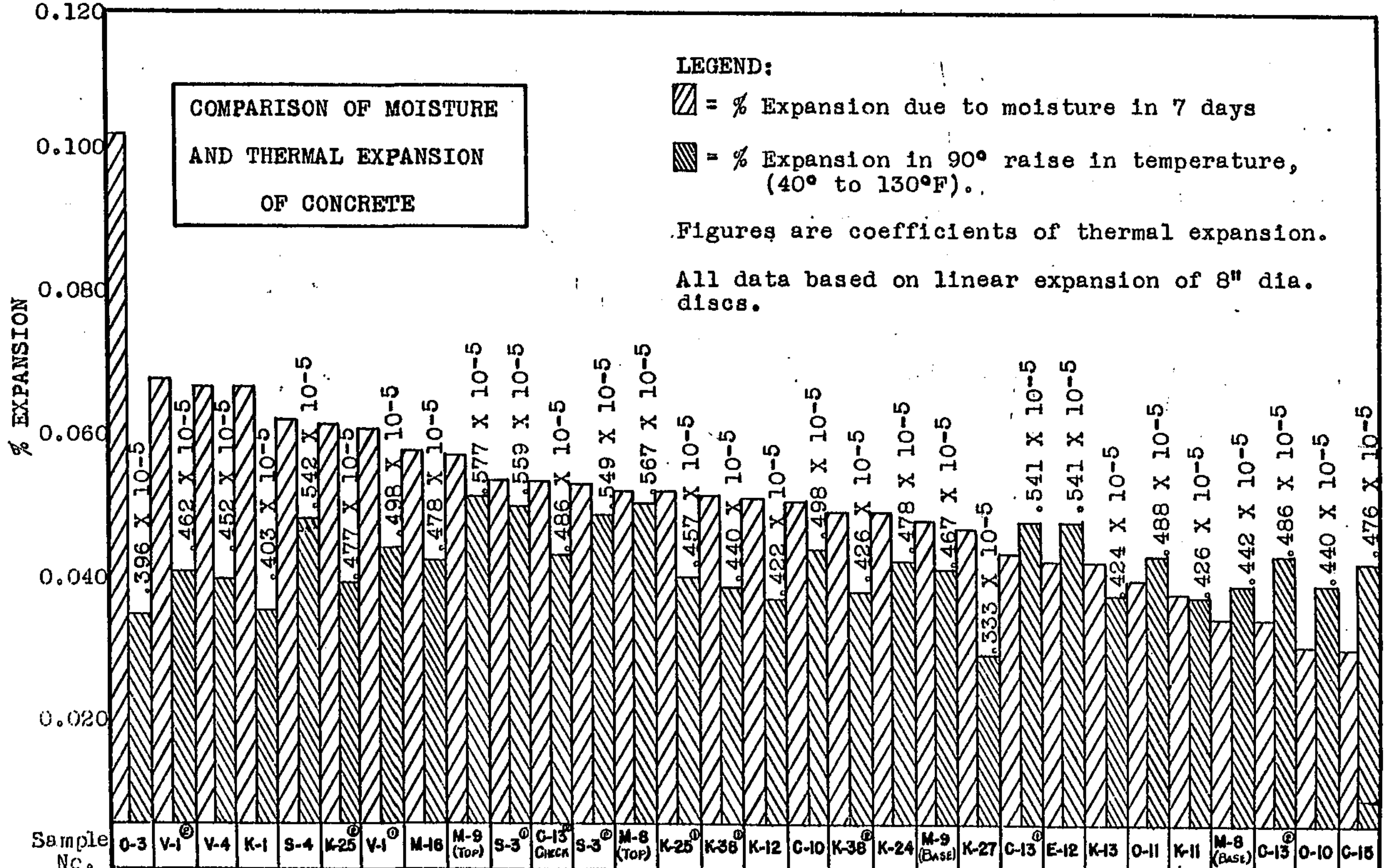
Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 24



Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 25



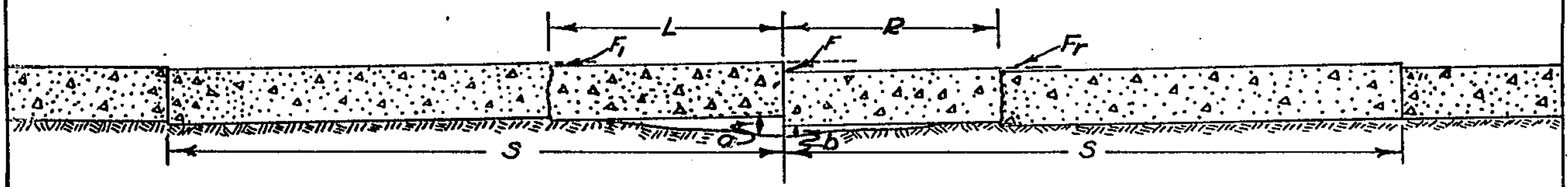
PAVEMENT DETAILS

The accompanying tabulation (26) was made in order to compare design details, traffic loads carried, present (at time of sampling) condition of the pavement and certain standard soil data.

Attention is directed to the lack of correlation between the amount of faulting in each group, the traffic loads carried and the soil test data.

As illustrated on the first page of this tabulation the letters used in the various column headings refer to the same measurements as those used in Reference No. 1. The "Type of Faulting" column refers to the various types which are detailed in Reference 1.

Pavement Details



Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Pavement Condition When Sampled: Faulting, Inches: Fl	F	Fr	Space Under Slabs: a	b	Distance to nearest crack: L	R	Soil Data: HRB class	% Pass 200 Sieve	PI
Faulting Group No. 1 (0.00 to 1.00"/Mile)																
F-22,23	-	Exp	20'	9		11,385,000	-	0.0	-	-	-	-	-	A-2-4	13	NP
N-21, 22,26	-	Exp	60'	5		1,937,000	-	0.0	-	Free Moisture Under Slab 0	0	-	-	A-2-6 A-2-4	19 24	17 8
T-5,6,7 (End Story)	-	Exp	20'	9		10,935,000	-	(0.02) 0.0	-	-	-	-	-	A-2-4	17	8
K-7,8,9	2c	Exp	20'	9	Intact	3,112,000	0.0	(0.03) 0.0	0.10	Very Slight Water Seepage Under Slab		11'	12'	A-1-a	13	4
B-7	-	Exp	20'	9		4,991,000	-	(0.04) 0.0	-	-	-	-	-	A-1-b	21	0
O-9,10,11	-	Exp	20'	5		1,365,000	-	(0.04) 0.0	-	-	-	-	-	A-2-4	27	NP
S-7,8,9,10	-	Exp	20'	9		649,000	-	(0.03) 0.0	-	0	Thin opening under slab	-	-	A-4	Range 43-57	3
Faulting Group No. 2 (1.00 to 2.00"/mile)																
O-4,5,6	2c	WP	30'	5		1,482,000	0.0	(0.04) 0.0	0.0	-	-	10'	13'	A-1-b	11	NP
S-1,2,3,4 5,6,11,12	2a	Exp	20'	9	Intact	649,000	-	(0.03) 0.0	-	Thin opening under Slab				A-4 A-6	Range 40-53	Range 8-16
B-1,2	2a	Exp	20'	9		6,090,000	-	(0.05) 0.0	-	-	-	Crazed Cracking		A-2-4	19	9
D-1,2,3,4	2b	Exp	20'	9		1,776,000	-	(0.10) 0.0	-	-	-	5'	-	A-1-b	16	2
H-9,10	2a	Exp	20'	9		10,410,000	-	(0.03) 0.0	-	-	-	-	-	A-2-4	33	1
V-1,2,3	2c	(60' from cores) Exp	200' [illegible]	0		44,072,500	0.06	(0.10) 0.10	0.05	-	-	45'	27'	A-2-6	19	13

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No.	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Pavement Condition When Sampled: Faulting, Inches F_l	F	F_r	Space Under Slabs: a	b	Distance to nearest Crack: L	R	HRB Class	200 Sieve	PI
V-4,5,6	2c	Exp	200'# 225	0		101,804,500	0.05	(0.10) 0.10	0.04	-	-	66	36	A-2-4	16	9
Faulting Group No. 3 (2.00 to 4.00"/mile)																
X-1,2,3	2c		200'+			No Data	0.0	(0.12) 0.10	0.0	-	-	44'	42'	A-6	50	18
O-1,2,3	2a	WP	30'	5		1,482,000	-	(0.04) 0.04	-	-	-	-	-	A-1-b	14	3
T-10,11	2c	Exp	60'	5		13,500,000	0.10	(0.04) 0.05	0.0	-	-	12'	14'	A-2-4	25	NP
C-5,10	2a	Exp	20'	9		3,962,000	-	(0.08) 0.04	-	-	-	Long. Edge	-	A-2-6	30	12
H-6,7,8	1	Exp	20'	9		13,185,000	-	(0.05) 0.04	0.0	-	-	-	9'	A-2-4	34	2
B-11,12	1 & 2b	Exp	20'	9		6,090,000	0.0	(0.08) 0.0	0.0	Slight Water seepage Under Slab		10'	7'	A-2-6	20	13
S-16,17,18	2a	Exp	20'	4		2,625,000	-	(0.05) 0.0	-	Slight opening Under Slab		-	-	A-2-5	13	9
O-15,16,17,18,21,23	Exp. Fltd. Exp.	Exp	20'	5	Bent Broken	1,378,000	-	(0.04) 0.09	-	-	0.25"	-	-	A-2-4	Range 26-32	NP
Faulting Group No. 4 (4.00 to 8.00"/mile)																
F-13	2a	WP	20'	5		8,073,000	-	(0.06) 0.06	-	-	-	-	-	A-4	49	5
S-13,14,15	2a	WP	20'	4		2,625,000	-	(0.04) 0.00	-	Thin opening Under Slabs		-	-	Range A-2-6 to A-6	Range 19-49	Range 17-23
W-1,2,3	2a	WP	25'	0		No Data	-	(0.04) 0.00	-	-	-	-	-	A-6	51	16
O-7,8	2a	WP	20'	5		1,150,500	-	(0.06) 0.00	-	-	-	-	-	A-1-b A-2-4	21 17	NP NP
R-4,5,6	2c	Exp	20'	9	Intact	2,432,000	0.0	(0.04) 0.02	-	-	-	11.5'	9.0'	A-1-a	12	4
H-1,2,3	1	Exp	20'	9		13,185,000	0.07	(0.04) 0.06	-	-	-	11	-	A-2-4	25	2
A-13,14	2a	Exp	20'	5	Broken	7,504,000	-	(0.05) 0.00	-	-	-	-	-	A-2-4	28	NP
N-19,20	2a	Exp	60'	5		1,937,000	-	(0.03) 0.12	-	0	-	-	-	A-2-4	28	8

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels No.	Dowels Condition	Traffic in 5000 Lbs. EWLs	Faulting, Inches: Fl	F	Fr	Space Under Slabs: a	b	Distance to nearest crack: L	R	Soil Data: HRB Class	% Pass 200 Sieve	PI
P-7,8		WP	20'	5		4,913,000	-	(0.08) 0.00	0.02	-	-	-	14.0'	A-1-b	10	NP
0-12,13, 14	2a	Exp	20'	5		1,365,000	-	(0.05) 0.00	-	-	-	-	-	A-2-4	22	NP
K-19,20, 21	1	Exp	20'	9		9,420,000	0.0	(0.04) 0.00	-	0.0	0.0	10.0'	-	A-1-b	17	NP
F-8,9	2a	Exp	7½' 15'	0		630,500	-	(0.14) 0.00	-	-	-	-	-	A-1-b	17	5
K-3,4	2a	Exp	25'	0		13,507,500	-	(0.05) 0.08	-	-	-	-	-	A-2-4	26	NP
K-8,9, 10	2a	Exp	20'	9	Intact	11,385,000	-	(0.04) 0.03	-	-	-	-	-	A-1-b	13	NP
N-1	2a	Exp	20'	5		2,717,000	-	(0.04) 0.02	-	*Slight Water Seepage*		-	-	A-7-6	57	32
R-10	2c	WP	20'	9		3,112,000	0.05	(0.04) 0.00	0.06	-	-	12.0'	13.0'	A-1-b	10	4
C-1,2, 3,11	1 & 2b	Exp	20'	9	Intact	3,962,000	0	(0.04) 0.13	0	-	-	10.5'	7.0'	A-6	60	12
I-4,5	2a	Exp	20'	5		5,474,000	-	(0.08) 0.00	-	-	-	-	-	A-6	46	12
A-1,2, 3,4	2b	Exp	20'	5	*Broken-Evidence of wear on face*	7,504,000	-	(0.05) 0.00	-	*¼" Mudjack mortar on bottom of core*		-	6.5'	A-6	Range 50-71	Range 9-12
C-4	2c	Exp	20'	9		3,962,000	0.25	(0.06) 0.05	0	-	-	2.5	2.0'	A-6	52	12
B-3	1	WP	20'	Exp 5		7,525,000	-	(0.05) 0.06	0.0	-	-	-	12.0'	A-2-4	25	9
0-29,30, 31	2a	Exp	20'	5		1,436,500	-	([illegible]) 0.04	-	-	-	-	-	A-2-4	22	NP
F-1,2, 5,6	2a	Exp	20'	5	Intact	8,073,000	-	(0.05) 0.00	-	-	-	-	-	A-2-4	41	4
Faulting Group No. 5 (8.00 to 16.00"/mile)																
K-1,2	2a	Exp	50'	0		17,317,500	-	(0.09) 0.07	-	-	-	-	-	A-1-b	15	6
0-22,28	2a	Exp	20'	5		1,475,500	-	(0.05) 0.05	-	-	-	-	-	A-2-4	32	6
[illegible]	[illegible]	WP	20'	[illegible]		[illegible],475,500	-	(0.06) 0.02	-	-	-	-	-	A-2-4	25	NP

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No.	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Pavement Condition When Sampled: Faulting, Inches: Fl	F	Fr	Space Under Slabs: a	b	Distance to nearest crack: L	R	Soil Data: HRB Class	% Pass 200 Sieve	PI
0-39,40	2a	WP	20'	5		2,762,500	-	(0.07) 0.08	-	-	-	-	12'	A-4	40	NP
B-8	2a	WP	20'	Exp 5		6,405,000	-	(0.06) 0.06	-	-	-	-	-	A-2-4	31	9
0-36, 37,38 (Exp Story)	2a	Exp	20'	5		2,658,500	-	(0.05) 0.09	-	-	-	-	-	A-1-b	17	NP
B-4	1	WP	20'	Exp 5		10,584,000	-	(0.06) 0.06	-	-	-	-	-	A-2-6	21	11
F-10, 11,12	2a	WP	20'	5		8,073,000	-	(0.07) 0.07	-	-	-	-	-	A-4	50	5
0-32,33	2a	WP	20'	5		1,436,500	-	(0.08) 0.04	-	Slight Water Seepage Under Slab		-	-	A-6	49	13
N-2	2a	Exp	20'	5		604,500	-	(0.07) 0.00	-	-	-	-	-	A-7-6	60	32
P-3,4 15,18 (Sand Cushion)	2c	WP	20'	5		5,950,000	0.0	(0.06) 0.08	0.0	-	-	6'	9'	A-4	47	NP
B-6	2a	Exp	20'	Exp 5		8,960,000	0	(0.07) 0.07	0	-	-	-	-	A-2-4	29	10
D-5,6	2b	WP	40'	Exp 5		9,264,000	-	(0.11) 0.20	0	-	-	-	5.5'	A-1-a	6	2
M-1,2 (Trees along edge of road)	2c	Exp	20'	5		8,204,000	0.0	(0.07) 0.00	0.0	-	-	15'	7'	A-6	61	11
M-17	2c	Exp	20'	5		8,204,000	0.0	(0.07) 0.00	0.0	0	0	15'	7'	A-6	76	13
M-3	2c	WP	20'	5		8,204,000	0.03	(0.07) 0.10	0.0	-	-	7'	6'	A-6	61	11
M-18	2c	WP	20'	5		8,204,000	0.03	(0.07) 0.10	0.0	1/32	1/32	7'	6'	A-6	63	25
19,20	2c	WP	20'	5		8,204,000	0.03	(0.07) 0.10	0.0	1/32	1/32	7'	6'	A-6	55	25
0-34,35	2a	Exp	20'	5		2,398,500	-	(0.06) 0.09	-	-	-	-	-	A-2-4	23	NP
G-28,29	2c	Exp	40'	5	Intact	3,936,000	0.0	(0.11) 0.20	0.0	-	-	14.0'	9.0'	A-2-4	21	NP
T-2,3,4	2a	Exp	20'	5		16,155,000	-	(0.06) 0.05	-	-	-	-	-	A-1-a	12	NP
P-5,6 14 (Sel. Mat'l)	1	WP	20'	5	Intact	4,913,000	0.0	(0.06) 0.07	-	-	-	12.0'	-	A-1-a	4	NP

Research No. 00204 | Reference No. 26 (e)

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Construction Details: Orig. Slab Length (S)	Construction Details: Dowels No.	Construction Details: Dowels Condition	Traffic in 5000 Lbs. EWLs	Pavement Condition When Sampled: Faulting, Inches F1	Faulting, Inches F	Faulting, Inches Fr	Space Under Slabs a	Space Under Slabs b	Distance to nearest crack L	Distance to nearest crack R	Soil Data: HRB Class	Soil Data: % Pass 200 Sieve	PI
Faulting Group No. 6 (16.00 to 32.00"/mile)																
K-30,33,34,36,37	2a	Exp	20'	9		2,737,500	-	(0.08) 0.02	-	-	-	-	-	A-6	71	14
38,39,40	2a	Exp	20'	9		2,737,500	-	(0.08) 0.10	-	-	-	-	-	A-4	68	8
(Sel.Mat'l) P-1,2,13	2c	WP	20'	5	Intact, Rusty Sleeve Rusted Away	5,950,000	-	(0.09) 0.08	-	-	-	13.5'	Part Width 6.5'	A-1-a	8	NP
D-18	2c	Exp	30'	Exp 5		20,808,000	0	(0.09) 0.19	0	-	-	5.5'	7.5'	A-1-a	11	5
G-11,12,13	2b	WP	40'	5		3,936,000	0.0	(0.15) 0.45	0.0	-	-	-	9.0'	A-2-4	23	2
F-14,15	2a	Exp	20'	5		5,499,000	-	(0.09) 0.09	-	-	-	-	-	A-2-4	15	3
I-1,2,3	2a	Exp	20'	Exp 5		10,939,500	-	(0.07) 0.08	-	1/32	1/16	-	-	A-4	50	10
D-19,20, 21,22	2a	WP	30'	Exp 5		20,808,000	-	(0.10) 0.25	-	-	-	-	-	A-2-4	19	8
D-17	2a	Exp	30'	Exp 5		20,808,000	-	(0.11) 0.25	-	-	-	-	-	A-1-b	18	4
G-3,4	2c	WP	20'	5		3,968,000	0.03	(0.09) 0.23	0.0	-	-	12'	14'	A-2-4	19	NP
K-14,15 31,32	2a	Exp	20'	9		11,175,000	-	(0.08) 0.14	-	1/4	1/4	-	-	No Soil Samples		
N-9,10	2b	Exp	20'	5		2,717,000	-	(0.11) 0.25	0.0	0.0	1/4	-	9	A-2-4	15	NP
G-14,15,16 17,18	1	Exp	20'	5		3,880,000	0.0	(0.08) 0.06	-	-	-	10.0'	-	A-1-b	19	NP
G-1,2,27	2a	Exp	20'	5	Intact	3,968,000	-	(0.09) 0.12	-	1/64	-	-	-	A-2-4	13	NP
G-14,15, 17,20	2c	Exp	20'	5		7,735,000	0.0	(0.09) 0.52	0.13	-	-	6.0'	7.5'	A-2-4	33	1
A-5,6,7,8,9, 10,11,12	1	WP	20'	5	Note: Vert. striations on contact faces	7,504,000	0.0	(0.11) 0.00	0.0	¼"(±) Mudjack mortar under both slabs		12'	9.5'	A-4	37	6
P-9,10,11, (Silt 13,16,17 Cushion)	2c	Exp	20'	5	Broken	5,950,000	0.03	(0.11) 0.30	0.0	-	-	Corner Cr. 3.5'	4'	A-4	60	NP
B-9,13, 14	2b	Exp	20'	Exp 5	Broken	10,507,000	0.0	(0.09) 0.38	0.0	Slow steady flow of water under slab		15'	6.5'	A-2-6	29	13

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No.	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Faulting, Inches: F_1	Faulting, Inches: F	Faulting, Inches: F_r	Space Under Slabs: a	Space Under Slabs: b	Distance to nearest crack: L	Distance to nearest crack: R	Soil Data: HRB Class	% Pass 200 Sieve	PI
T-1,12	2a	WP	20'	5		16,612,500	-	(0.09) 0.10	-	-	-	-	-	A-1-a	4	NP
G-24,25	2c	Exp	20'	5	G-24 Broken G-25 Intact	3,968,000	0.0	(0.10) 0.20	0.0	-	-	10.0'	9.5'	No Soil Samples		
F-3,4	2a	Exp	20'	5		8,073,000	-	(0.08) 0.09	-	-	-	-	-	Range A-1-b to A-4	Range 14-43	Range 2-6
G-7	2a	WP	20'	5		3,968,000	-	(0.09) 0.08	-	-	-	-	-	A-2-4	22	NP
G-26	2c	Exp	20'	5	Broken Ends Rusted	3,968,000	-	(0.10) 0.20	-	-	-	11.0'	9.5'	A-2-4	13	NP
C-16, 18,19	2a	Exp	20'	5		9,226,000	-	0.11 0.50	-	Very slight water seepage from under slab		-	-	A-4	45	5
F-19	2a	WP	20'	5		5,499,000	-	(0.09) 0.10	-	0	0	-	-	A-2-6	31	11
G-8	2c	WP	20'	5		3,968,000	0.0	(0.10) 0.05	0.0	-	-	10.5'	11'	A-2-4	8	NP
K 11,12,13,24, 25,26,27,28,29,30	2a	Exp	20'	9		11,175,000	-	(0.10) 0.06	-	0.25"	0.25"	-	-	A-6	68	14
E-18,21, 22	2a	WP	20'	5		13,848,000	-	(0.11) 0.10		0	0.07	-	-	A-2-6	28	17
I-9	2a	Exp	20'	Exp 5		5,729,000	-	(0.23) 1.25	-	0.25	(b @ 8.0' from joint) 1.25"	-	-	A-1-b	17	4
E-1,2,3,4,5,9, 19,20.	2a	Exp	20'	5	Intact	13,848,000	-	(0.11) 0.15	-	Slight Water Seepage Under Slab		-	-	A-2-6	35	19
D-7	2c	Exp	30'	6	Broken	20,808,000	0.1	(0.17) 0.22	0.0	Cons. Water in gravel base. Couldn't see any opening		7'	9'	A-2-4	14	10
D-10,11, 15,16	2c	WP	30'	6		20,808,000	0.0	(0.18) 0.38	0.0	-	-	7'	9'	A-1-b	13	3
Faulting Group No. 7 (32.00 to 64.00"/mile)																
F-7	2a	Exp	20'	5	Broken	7,026,500	-	(0.12) 0.22	-	-	-	-	-	A-2-4	26	9
H-4 to 8 23-to 25	2b	Exp	20'	5		2,717,000	-	(0.13) Range 0.15 to 0.25	0.0	0.0	0.25	-	Range 8' to 10'	A-2-4	15	NP to 6
N-11	2c	Exp	20'	5		2,717,000	0.0	(0.13) 0.30	0.0	Water flowing under slab, pumping		10'	8'	A-2-4	17	NP
F-18	2a	Exp	20'	5		5,499,000	-	(0.14) 0.23	-	-	-	-	-	A-2-4	22	7

Pavement Details

Core Numbers	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Faulting, Inches: F_1	F	F_r	Space Under Slab: a	b	Distance to nearest crack: L	R	Soil Data: HRB Class	% Pass 200 Sieve	PI
F-16,17 18	2c	Exp	20'	Exp 5		11,175,000	0.0	(0.14) 0.26	0.0	0.19	0.25	9.5'	6.5'	A-4	46	2
M-16 *Trees*	2b	WP	20'	5		8,204,000	-	(0.18) 0.50	0.0	-	-	-	8.5	A-7-6	67	40
H-11, 12,13	2c	Exp	20'	5	Intact	4,360,000	0.0	(0.15) 0.12	0.05	-	-	14.0'	2.0'	A-4	45	8
F-16	2b	WP	20'	5		5,499,000	-	(0.20) 0.36	0.0	0.0	0.07	-	7.5'	A-2-4	26	2
I-6,7,8	2a	Exp	20'	Exp 5		11,653,500	-	(0.16) 0.15	-	*Pumping* 0.25	0.25	-	-	A-2-4	25	9
N-18	2c	WP	20'	5		2,717,000	0.0	(0.16) 0.25	0.0	*Free Moisture,* -	-	14.0'	9.0'	A-2-6	25	15
N-15,16 17	2b	WP	20'	5		2,717,000	-	(0.18) 0.25	0.0	Yes	Yes	-	8.0'	A-2-6	34	12
G-30,31	2b	WP	20'	5		4,272,000	-	(0.19) 0.25	0.0	-	-	-	8.5'	A-4	62	7
K-5	2a	Exp	20'	5		13,650,000	-	(0.19) 0.31	-	-	-	-	-	A-1-b	4	NP
K-6,7	2a	Exp	20'	5		13,650,000	-	(0.19) 0.31	-	-	-	-	-	A-2-4	8	NP
E-23,24	2c	Exp	20'	Exp 5		11,584,000	0.0	(0.19) 0.63	0.0	-	-	6.5'	7.5'	A-2-7	32	25
M-11, *No Trees* 12,13	2b	Exp	20'	5		5,509,000	-	(0.20) 0.35	0.0	-	1/8"	-	7.0'	A-7-6	58	27
M-3	2b	Exp	20'	5		2,717,000	-	0.21 0.25	0.0	*Slab Mudjacked 1¼ to 1½" mortar water flow into hole*		-	10.0'	A-7-6	62	32
F-17	2b	WP	20'	5		5,499,000	-	(0.26) 0.44	0.03	*Water seepage under slab. Joint pumps after rains.*		-	9.5'	A-2-4	23	7
M-4,5,6 *No Trees* 21 to 26	2b	WP & Exp	20'	5		8,204,000	-	*0.23 Range 0.20 to 0.24*	0.0	*None to Very Thin*	*None to Very Thin*	-	*Range 6' to 8'*	*Range A-2-6 to A-6*	*Range 34% to 49%*	*Range 6% to 22%*
G-19,20, 21,22,23	2c	Exp	20'	5	Intact	3,880,000	0.0	(0.22) 0.47	0.0	*Water Seepage Under Slab*		9.5'	7.5'	A-2-4	34	5
E-17	2c	Exp	20'	Exp 5	Broken	11,584,000	0.0	(0.23) 0.63	0.0	-	-	11.0'	5.5'	A-2-6	34	20
E-10,11 12,13	2c	Exp	20'	Exp 5	*Intact but pitted. Sleeve gone*	11,584,000	0.0	(0.23) 0.63	0.0	-	-	6.5'	7.5'	A-2-7	32	25

Pavement Details

Core Number	Type Fltg.	Construction Details: Type Joint	Orig. Slab Length (S)	Dowels: No	Dowels: Condition	Traffic in 5000 Lbs. EWLs	Pavement Condition When Sampled: Faulting, Inches: Fl	F	Fr	Space Under Slab: a	b	Distance to nearest crack: L	R	HRB Class	% Pass 200 Sieve	PI
Faulting Group No. 8 (72.00" +/mile)																
N-12,13, 14	2a	WP	20'	5		2,717,000	-	(0.29) 0.36	-	0.25	0.25	-	-	A-1-b	14	2
Faulting Group No. 9 (100.00" +/mile)																
M-15 No Trees	2c	Exp	20'	5		8,204,000	0.0	(0.38) 0.33	0.0	-	-	14.0'	6.0'	A-7-6	64	40
M-14 No Trees	2b	Exp	20'	5		8,204,000	0.0	(0.61) 1.50	-	-	-	14.0'	-	A-4	52	10

The use of the letters "Exp" above the number of dowels indicates that the expansion joints on the particular contract were dowelled but that the weakened plane joints were not.

In the faulting column (F) figures not in parentheses are the faulting at the actual joint from which cores were cut. Figures in parentheses are the average faulting per joint for the entire section of pavement involved.

Absence of measurements in the column headed "Distance to nearest crack" indicates that the slabs immediately adjacent to the cored joint were not cracked.

TYPES AND SOURCES OF CONSTRUCTION MATERIALS

A tabulation of the various materials used in manufacturing and curing concrete pavements was made as a part of the study (27). In accumulating this data, the various brands of cement, aggregates and curing compounds and the sources of all materials were listed.

The tabulation cannot be regarded as complete for it was impossible to obtain some of the data on the oldest contracts, some of which date back to 1914. However, the tabulation is as complete as possible and it lists the sources of concrete materials used in various parts of the State.

There is no apparent tie-in, however, between types or sources of cement, aggregate, water, or curing methods, so far as performance of pavement joints is concerned. In some cases, pavements that are considered to have given excellent service were constructed of materials that were from the same sources as used on other pavements which are classed as relatively poor from the standpoint of service.

TYPES AND SOURCES OF CONSTRUCTION MATERIALS

Proj. Let.	Dist., County, Rte., Sec.	Contract Data: Number	Contract Data: Date	Contract Data: Limits	Cement Source	Cl. PCC	Aggregate Sources: Coarse	Aggregate Sources: Fine	Water Source	Type & Source of Cure
A	X-Sol-7-B	41UCN2	5-11, 1932	1/2 Mi. W of Cordelia to 1/3 Mi. E of Fairfield	Mt. Diablo from Cowell	A	Thomasson-Cordelia Quarry	Basalt Rock Healdsburg	(1) Vallejo City Mains & (2) Well Sta. 200	Ponding
B	IV-Mrn-1-A	208	1917	Northerly Boundary to San Rafael	Standard Port. Cement Co., Davenport	6 Sk	Russian River Gravel Co., Healdsburg	Russian River Gravel Co., Healdsburg		
		94EC7	5/1928 to 4/1929	Ignacio to Gallinas Creek Sta. 517+72 to Sta. 750+04	Calaveras	A	Grant Rock Healdsburg	Grant Rock Healdsburg	San Jose, Pacheco & Miller Creeks	Ponding
		24EC5	1929 1930	Gallinas Creek to San Rafael Sta. 786+29 to Sta 899+48	Golden Gate, Redwood City	A	Grant Rock, Healdsburg	Grant Rock Healdsburg	Marin Municipal Water District	Ponding
		04TC6	6/1938 to 1/1939	Ignacio to San Rafael (4th Lane & Widening) Sta. 460+00 to Sta. 29+18	Golden Gate, Redwood City (Low tricalcium aluminate content)	B	Basalt Rock Healdsburg	Basalt Rock Healdsburg	Marin Municipal Water District	Lay-Kold Paraffine Emulsion
C	X-SJ-4- D	256	1919	Houston School to No. Bound. Sta. 0+00 to 277+03. (27+94 to 101+00 still in use in 1944)			Atlas Rock, Oakdale	Atlas Rock, Oakdale	Well: near Sta 85+00	"Usual manner" (1931)
	D	210EC3	1930	1/2 Mi. No. Houston School to Forest Lake. Still in use. 27+94 to 101+00	Golden Gate, Redwood City	A				
	D C	410CN1	1931	Lodi to 1/2 Mi. No. Houston School. 'C' 516+00 to 782+02, 'D' 0+00 to 27+94	Monolith	A	P.C.A., Fair Oaks	P.C.A. Fair Oaks	Stockton City Mains	Burlap, then wet earth. Also some Ponding
	III-Sac-4-A D	010TC3	12/1937 to 7/1938	Jahant's Corners to 1 Mi. No. of Galt. 'D' 10+00 to 269+09 'A' 0+00 to 114+00	Calaveras	B	Kaiser, Radum	Kaiser, Radum	Well on Property of Altnow, near Galt	Cotton Mats furnished by State
D	IV-SCl-68- B	84TC11	1936 1937	Sta. 278+00 to Sta. 414+00	Golden Gate, Redwood City	A	Arrowhead, San Jose	30% Atlas Olympia 70% Arrowhead San Jose	San Jose City Mains	Waterspray, then wet earth
	B	64TC4	1933 1934	Sta. 121+00 to Sta. 262+00	Pacific Portland, Redwood City	A	Kaiser, P.C.A.	Kaiser, P.C.A.	Well: 300' Rt. Sta. 190	Burlap, then wet earth
	B A	44CN2	1932 1933	'B' 0+00 to 121+00 'A' 276+40 to 339+71.58	Pacific Portland, Redwood City	A	Kaiser - Radum P.C.A., Eliot Arrowhead, San Jose	Kaiser - Radum P.C.A. Eliot Arrowhead, San Jose	Well: 200' Rt. Sta. 216	Burlap, then wet earth
	A	44TC6	1932 1933	Sta. 27+58.58 to Sta. 276+40	Pacific Portland, Redwood City	A	Kaiser - Radum P.C.A. Eliot Arrowhead, San Jose	Kaiser - Radum P.C.A. Eliot Arrowhead, San Jose	Not mentioned in final report	Burlap, then wet earth
	A D C	44TC2	1931 1932	'A' 0+00 to 27+58.58 'D' 3+05.13 to 152+83.25 'D' 174+73.15 to 322+64.60 'E' 1071+25 to 1073+80.42	Pacific Portland, Redwood City	A	Kaiser - Radum P.C.A. Eliot	Kaiser - Radum P.C.A. Eliot	Palo Alto City Mains	Burlap, then wet earth
	C B	24TC7	1931	'C' 612+92.44 to 1023+77 'B' 528+00 to 612+92.44	Pacific Portland, Redwood City	A	Kaiser - Radum P.C.A. Eliot	Kaiser - Radum P.C.A. Eliot	Pacific Water Co. San Mateo	Burlap, then wet earth
	B	24TC2	1930	Sta. 255+88 to Sta. 528+00	Left Lane: Santa Cruz Right Lane: Pacific Portland	A	Kaiser, Livermore	Kaiser, Livermore	Pacific Water Co. So. San Francisco	Burlap, then wet earth
	IV-SM-68- B A	24TC4	11,12 1930	'B' 237+99.59 to 241+05.82 'A' 186+34.45 to 229+74.58	Pacific Portland, Redwood City	A	Kaiser, Livermore	Kaiser, Livermore	Pacific Water Co. So. San Francisco	Burlap, then wet earth
	A	44TC8	4-7 1933	'A' 0+14.6 to 136+50 'A' 146+50 to 174+50	Golden Gate, Redwood City	A	Kaiser - Radum P.C.A. Eliot	Kaiser - Radum P.C.A. Eliot	So. San Francisco Water Mains	Burlap 1st day, then earth blanket
	A	44TC4	1932 1933	'A' 136+34 to 146+50 'A' 174+50 to 186+34	Exp. Pav't. many types cement from: Santa Cruz, Yosemite, Calaveras, Golden Gate, Cowell	A	Healdsburg	Healdsburg	No. Section: San Francisco Water Mains. So. Section: So. San Francisco Mains	Burlap, then wet earth
E	IV-Ala-5-C	230	1918	Overackers Corners to South Boundary	Cowell	6 Sk	Calif. Bldg. Materials Co., Niles	Calif. Bldg. Materials Co., Niles		
	IV-SCl-5-A	94EC3	12/1927-1/1928	Warm Springs to Milpitas 'C' 839+30 to 925+16 'A' 0+00 to 60+00	Santa Cruz	A	Coast Rock & Gravel Co., Eliot	Coast Rock & Gravel Co., Eliot	Well: 200' Rt. Sta. 846+75	Not mentioned in final report
		89	1914	North Boundary to San Jose	Pacific Portland Cement Co.					
F	V-Mon-2- A	55EC2	12-1927 to 2-1928	Salinas to Santa Rita Rd. Sta. 111+87 to Sta. 210+35	Old Mission Brand, San Juan		Granite Rock Logan	Granite Rock, Logan	Well: 300' Lt. Sta. 210+50	Hunt Process Sta. 111+86 to 121+00 Balance, wet earth blanket
		45TC2	1943	Salinas to 1/4 Mi. No. of Santa Rita, Sta. 111+00 to Sta. 265+50	Permanente	B	Granite Logan	Kaiser, Olympia	Salinas Muncipal Water Co.	Earth Blanket
		45EC1	8/1931 to 2/1932	2 Mi. No. of Salinas to No. Boundary, Sta. 210+35 to Sta. 794+72	Golden Gate, Redwood City	A	Granite Rock Logan	Assoc. Rock Co. Lappis & Local from Gabilan Cr (60% - 40%)	Well: Rt. Sta. 406+50. Also: sump hole right of Sta. 689	Water Cure, Sta 320+29 to 338+29 Rt. Balance 'Pave Cure' from SW Curing Co. Oakland

TYPES AND SOURCES OF CONSTRUCTION MATERIALS

Proj Let.	Dist., County, Rte., Sec.	Contract Data: Number	Contract Data: Date	Contract Data: Limits	Cement Source	Cl PCC	Aggregate Sources: Coarse	Aggregate Sources: Fine	Water Source	Type & Source of Cure
G	V-SB-2- C M L	45CS1	5/1932 7/1932	Los Alamos to 2 Mi. No. Solomon Summit 'C' Sta. 570+00 to 621+84 'M' Sta. 51+84 to 400+00 'L' Sta. 0+00 to 94+00	Monolith	A	Gates, Sisquoc	Gates, Sisquoc	Union Oil Co. Pipeline	'Curecrete'
	L	45CS2	4/1932 6/1932	94+00 to 410+23.31	Calaveras		Gates, Sisquoc	Gates, Sisquoc	Union Oil Co. Pipeline	Hunt Process
H	VI-Fre-4-C	86TC3	West: 10 & 11 1936 East: 2 & 3 1937	Belmont Circle to Biola Jct. Sta. 8+33 to 223+28	Calaveras	A	Stewart & Nuss, Herndon	Stewart & Nuss Herndon, and 600 T. from Grant Service Rock, Friant	McDonnell Well: 80' Left Sta. 132+60	
		86TC4	3/1937 5/1937	Biola Jct. to Herndon, Sta. 223+25 to 462+00	Calaveras	A	Grant Service Rock, Friant	Grant Service Rock, Friant	So. Pacific Co.'s Line at Herndon Piped to Job	
I	VII-LA-4- I J	47FC5	5/1933 to 9/1933	'I' 118+00 to 199+73.35 Piru Creek to Gorman 0+00 to 571+00	Monolith (Avg. 5.002 sk. cu. yd.)	A	Imp. Rock Co. Plant at Junction of Piru Creek and Las Alamos Creek	Imp. Rock Co. Plant at Junction of Piru Creek and Las Alamos Creek	Piru & Las Alamos Creeks	'Agekote' from Pioneer Paper Co. Los Angeles
	D	47CS13	5/1933 to 6/1933	1 Mi. E. Gorman to County Line 'D' 571+00 to 773+69.1	Victorville	A	F. B. Marks Frazer Park (60-40) and (40-60)	F. B. Marks Frazer Park (40-60) and (60-40)	Gorman Hotel Well 1 Mi. W Sta. 760, and Sump in Gorman Creek	Earth Blanket
K	VII-LA-26- A	L.A. Co. Contract	1929		Colton	5.76 Sk.	Source Unknown 65%	Source Unknown 35%	"Local" 6.0 gal (±)	Ponding
	A B ElM C	87XC17	1936	Monterey Park to Pomona Sta. 'A' 277+56 to Sta. 'C' 516+60	Colton	A	Consolidated, Irwindale	Consolidated, Irwindale	Kellog Ranch well at Spadra	Wet earth blanket
	B	47XC3	2,4 1933	Mt. View Road to Orange Ave. Sta. 0+00 to 240+89 except 7+10 to 28+98	Blue Diamond	A	SAN GABRIEL WASH: 25% Graham Bros. 25% Blue Diamond 50% Consolidated Irwindale	SAN GABRIEL WASH: 25% Graham Bros. 25% Blue Diamond 50% Consolidated Irwindale	Calif. Domestic Water Supply	Burlap, then wet earth
	C	67XC1	12/1933 to 3/1934	Orange Ave. to Barranca St. Sta. 0+00 to 200+00 (Note: Sta. 0+00 to Sta. 133+00 Lt., paved just previous to 14" rainstorm on 12-31-33 and 1-1-34	Blue Diamond	A	Consolidated, Irwindale	Consolidated Irwindale (31-32%)	Azusa Irrigation Co. (41-42 Lbs.)	Earth blanket except Rt. Sta. 19+80 to 21+00 & 33+00 to 34+00; cement dusted on by orchard duster
	C	47XC1	11/1932 to 4/1933	Barranca St. to Pomona Sta. 200+00 to 516+60	Colton (Avg. 5.998 Sk. cu. yd.)	A	Consolidated, Irwindale, 13,970 Claremont 7,950	Consolidated Irwindale, 12,070 Claremont 7,150 (37-39%)	Kellog Ranch Reservoir & Valencia Heights Water Co. (40#)	'Warma'
M	VII-Ora-2-C	98	1914	Irvine to Santa Ana	Riverside (Avg. 5.33 Sk. cu. yd.)	A	Hodge Plant	San Gabriel		Dikes & Wet earth
		370 (M20)	7,9 1922	Irvine to Tustin Sta. 0+00 to 306+80	Colton (Avg. 6.32 Sk./cu.yd.)	A	Orange Co. Sand & Gravel; Yaeger Rock and Sand	Orange Co. Sand & Gravel; Yaeger Rock and Sand	Wells & Irrigation Ditch	Burlap, wet earth and ponding
		47VC14	4,5 1933	Irvine to Tustin 9+42.6 to 307+08.9	Colton	A	Capistrano Sand and Rock	Capistrano Sand and Rock	Tustin City Mains and Irvine Well 200' W Sta. 'B' 504+00	Burlap, then wet earth
N	VII-Ora-60-Lga Bch: Lga Bch	519	1927	Through Laguna Beach (Cypress St. North)	Monolith (Avg. 6.05 Sk./cu.yd.)		Orange Co. Rock Co.	Orange Co. Rock Co.	Laguna Beach Water Dist.	Ponding or earth blanket
	Lga Bch	47VC24 67VC20	4,6 1935	Cypress St. to South C/L Laguna Beach Sta. 32+41 to 90+08	Blue Diamond	A	So. Coast Rock Co., San Juan Capistrano	So. Coast Rock Co., San Juan Capistrano	Laguna Beach Water Supply	Impervious Membrane Richfield, Los Angeles
	C	27CS1 27VC12	10/1932 1/1933	Laguna Beach to Dana Point Sta. 90+08 to 359+30	Riverside	A	So. Coast Rock Co. plant on Trabuco Cr. Non-uniform grading: short on 2-1/2" to 1-1/2"	So. Coast Rock Co. plant on Trabuco Cr. Poor moisture content control	Dana Point Water Co.	Burlap, then wet earth
O	XI-SD-12 C	47CS1	6/1931	At Bostonia. Sta. 18+00 to Sta. 149+00	Riverside	A	Fenton Materials Otay Plant	Fenton Materials Otay Plant	San Diego City Water Supply Lake Cuyamaca	Burlap, then wet earth
	C	47CS7	8,10 1932	Bostonia to Chocolate Creek Sta. 149+00 to 546+00	Golden Gate	A	Fenton Materials Otay Plant	Fenton Materials Otay Plant	La Mesa, Lemon Grove & Spring Valley Irrigation Dist. Main	'Agekote'
	C	47CS9	5,6 1933	Chocolate Creek to Alpine Sta. 546+00 to 725+53	Riverside (Avg. 5.999 Sk/cu.yd.)	A	Fenton Materials Otay Plant	Johnston, Lakeside (SD River)	Viejas Creek	Burlap, then wet earth (10 days)
	D	47CS10	3,8 1933	Alpine to Viejas Creek 0+00 to 233+60	Riverside	A	Lakeside San Diego River	Fenton Materials Otay Plant	Viejas Creek	Wet earth
	D	27VC6	9/1930 to 4/1931	Viejas Creek to Pine Valley Sta. 237+35 to 852+00	Monolith (Avg. 6.00 sk/cu.yd.)	A	Fenton Materials Otay Plant	Local pit, 4 Miles W of Pine Valley	Sweetwater River	Water
	D E F	07CS1	7,12 1929	Pine Valley to Kitchen Creek 'D' 852+00 to 877+39 'E' 0+00 to 356+08.85 'F' 0+00 to 46+75.5	Victorville (Avg. 6.00 Sk/cu.yd.)	A	Local ledge on Laguna Mt. Rd., 1-1/2 Mi. NE Sta. 93+62	Local Pine Valley Creek	Cottonwood Creek	Dirt or burlap blanket during Nov. and Dec.
	F	07VC7	3,4 1930	Kitchen Cr. to La Posta Creek Sta. 49+45 to 255+25	Victorville (Avg. 6.00 Sk/cu.yd.)	A	Spreckels Plant Otay	Local Pit, Pine Valley Creek	La Posta Creek	Wet earth
	F G	27VC11	5,7 1931	La Posta Cr. to Tecate Divide Sta. 'F' 252+00 to Sta 'G' 23+50	Golden Gate (Avg. 6.00 Sk/cu.yd.)	A	Fenton Materials Otay	Fenton Materials Otay	La Posta Creek	Water

TYPES AND SOURCES OF CONSTRUCTION MATERIALS

Proj. Let.	Dist., County Rte., Sec.	Contract Data			Cement Source	Cl. PCC	Aggregate Sources		Water Source	Type & Source of Cure
		Number	Date	Limits			Coarse	Fine		
O	XI-SD-12- G	47CS2	6/1932	At Jacumba Sta. 444+40 to 458+12	Left Lane: Golden Gate, Right Lane Riverside	A	Local, Rainey Pit, Imperial Rock Co.	Local, Rainey Pit, Imperial Rock Co.	Well 1000' No. Sta. 200+00 Well No. 2, Mtn. Meadow Creamery Co.	'Pavecure'
	G H	47CS4	6,10 1932	Tecate Divide to Mtn. Springs Grade Sta. 'G' 23+50 to 'H' 51+47.98	1 Car of Golden Gate Balance: Riverside and Ora Grande	A	Local, Rainey Pit, Imperial Rock Co.	Local, Rainey Pit, Imperial Rock Co.	Well 1000' No. Sta. 200+00 Well No. 2, Mtn. Meadow Creamery Co.	'Pavecure'
		48CS2	11/1932 1/1933	Ave. 62 to Ave. 74 Sta. 'F' 449+00 to 'G' 437+00	Victorville	A	Local, 600' Rt. Sta. 682+00	Local, 600' Rt. Sta. 682+00	Private well left of Sta. 223+00	Burlap & wet earth
P	XI-Riv-26-G	48FC2	1,3 1933	Ave. 74 to Imp. Co. Line Sta. 'G' 437+00 to 755+12.3	Victorville	A	Local, 600' Rt. Sta. 682+00. Mix was heavy to coarse rock	Local, 600' Rt. Sta. 682+00	Private well left of Sta. 750+00	Burlap & wet earth
	E D	279	6/1921 to 8/1922	Las Cruces to Zaca Sta. Sta. 'E' 261+40.3 to 'D' 622+44	Colton Sta. 'E' 1+40 to 251+84 = 1:2:4 Sta. E 405+00 to 'D' 622+44 1:2:4 Sta. 'E' 291+84 to 405+00 1:2:3		Gravel: Gates at Sisquoc Crushed: Doughery San Luis Obispo	Gates at Sisquoc	Nojoqui & Gaviota Creeks, Santa Ynez River, Wells on Rchs. along R/W	Burlap, then wet earth. Ponding on slopes less than 2%
	C	25CS2	5,7 1930	Zaca Sta. to Wigmore Sta 161+00 to 372+21.65 = 373+43.01	Monolith	A	Gates at Sisquoc	Gates at Sisquoc	Well drilled by contractor 500' Lt. Sta 166+00 bank of Zaca Cr.	Earth & Water
R	V-SB-2-D	25FC4	3/1931	Nojoqui Line Change Sta. 232+00 to 260+00	Monolith	A	Gates at Sisquoc	Gates at Sisquoc	De la Cuesta Reservoir, Sante Ynez River	Wet earth
	D	65VC13	10/1938 to 3/1939	Gaviota Pass to Santa Ynez River Sta. 94+00 to Sta. 247+59	Colton. Victor high early strength: Sta. 125+84 to 226+84, Sta. 231+24 to 232+04		Gates, Sisquoc. 11% Blue Diamond added at Sta. Lt. 94+00 to 117+00 144+96 to 173+14 Rt. 94+00 to 144+80 144+96 to 162+36	Gates at Sisquoc	Nojoqui Creek	Wet earth & Ponding
	D E	65VC8	7,9 1935	Gaviota Creek to Nojoqui Cr. Sta. 'E' 260+88 to Sta. 'D' 54+00	Monolith		Gates Plant (Special set up for this job) in San Ynez River E of Buellton	Gates at Sisquoc	Well, left of Sta. 'D' 66+00	Wet earth
	E	25FC5	6,7 1931	Gaviota to 1 Mi. No. of Las Cruces Sta. 103+00 to 260+88	Riverside	A	Crushed: Honda	Saticoy Rock Co.	Creek, 1/4 Mi. Rt. of Sta. 220+00	Hunt Process
S	VII-Ora-171-A	07XC3	11/1937	Coast Blvd. to Garfield St. Sta. 0+38 to 139+30	Blue Diamond	A	Graham, Orange Co. Consolidated Orange Co.	Graham, Orange Co. Consolidated Orange Co.	Standard Oil Huntington Beach Water Line	Wet earth
	VII-Ora-184-A	Orange County	11/1928 1/1929	S. Main St. in Santa Ana to Sta. 139+30	Victorville (Avg. 6.00 Sk/cu.yd.)	6 Sk	Olive	Olive		Burlap, then ponding
	D	48CS3	4,5 1933	Vineyard Ave. to Sierra Ave. Sta. 69+50 to 611+78	Riverside	A	Triangle Rock San Bd. Commercial Rock Co., Upland	Triangle Rock San Bd. Commercial Rock Co., Upland	Fontana Water Co.	Burlap, then wet earth
T	VIII-SBd-26-D	68XC4	1,4 1934	Sierra Ave. to Riverside Ave. Sta. 607+78.19 to 809+87.6 except 722+00 to 742+00	Colton	A	Triangle Rock San Bernardino	Triangle Rock San Bernardino	Fontana Water Co.	Burlap, then wet earth
		68XC10	1/1934	Thru Bloomington Sta. 722+00 to 742+00	Riverside	A	Consolidated Claremont	Consolidated, Claremont	Citizen's Water Co., Bloomington	Burlap, then wet earth
	D	68XC13	5,6 1935	Riverside to Colton Sta. 805+97.3 to 910+76.16	Colton		Triangle Rock San Bernardino	Triangle Rock San Bernardino	Colton City Mains	Transparent Membrane
	C D Ria Col	08XC1	12/1937 2/1938	Widening LA Co. Line to Colton 'C' 0+00 to 'Col' 1+22	Riverside Colton	5 Sk	Commercial Rock, Upland	Commercial Rock, Upland	Amer. States, Bloomington, Fontana Domestic, City of Ontario Monte Vista Water Co.	Cotton Mats
		L.A. Co Contract	1920	Burton Ave. to So. C/L of Compton		1:2:4			No Limit on mixing water	Ponding
V	VII-LA-Alameda Street		1921	Slauson Ave. to Burton Ave.		1:2:3½			No limit on mixing water	Ponding
			1923	So. C/L Compton to Wilmington		1:2:4			1½" to 2" slump	Ponding
			1926	Florence Ave. to No. C/L of Compton (Widening)		1:2:4	Calc. Chloride Admixture			Calc. Chloride

PAVEMENT STRENGTH

All concrete cores tested for compressive strength gave very "satisfactory" results. The lowest values were found in cores from a section of concrete made with light weight Haydite aggregates on the Bayshore Highway, IV-SM-68-A, which ranged from 3800 to 4400 lb/sq.in. However, these slabs and joints were in as good condition as many other sections of standard concrete exceeding 8000 lbs. compressive strength (28).

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 28 (a)

TEST RESULTS ON CONCRETE CORE SPECIMENS

Project Identity &	Core No.	Year Placed	Age When Tested	Sacks Cement c.y.	Wt. Per Cu.. Ft. Soaked	Comp. Strength p.s.i.	Modulus of Elasticity 1000 p.s.i.	EXPANSION THERMAL: Coefficient	EXPANSION MOISTURE-% in 8 Hrs.	EXPANSION Dry Length in 7 days	Remarks
A	1	1932	12 Yrs	6	157.0	7350	-	-	-	-	
X-Sol-	2			6	154.7	7545	5,000,000	-	-	-	
7-B	3			6	155.4	8470	5,555,000	-	-	-	
	4			6	157.5	8115	4,760,000	-	-	-	
	5			6	158.0	7860	5,000,000	-	-	-	
Project Average					156.5	7870	5,079,000	-	-	-	
B	3	1929	15 Yrs	6	154.2	7630	-	-	.02595	.0630	
IV-Mrn-	6	1929	15 Yrs	6	-	-	-	-	.0375	.0667	
1-A	11	1938	6 Yrs	5	156.4	6070	-	-			
	12	1938	6 Yrs	5	156.0	4885	-	-			
	13	1930	14 Yrs	5	154.3	6380	-	-			
Project Average					155.2	6240		-	.031725	.06485	
C	4	1938	6 Yrs	5	-	-	-	.00000553			
X-SJ-	6	1919	25 Yrs	6	153.5	-6765	-	-			
4-C,D	8	1930	14 Yrs	6	-	-	-	-	.01825	.0338	
	10	1938	6 Yrs	5	-	-	-	.000004978	.0305	.0515	
	13a	1919	25 Yrs	6	-	-	-	.000005406	.0237	.0440	
	13b	1919	25 Yrs	6	-	-	-	.000004858	.0185	.0350	
	15	1931	13 Yrs	6	-	-	-	.00000476	.0200	.0310	
	18	1931	13 Yrs	6	163.1	8385	4,760,000	-			
	19	1931	13 Yrs	6	160.7	8165	5,000,000	-			
	20	1931	13 Yrs	6	159.0	8940	5,265,000	-			
	21	1919	25 Yrs	6	158.4	6590	3,449,000	-			
	23	1930	14 Yrs	6	156.5	6470	2,855,000	-			
	24	1919	25 Yrs	6	158.7	6035		-			
Project Average					158.6	7335	4,266,000	.000005106	.02219	.03906	
D	1	1937	7 Yrs	6	156.6	7445	-	-			
IV-SCl-	2	1937	7 Yrs	6	156.5	7615	-	-			
68-B	3	1937	7 Yrs	6	154.0	7500	3,572,000	-			
	8	1933	11 Yrs	6	154.0	6085	3,846,000	-			
IV-SM-	9	1932	12 Yrs	6	154.0	6620	4,545,000	-			
68-A	10	1933	11 Yrs	6	111.2	4475	2,941,000	-			Lt.Wt.Agg.

TEST RESULTS ON CONCRETE CORE SPECIMENS

Project Identity & Core No.	Year Placed	Age When Tested	Sacks Cement c.y.	Wt. Per Cu. Ft. Soaked	Comp. Strength p.s.i.	Modulus of Elasticity 1000 p.s.i.	EXPANSION THERMAL: Coefficient	EXPANSION MOISTURE-% in 8 Hrs.	EXPANSION Dry Length in 7 Days	Remarks
D 11	1933	11 Yrs	6	106.7	3820	2,855,000	-			Lt.Wt.Agg.
IV-SM- 12	1932	12 Yrs	6	153.2	6765	3,226,000	-			
68-A 13	1932	12 Yrs	6	156.6	7670	3,125,000	-			
(Con't) 14	1932	12 Yrs	6	155.0	8415	3,571,000	-			
15	1933	11 Yrs	6	109.8	3880	2,778,000	-			Lt.Wt.Agg.
16	1933	11 Yrs	6	113.7	4240	3,030,000	-			Lt.Wt.Agg.
17	1933	11 Yrs	6	156.5	7115	3,125,000	-			
19	1933	11 Yrs	6	155.1	6380	3,700,000	-			
20	1933	11 Yrs	6	154.0	7060	4,350,000	-			
21	1933	11 Yrs	6	154.0	7445	4,760,000	-			
22	1933	11 Yrs	6	153.1	7100	5,000,000	-			
Averages Lt.Wt.Aggregate P.C.C.				110.4	4105	2,901,000	-	-	-	
Standard P.C.C.				154.8	7170	3,893,000	-	-	-	
E IV-SCl-5-A 1	1927	17 Yrs	6	155.0	8180	4,445,000	-			
2	1927	17 Yrs	6	154.4	8300	4,445,000	-			
5	1927	17 Yrs	6	153.5	7580	-	-	.0347	.0597	
IV-Ala-5-C 12	1928	16 Yrs	6	-	-	-	.000005412	.0162	.0430	
16	1914	30 Yrs	6	161.0	8900		-			
IV-SCl-5-A 19	1927	17 Yrs	6	154.1	8400		-			
20	1927	17 Yrs	6	155.6	7150	4,170,000	-			
21	1927	17 Yrs	6	156.6	7020	4,545,000	-			
22	1927	17 Yrs	6	155.6	6250	4,000,000	-			
IV-Ala-5-C 23	1927	17 Yrs	6	155.6	7490	4,170,000	-			
24	1927	17 Yrs	6	153.2	7515	4,760,000	-			
Project Average				155.5	7680	4,362,000	.000005412	.02545	.05135	
F 2	1928	17 Yrs	6	153.5	7385	-	-			
9	1943	2 Yrs	5	156.6	7096	-	-	.0202	.0316	
V-[illegible]- 16	1931	14 Yrs	6	159.8	7575	-	-			
2-AJ 19	1932	13 Yrs	6	-	-	-	-	.0218	.0426	
Project Average				156.6	7350	-	-	.0210	.0371	

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 28 (c)

TEST RESULTS ON CONCRETE CORE SPECIMENS

Project Identity & Core No.		Year Placed	Age When Tested	Sacks Cement c.y.	Wt. Per Cu. Ft. Soaked	Comp. Strength p.s.i.	Modulus of Elasticity 1000 p.s.i.	EXPANSION THERMAL: Coefficient	EXPANSION MOISTURE-% in 8 Hrs.	EXPANSION Dry Length in 7 Days	Remarks
G	1	1932	13 Yrs.	6	149.6	7980	3,635,000	-			
V-SB-	2	1932	13 Yrs	6	148.4	7050	3,635,000	-			
2-ML	3	1932	13 Yrs	6	150.2	7825	3,635,000	-			
	4	1932	13 Yrs	6	149.6	8200	3,635,000	-			
	5	1932	13 Yrs	6	147.8	6315	3,720,000	-			
	6	1932	13 Yrs	6	148.4	7625	4,000,000	-			
	7	1932	13 Yrs	6	147.8	7515	3,720,000	-			
	11	1932	13 Yrs	6				-	.0283	.0458	
	13	1932	13 Yrs	6	147.0	7220	2,940,000	-			
	15	1932	13 Yrs	6	148.0	5505	3,455,000	-			
Project Average					148.5	7250	3,597,000	-	.0283	.0458	
H	11	1937	9 Yrs		153.5	7287	4,760,000	-			
	12				152.2	7843	-	-			
VI-Fre-	13				151.4	7197	-	-			
4-C	15				150.8	8773	-	-			
	16				152.0	7188	-	-			
	17				153.7	8238	-	-			
Project Average					152.3	7754	4,760,000	-			
K	1①	1929	17 Yrs	5.75				.0000040257	.0384	.0675	
VII-LA-	1②	1929	17 Yrs	5.75				-	.0268	.0555	Check Test
26-A	2	1929	17 Yrs	5.75	153.3	7688	-	-	-	-	
	3	1937	9 Yrs	6	152.5	8511	4,760,000	-	-	-	
	5	1933	13 Yrs	6	155.1	7974	4,760,000	-	-	-	
	11	1933	13 Yrs	6				.0000042565	.0240	.0387	
VII-LA-	12	1933	13 Yrs	6				.0000042167	.0316	.0518	
26-B	13	1933	13 Yrs	6				.0000042401	.0262	.0419	
VII-LA-	16	1933	13 Yrs	6	152.4	9202	4,540,000	-	-	-	
26-C	24	1933	13 Yrs	6				.0000047794	.0295	.0498	
	25①	1933	13 Yrs	6				.0000045670	.0275	.0527	
VII-LA-	25②	1933	13 Yrs	6				.0000044656	.0392	.0623	Check Test
26-B	27	1933	13 Yrs	6				.0000033275	.0269	.0475	
	38①	1933	13 Yrs	6				.000004404	.0355	.0500	
	38②	1933	13 Yrs	6				.0000042563	.0355	.0522	Check Test
Project Average					153.3	8340	4,687,000	.000004254	.03101	.0518	

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 28 (d)

TEST RESULTS ON CONCRETE CORE SPECIMENS

Project Identity & Core No.	Year Placed	Age When Tested	Sacks Cement c.y.	Wt. Per Cu.Ft. Soaked	Comp Strength p.s.i.	Modulus of Elasticity 1000 p.s.i.	EXPANSION THERMAL: Coefficient	EXPANSION MOISTURE-% in 8 Hrs.	EXPANSION Dry Length in 7 Days	Remarks
M 2	1933	13 Yrs	6					.0281	.0478	
VII-Ora- 7	1922	24 Yrs	6.32	151.1	8364	4,540,000				
2-C 8 Top	1922	24 Yrs	6.32				.0000056725	.0287	.0528	2nd Story
8 Btm	1914	32 Yrs	5.35				.000004418	.0260	.0352	
9 Top	1922	24 Yrs	6.32				.0000057705	.0390	.0579	2nd Story
9 Btm	1914	32 Yrs	5.33				.00000467	.0323	.0487	
16	1933	13 Yrs	6				.000004782	.0365	.0585	
24	1933	13 Yrs	6	154.2	7918	4,760,000				
Project Average				152.7	8140	4,650,000	.000005063	.03176	.05015	
N 6	1932	14 Yrs	6					.0228	.04145	
VII-Ora-7	1932	14 Yrs	6					.0255	.0539	
60-C, 20	1935	11 Yrs	6					.0278	.0486	
LgaBch 22	1935	11 Yrs	6				.00000478	.0260	-	
Project Average				-	-	-	.00000478	.02553	.04465	
O 1 ①	1932	14 Yrs	6	153.6	5409					
XI-SD- 3 ①	1932	14 Yrs	6					.0424	0.10315	
12-G 3 ②	1932	14 Yrs	6					.0460	0.10155	Check Test
5	1932	14 Yrs	6				.000003961	.0327	0.0747	
7	1931	15 Yrs	6				.0000037195	.0311	-	
8	1931	15 Yrs	6					.0261	0.0378	
XI-SD- 9	1930	16 Yrs	6	153.7	8737	4,760,000				
12-F 10	1930	16 Yrs	6				.0000043995	.0153	0.0314	
11	1930	16 Yrs	6				.0000048800	.0234	0.0405	
E 13	1929	17 Yrs	6				-	.0165	0.0326	
19	1930	16 Yrs	6	153.5	8572			.0110	0.02345	
D 22	1930	16 Yrs	6					.0209	0.0385	
E 23	1929	17 Yrs	6					0.0162	0.0296	
C 35	1932	14 Yrs	6				.0000049241	0.0164	-	
Project Average				153.6	7570	4,760,000	.0000043768	.02483	.05133	
P 2	1932	14 Yrs	6					.0181	0.0326	
XI-Riv-26-G Proj. Ave.								0.0181	0.0326	

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 28 (e)

TEST RESULTS ON CONCRETE CORE SPECIMENS

Project Identity & Core No.	Year Placed	Age When Tested	Sacks Cement c.y.	Wt. Per Cu.Ft. Soaked	Comp Strength p.s.i.	Modulus of Elasticity 1000 p.s.i.	EXPANSION THERMAL: Coefficient	EXPANSION MOISTURE-% in 8 Hrs.	EXPANSION Dry Length in 7 Days	Remarks
S VII-Ora-171-A 3®	1937	9 Yrs	6				.0000055921	.0290	.0545	
S VII-Ora-171-A 3®	1937	9 Yrs	6				.0000054879	.0272	.0538	Check Test
S VII-Ora-171-A 4	1937	9 Yrs	6				.000005421	.0350	.0627	
S VII-Ora-171-A 8	1937	9 Yrs	6					.0297	.0545	
VII-Ora-184-A 13	1928	18 Yrs	6					.0266	.0507	
VII-Ora-184-A 15	1928	18 Yrs	6					.0297	.0505	
Project Averages					Ora-171-A	-	.000005500	.0302	.0564	
					Ora-184-A	-	-	.0282	.0506	
V VII-LA-Ala.St 1®	1923	13 Yrs	5.5				.0000049795	.0301	.0617	
V VII-LA-Ala.St 1®	1923	13 Yrs	5.5				.0000046238	.0325	.0686	Check Test
V VII-LA-Ala.St 4	1921	15 Yrs	6				.0000045177	.0328	.0675	
Project Average							.000004707	.0318	.0659	
Average For All Projects				154.2	7450	4,192,000	.000004730	.0276	0.05063	

*Light weight aggregate concrete test results not included in over-all averages

APPENDIX E - Subgrade Soils. Test Data and Soil Classification

(1) Procedure in Field Work

At each location where 8" cores were cut, the drill was stopped from 1/2" to 1" above the bottom of pavement and all sludge was washed from the hole. As much water as possible was removed and the remainder of the hole was cut with no water being added. In most cases, the small amount of water left in the hole was dried up by the heat from the bit and the hole was completed with no moisture from the drilling process entering the subgrade. When a core was being cut close to a joint or crack through which it appeared probable that drilling water might enter the subgrade, the joints or cracks were sealed off with plaster of paris before actually starting work.

Density of subgrade material in place immediately under the pavement was determined by the sand volume technique which was employed to a depth of 6" or until a definite change in material occured if at less than 6" in depth. The major portion of the standard sand used in measuring the volume of the hole was removed and saved. The remainder of sand was removed and discarded and the sides of hole were trimmed to remove any partially dried material. Representative moisture samples were taken and sealed in tared glass jars. A 50-75 lb. sample of material in each layer was obtained by cutting back under the pavement with bars. Soil sampling by 6" layers was continued to a total depth of 24" below the bottom of the pavement. Similar procedure was followed for each 6" layer. In many cases the density determination was carried only to a depth of 18" and the lowest layer (-18' to -24") was sampled for moisture only.

A station wagon was fitted out with scales, drying oven and other equipment, so that many of the field density tests were completed in the field. The remainder of the field density samples, the moisture samples and the sample taken for soil tests were forwarded to Headquarters Laboratory for complete tests.

Although procedure varied according to the conditions found on each section, in general, several cores were cut on both sides of faulted joints and in some cases in the middle of the slabs adjacent to the joints.

(2) Laboratory Tests

In general, all subgrade materials were subjected to standard routine tests. Wash grading analysis, weight per cu.ft., moisture content, specific gravity, Atterberg limits and California Bearing Ratio tests at "Standard Compaction" were run on each <u>type</u>

of subgrade soil encountered on a section. In addition to the above, a California Bearing Ratio test was run on each type, using the moisture and density typical of the material in place under the pavement.

From results of field and laboratory tests, data were compiled for each section sampled on each project considered. Using the soils test data, relative compaction and the theoretical moisture content at saturation were calculated. From this latter figure, the relative degree of saturation found in the subgrade sampled at each core hole was computed.

All soils were classified according to the Highway Research Board System, using their Table No. 2.

Reference Nos. 29, 30, 31

Immediately following is a summary tabulation (29) of all the pertinent soil test data collected for the 6" subgrade soil layer immediately underlying the pavements investigation. This tabulation is made on a project basis and includes the faulting group in which the particular section of pavement fell. In addition, the subgrade soil was classified by the Highway Research Board System of classification as noted above. (33)

Following the summary tabulation, is a graphic summary of some of the more pertinent soil data, recorded both from tests in the laboratory and conditions encountered in the field, (30). The charts were plotted after all test data had been summarized and limits of the faulting groups established. It was anticipated that some "trend" in test results would appear on plotting the data, but such was not the case. There is little apparent correlation between test results data and joint faulting, for it will be noted that within every faulting group from #1 through #9, there is a wide variation of test results. The only test results in which there appears to be any definite trend is in the "Plasticity Index" and "Percent Saturation in Place" charts, and these trends are not marked.

The tabulation of "Average and Extreme Value of Traffic and Soil Test Data" (31) represents the essence of all accumulated data as to joint faulting, traffic load, soil conditions in place, and test results on the subgrade soils.

The tabulation is arranged according to faulting groups and covers the minimum, maximum and average figures for each group as well as for the entire investigation.

The lack of correlation between "good" or "bad" subgrade soils, judged by test results, and "good" or "poor" pavement conditions, as judged by joint faulting, is readily apparent. Also, the traffic loads carried show no correlation. Faulting Group No. 2, which represents the second best pavements has carried the highest traffic load of any group.

The slight "trends" which appeared in plotting test results (30) in the "Percent Saturation in Place" and the "Plasticity Index" columns are again apparent but again are not very definite.

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (a)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l in Place: Rel. Comp. (%)	Mat'l in Place: Degree Satur. (%)	Mat'l in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi	Liquid Limit	Plastic Index	Calif. Bear. Ratio, 0.1" Pen. Comptd at: Field M&D	Calif. Bear. Ratio, 0.1" Pen. Comptd at: Opt. Cond.	Expan. During Soaking: Fld	Expan. During Soaking: Opt	Remarks
A-1	X-Sol-7-B	4	A-6	92	100	23.1	80	73	50	18	34	12	0	17	0.0	1.7	Native Material
A-2,3 4	"	4	A-6	84	95	21.6	99	98	71	27	31	9	1	14	0.5	2.0	Native Material
A-5,6, 7,8,11	"	6	A-4	76	100	36.1	91	84	37	11	37	6	-	87	-	0.2	Imported Subgrade Material - Tuffa
A-13, 14	"	4	A-2-4	-	-	28.3	85	79	28	5	NP	NP		124	-	0.2	Imported Subgrade Mat'l. - Rock & Sand
B-1,2	IV-Mrn-1-A	2	A-2-4	-	-	9.4	72	57	19	8	29	9	-	35	-	1.7	Imported Subgrade Sandy Gravel Mat'l.
B-3	"	4	A-2-4	-	-	9.1	58	47	25	8	27	9	-	23	-	1.9	Rocky Sandy Shale
B-4	"	5	A-2-6	-	-	8.3	54	41	21	8	27	11	-	23	-	2.4	Sandy Shale
B-6	"	5	A-2-4	-	-	8.3	72	63	29	13	28	10	-	89	-	1.0	Sandy, rocky soil and gravel
B-7	"	1	A-1-b	-	-	9.8	67	56	21	9	19	0	-	20	-	2.5	Imported Subgrade Sandy Rocky Mat'l.
B-8	"	5	A-2-4	100	95	9.4	79	76	31	15	25	9	111	77	0.9	1.0	Sandy Gravelly Soil
B-9, 14	"	6	A-2-6	74	57	12.6	78	67	32	12	30	13	3	8	0.5	4.9	Crusher Run Base
B-11, 12	"	3	A-2-6	85	73	12.3	66	53	20	9	32	13	8	25	0.5	2.7	Broken Rock (2"-) & Clayey Soil
B-13	"	6	A-2-6	94	100	10.8	66	56	27	14	30	13	23	15	0.7	2.9	Clayey Soil & Rock
C-1	X-SJ-4-D	4	A-2-6	75	48	10.9	81	71	29	12	28	12	3	22	-	2.2	Imp. Sg. Mat'l. Clayey Sand & Gravel
C-2	"	4	A-6	87	100	17.5	100	99	60	23	31	12	2	4	0.8	6.3	Imp. Sg. Mat'l. Clayey Sand & Gravel
C-3, 11	"	4	A-6	92	100	15.6	98	96	47	20	28	13	6	6	1.3	4.8	Imp. Sg. Mat'l. Clayey Sand & Gravel
C-4	"	4	A-6	88	90	14.7	91	87	52	21	30	12	10	6	1.1	5.3	Imp. Sg. Mat'l. Clayey Sand & Gravel
C-5	"	3	A-4	87	99	15.9	97	97	47	14	26	10	3	7	0.4	4.8	Imp. Sg. Mat'l. Clayey Sand & Gravel

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. Comptd. at field M&D	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Opt. Cond.	Expan. During Soaking: Fld.	Expan. During Soaking: Opt.	Remarks
C-6, 24	X-SJ-4-D	NJ (1)	A-4	96	66	7.6	100	99	47	14	16	2	56	36	0.5	0.5	Native Mat'l. Sandy Silty Loam
C-7, 21	"	NJ (4)	A-4	93	72	11.0	100	99	57	20	18	5	10	14	0.2	0.5	Native Mat'l. Sandy Silty Loam
C-8,9, 12,23	"	NJ (20)	A-4	92	40	6.1	100	99	40	12	14	1	22	37	0.3	0.2	Native Mat'l. Sandy Silty Loam
C-10	"	3	A-2-6	91	91	10.8	85	72	30	13	27	12	9	12	0.7	2.4	Imp. Sg. Mat'l. Sandy Silty Gravel
C-13	"	NJ (2)	A-4	99	67	7.2	100	99	46	14	16	3	6	38	0.5	0.2	Native Mat'l. Micaceous Sandy Soil
C-14,15 17,20	"	6	A-2-4	90	44	7.2	100	99	33	9	15	1	12	32	0.2	0.4	Native Mat'l. Micaceous Sandy Soil
C-16 18,19	X-SJ-4-C	6	A-4	96	87	11.0	95	94	45	13	18	5	7	31	0.2	0.4	Imp.Sg.M. Silty Clayey Micaceous Sd & Gr.
D-1,2 3,4	IV-Scl 68-B	2	A-1-b	94	61	5.6	72	58	16	6	18	2	56	93	0.3	0.2	Imp. Sg. Mat'l. Gravel & Coarse Sand
D-5,6	IV-Scl 68-A	5	A-1-a	101	100	7.0	50	39	6	3	20	2	98	123	0.1	0.3	Imp. Sg. Mat'l. Gravel & Coarse Sand
D-7	IV-SM-68-A	6	A-2-4	-	-	-	40	29	14	5	31	10	-	107	-	0.5	Imp. Material Clayey Gravel
D-8	"	6	A-2-6	-	-	12.1	57	48	20	5	29	12	-	15	-	2.5	Imp. Sg. Mat'l. Crusher Run Base
D-9	"	NJ (14)	A-2-4	89	69	16.4	95	93	19	7	NP	NP	2	29	0.0	0.7	Imp. Sg. Mat'l. Brown Clayey Sand
D-10,11 15,16	"	6	A-1-b	86	62	10.0	69	57	13	5	23	3	11	118	0.0	0.2	Imp. Sg. Mat'l. Sand & Crushed Rock
D-12	"	NJ (8)	A-2-4	101	95	13.9	93	91	17	7	NP	NP	8	33	0.2	0.6	Imp. Sg. Mat'l. Fine, Clayey Sand
D-13	"	NJ (10)	A-2-4	96	76	12.9	97	96	20	9	NP	NP	21	40	0.2	0.5	Imp. Sg. Mat'l. Fine, Clayey Sand
D-14	"	NJ (6)	A-2-4	99	95	15.1	100	98	20	7	NP	NP	22	31	-	0.7	Imp. Sg. Mat'l. Fine, Clayey Sand
D-17	"	6	A-1-b	90	86	10.6	59	48	18	6	26	4	19	90	0.2	0.3	Imp. Sg. Mat'l. Clayey Soil & Rock
D-18	"	6	A-1-a	-	-	-	38	29	11	3	26	5	-	214	-	0.2	0 to -4" Gravel for Joint Drain

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (c)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in place: Rel. Comp. (%)	Mat'l. in place: Degree Satur. (%)	Mat'l. in place: Moist. Cont. (%)	Grading (% Passing): #4	Grading: #10	Grading: #200	Grading: 5 mi	Liquid Limit	Plastic. Index.	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Field M&D	0.1" Pen. Comptd. at Opt Cond.	Expan. During Soaking: Fld	Expan. During Soaking: Opt	Remarks
D-19,20 21,22	IV-SM-68-A	6	A-2-4	91	78	9.0	57	47	19	8	27	8	27	85	0.3	0.9	Local Mat'l. Clayey Soil and Shale
D-23	"	B(1)	A-2-4	89	86	12.4	78	68	28	12	27	9	8	27	0.6	1.9	Local Mat'l. Clayey Soil and Shale
E-1,2,5 9,19,20	IV-Scl-5-A	6	A-2-6	82	62	13.0	83	61	21	11	36	15	11	67	0.5	1.2	Imp. Sg. Mat'l. Clayey Cherty Mat'l.
E-3, 4	"	6	A-2-6	86	100	19.2	84	71	35	22	39	19	2	15	-	2.0	Imp. Sg. Mat'l. Clayey Cherty Mat'l.
E-6, 7	"	B(2)	A-7-6	81	97	21.9	100	97	72	44	48	29	11	3	2.6	3.3	Native Material Black Adobe
E-10,11 12,13	IV-Ala-5-C	7	A-2-7	88	94	14.3	89	72	32	18	46	25	14	88	-	2.6	Top 2" Clean Sd. -2" Clayey Cherty Mat'l.
E-14	"	B(5)	A-6	89	100	12.8	89	84	44	25	36	22	9	7	1.0	4.0	Imp. Sg. Mat'l. Shaley Clay Soil
E-16	"	B(6)	A-7-6	87	100	14.9	100	95	67	41	47	27	19	4	4.6	7.7	Imp. Sg. Mat'l. Shaley Clay Soil
E-17	"	7	A-2-6	85	88	14.7	86	73	34	20	40	20	6	8	0.6	5.0	Imp. Sg. Mat'l. Shaley Clay Soil
E-18, 21,22	IV-Scl 5-A	6	A-2-6	98	100	13.2	91	68	28	16	38	17	15	23	0.8	2.3	Imp. Sg. Mat'l. Clayey Cherty Mat'l.
E-23, 24	IV-Ala 5-C	7	A-2-7	88	94	14.3	89	72	32	18	46	25	5	14	-	2.6	Thin Sd. Layer Over Clayey Cherty Mat'l.
F-1,2, 5,6	V-Mon-2-A	4	A-2-4	93	79	9.8	94	88	41	14	18	4	8	51	0.2	0.2	Native Material Sandy Loam
F-3	V-Mon-2-J	6	A-1-b	89	54	7.2	67	50	14	3	21	2	24	164	0.2	0.1	Imp. Sg. Mat'l. D.G.
F-4	"	6	A-4	86	66	11.3	95	93	43	14	18	6	1	38	-	0.6	Native Material Sandy Loam
F-7	"	7	A-2-4	82	53	10.2	92	79	26	11	23	9	3	79	-	0.6	Imp. Sg. Mat'l. D.G.
F-8, 9	(8)2-J (9)2-A	4	A-1-b	85	54	9.4	91	69	17	5	30	5	12	81	0.3	0.7	Imp. Sg. Mat'l. D.G.
F-10, 11,12	V-Mon-2-A	5	A-4	101	92	11.5	94	89	50	17	19	5	4	64	0.0	0.6	Native Material Sandy Loam
F-13	"	4	A-4	100	100	11.0	95	91	49	16	19	5	5	72	0.1	0.7	Native Material Sandy Loam

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Field M&D	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Opt. Cond.	Calif. Bear. Ratio: Expan. During Soaking Fld	Calif. Bear. Ratio: Expan. During Soaking Opt.	Remarks
F-14, 15	V-Mon-2-J	6	A-2-4	91	52	10.2		100	15	11	19	3	12	21	0.3	0.3	Native Material Sandy Soil
F-16	"	7	A-2-4	94	68	10.6	100	99	26	14	16	2	11	22	0.1	1.2	Native Material Sandy Soil
F-17	"	7	A-2-4	97	100	17.2	100	99	23	14	22	7	-	23	-	1.7	Native Material Sandy Soil
F-18	"	7	A-2-4	92	92	16.0	100	99	22	15	22	7	3	31	-	1.0	Native Material Sandy Soil
F-19	"	6	A-2-6	89	71	12.4	100	99	31	18	24	11	10	15	0.1	2.1	Native Material Sandy Soil
G-1,2 27	V-SB-2-L	6	A-2-4	104	26	5.1		100	13	5	NP	NP	72	13	0.2	0.1	Native Material Sand
G-3	"	6	A-2-4	111	57	7.3		100	19	6	NP	NP	81	10	0.2	0.1	Native Material Silty Sand
G-4	"	6	A-2-4	31	14	8.2		100	15	5	NP	NP	31	14	0.1	0.2	Native Material Sandy Soil
G-5,6	"	NJ (18)	A-2-4	102	53	8.1		100	26	7	NP	NP	29	53	0.1	0.2	Native Material Clayey Sandy Soil
G-7	"	6	A-2-4	101	45	7.4		100	22	7	NP	NP	51	20	0.1	0.2	Native Material Sand
G-8	"	6	A-2-4	112	37	5.8		100	8	3	NP	NP	46	14	0.1	0.2	Native Material Sand
G-9	"	B(3)	A-4	83	98	22.4	99	98	63	25	31	4	3	4	-	6.2	Local Material Plastic, Silty Clay
G-10	"	B(4)	A-7-6	78	100	28.3	100	99	74	37	46	27	1	4	-	5.0	Local Material Plastic Clay
G-11	"	6	A-2-4	103	85	11.5	96	95	23	9	16	2	31	29	0.1	0.3	Imp. Sg. Mat'l. Clayey Sand
G-12,13	"	6	A-2-4	94	72	13.4	97	95	22	10	16	2	7	29	0.0	0.6	Imp. Sg. Mat'l. Clayey Sand
G-14,15 16,17,18	V- SB-2-M	6	A-1-b	91	96	14.7	78	65	19	5	NP	NP	-	52	-	1.2	Imp. Sg. Mat'l. Oiled Sand
G-19, 23	"	7	A-2-4	97	94	15.6	99	97	34	13	23	5	2	50		0.5	Native Material Clayey Sand
G-20, 21	"	7	A-2-4	93	90	18.2	99	96	32	11	23	5	0	62	-	0.3	Native Material Clayey Sand

Research No. 00204 — Reference No. 29 (e)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l in Place: Rel. Comp. (%)	Mat'l in Place: Degree Satur. (%)	Mat'l in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading: # 10	Grading: # 200	Grading: 5 Mi	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. Comptd at Field M&D	Calif. Bear. Ratio: 0.1" Pen. Comptd at Opt Cond	Expan. During Soaking: Fld	Expan. During Soaking: Opt	Remarks
G-26	V-SB-2-L	6	A-2-4	104	26	5.1		100	13	5	NP	NP	72	13	0.2	0.1	Native Material Sd. some clay chunks
G-28, 29	"	5	A-2-4	-	-	9.6	94	91	21	8	NP	NP	-	35	-	0.3	Imp. Sg. Mat'l. Clayey Sd., Small rock
G-30	V-SB-2-M	7	A-4	85	87	19.0	100	99	62	17	26	7	2	8	-	3.0	Imp. Sg. Mat'l. Silty, Sandy Clay
G-31	"	7	A-4	88	78	15.5		100	54	17	26	7	10	8	0.8	3.0	Imp. Sg. Mat'l. Silty Sandy Clay
H-1,2, 3	VI-Fre-4-C	4	A-2-4	98	64	8.8	98	96	25	9	15	2	55	63	0.4	0.2	Imp. Sg. Mat'l. Sandy Soil & Hardpan
H-6,7, 8	"	3	A-2-4	100	70	7.7	100	98	34	9	14	2	70	31	0.2	0.0	Imp. Sg. Mat'l. Sandy, Micaceous Soil
H-9, 10	"	2	A-2-4	97	77	10.9	100	98	33	5	15	1	22	65	0.1	0.3	Imp. Sg. Mat'l. Sandy Soil
I-1, 2,3	VII-LA 4-J	6	A-4	89	75	14.2	100	98	50	8	25	10	11	14	0.7	2.0	Native Material Sandy Clayey Soil
I-4,5	"	4	A-6	97	91	13.7	100	99	46	7	28	12	19	20	0.5	1.7	Native Material Sandy Clayey Soil
I-6,7 8	"	7	A-2-4	104	99	7.8	85	72	25	6	22	9	82	52	0.2	0.2	Imp. Sg. Mat'l. D.G.
I-9	"	6	A-1-b	98	68	8.6	91	83	17	5	19	4	69	101	0.1	0.1	Imp. Sg. Mat'l. D.G. & Sandy Soil
K-1,2	VII-LA 26-A	5	A-1-b	105	91	8.2	74	63	15	5	23	6	142	140	0.2	0.2	Imp. Sg. Mat'l. D.G. & Gravel
K-3,4	"	4	A-2-4	103	61	8.8	96	93	26	4	NP	NP	107	55	1.0	0.9	Native Material Silty Sd. some rock
K-5	VII-LA 26-B	7	A-1-b	92	5	0.7	77	73	4	1	NP	NP	14	83	0.1	0.2	Imp.Sg.M Loose Fine Sand, some rock
K-6	"	7	A-2-4	100	17	3.3	86	82	8	1	NP	NP	61	61	0.3	0.2	Imp.Sg.M. Loose Fine Sand, some rock
K-7	"	7	A-2-4	94	11	2.6	91	87	11	1	NP	NP	16	61	0.2	0.2	Imp.Sg.M. Loose Fine Sand, some rock
K-8,9 10	"	4	A-1-b	95	25	3.9	75	69	13	3	NP	NP	60	119	0.5	0.5	Oil Treated Sand Gr. & Screenings
K-11, 12	"	6	A-6	83	63	14.3		100	70	19	31	13	11	4	1.5	5.1	Sandy, Clayey Micaceous silt

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (f)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l in Place: Rel. Comp. (%)	Mat'l in Place: Degree Satur. (%)	Mat'l in Place: Moist. Cont. (%)	Grading (% Passing): # 4	# 10	# 200	5 Mi	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. comptd. at Field M&D	0.1" Pen. comptd. at Opt Cond.	Expan. During Soaking Fld	Expan. During Soaking Opt	Remarks
K-13, 24 25,28,35	VII-LA 26-B	6	A-6	90	80	14.7		100	68	18	27	14	14	5	1.2	4.5	Native Material Micaceous Clayey Silt
K-16, 17, 18	VII-LA 26-C	7	A-4	95	70	9.6	99	94	46	12	15	2	38	39	1.3	1.1	Nat. Mat'l. Micaceous Clayey Sandy Silt
K-19	"	4	A-1-b	92	37	4.6	100	95	17	3	NP	NP	126	107	0.3	0.3	Imp. Sg. Mat'l. Rock Dust and Sand
K-20, 21	"	4	A-1-b	91	41	5.2	98	91	16	4	NP	NP	113	107	0.3	0.3	Imp. Sg. Mat'l. Rock Dust and Sand
K-22, 23	VII-LA 26-B	1	A-2-4	101	42	5.7	82	77	13	3	NP	NP	104	73	0.3	0.3	Imp. Sg. Mat'l. Clayey, Silty Sand
K-26, 28	"	6	A-4	86	59	12.8		100	69	18	25	10	20	5	2.2	3.9	Native Material Micaceous Clayey Silt
K-27 29	"	6	A-4	89	63	11.9		100	69	17	25	10	23	5	2.1	3.9	Native Material Micaceous Clayey Silt
K-30, 34	"	6	A-6	84	61	14.4		100	70	16	28	12	11	5	1.6	4.6	Native Material Micaceous Clayey Silt
K-33, 36	"	6	A-6	85	69	14.7		100	71	17	27	14	13	4	1.7	3.9	Native Material Micaceous Clayey Silt
K-37 39,40	"	6	A-4	91	98	16.5		100	68	17	25	8	10	8	0.8	3.8	Native Material Micaceous Clayey Silt
K-38	"	6	A-4	86	57	11.8		100	68	17	25	8	21	8	3.0	3.8	Native Material Micaceous Clayey Silt
M-1	VII-Ora 2-C	5	A-6	82	49	11.3	92	90	60	22	27	11	26	5	6.6	4.9	Native Material Sandy Silty Clay
M-2,3	"	5	A-6	89	55	10.4	94	93	61	22	27	11	45	5	6.3	4.9	Native Material Sandy Silty Clay
M-4,5	"	7	A-6	89	100	19.0	95	93	49	22	26	14	3	10	-	3.7	Native Material Sandy Silty Clay
M-6	"	7	A-4	93	94	12.7	95	92	40	17	22	6	12	20	0.5	2.0	Native Material Sandy Clay
M-7	"	2nd S (1)	A-6	85	81	16.1	100	99	46	19	29	17	6	10	0.6	2.5	Native Material Sandy Clay
M-8,9	"	2nd S (2)	A-6	85	40	7.4	100	99	44	17	28	18	47	24	4.0	1.9	Native Material Sandy Silty Clay
M-10	"	2Nd S (3)	A-6	94	95	12.4	100	99	47	20	28	18	54	24	2.1	1.9	Native Material Sandy Silty Clay

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (g)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter And Sample Number	Dist. County Route Sec-Tion	Faulting Group Number	H.R.B. Soil Class	Material in Place: Rel. Comp. (%)	Degree Satur. (%)	Moist. Cont. (%)	Grading (% Passing): # 4	# 10	# 100	5 Mi.	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. at Compt.: Field M&D	Opt. Cond.	Expan. During Soaking: Fld	Opt	Remarks
M-11	VII-Ora 2-C	7	A-7-6	88	100	16.7	92	90	58	23	41	27	8	3	1.1	6.4	Native Material Silty Clay
M-12, 13	"	7	A-7-6	85	95	18.3	99	97	59	27	42	28	10	3	1.4	6.4	Native Material Silty Clay
M-14	"	9	A-4	80	94	19.0	100	98	52	26	27	10	6	4	1.0	6.0	Native Material Silty, Clayey Soil
M-15	"	9	A-7-6	82	100	23.9	100	98	64	32	53	40	4	3	-	6.5	Native Material Silty Clay
M-16	"	7	A-7-6	80	74	17.4	100	99	67	39	53	40	22	3	4.3	6.5	Native Material Silty Clay
M-17	"	5	A-6	82	50	11.0	100	99	76	28	39	13	34	3	7.8	5.7	Native Material Silty, Clayey Sand
M-18	"	5	A-6	88	45	8.5	100	98	63	25	36	25	57	4	8.0	6.0	Native Material Silty, Clayey Sand
M-19, 20	"	5	A-6	87	38	7.6	87	86	55	21	36	25	105	4	10.7	5.0	Native Material, Silty Clayey Sd. Some Rock
M-21, 24	"	7	A-6	87	80	13.6	95	94	38	15	28	17	9	33	1.1	1.1	Native Material Clayey Sd. few rocks
M-22	"	7	A-2-6	98	85	9.6	100	98	34	13	28	17	69	33	1.2	1.0	Native Material Clayey Sd. few rocks
M-23, 25	"	7	A-6	92	100	14.0	98	96	49	17	32	22	11	15	0.7	3.0	Native Material Sandy Clay, few rocks
M-26	"	7	A-6	88	90	14.3	87	84	47	17	27	17	5	10	0.4	3.3	Native Material Sandy Clay, few rocks
N-1	VII-Ora 60-C	4	A-7-6	-	-	15.2	98	95	57	26	45	32	-	7	-	3.2	Imp. Sg. Mat'l. Sandy Adobe
N-2	"	5	A-7-6	83	95	18.5	96	94	60	32	45	32	6	7	1.5	3.2	Imp. Sg. Mat'l. Sandy Adobe
N-3	"	7	A-7-6	-	-	18.1	100	99	62	26	45	32	-	7	-	3.2	Imp. Sg. Mat'l. Sandy Adobe
N-4 6	"	7	A-2-4	98	41	7.4	100	98	15	6	NP	NP	38	37	0.2	0.2	Imp. Sg. Mat'l. Clayey Sand
N-5, 8	"	7	A-2-4	99	58	9.3	99	98	14	7	16	6	42	37	0.2	0.2	Native Material Clayey Sand
N-7, 24	"	7	A-2-4	94	56	10.7	100	99	14	7	16	6	21	40	0.1	0.2	Native Material Clayey Sand

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (h)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter And Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi.	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. at Comptd. Field M&D	Calif. Bear. Ratio: 0.1" Pen. at Opt Cond.	Calif. Bear. Ratio: Expan. During Soaking Fld	Calif. Bear. Ratio: Expan. During Soaking Opt	Remarks
N-9, 10	VII-Ora 60-C	6	A-2-4	97	60	10.8	100	99	15	10	NP	NP	35	40	0.1	0.1	Native Material Sandy Soil
N-11	"	7	A-6	89	100	27.1	100	94	48	21	40	23	2	6	-	3.8	Native Material Sandy Clay
N-12, 13	"	8	A-1-b	97	54	7.2	88	83	14	5	14	2	38	54	0.1	0.1	Imp. Sg. Mat'l. Rock Sand
N-14	"	8	A-1-b	95	56	8.1	88	80	9	4	14	2	24	56	0.1	0.1	Imp. Sg. Mat'l. Gravelly Sand
N-15	VII-Ora 60-LgaB	7	A-2-6	82	66	11.7	82	74	24	7	22	12	2	100	-	0.3	Native Material Clayey Sd Soil & Gr.
N-16	"	7	A-2-6	89	92	12.1	80	70	29	11	22	12	2	100	-	0.3	Native Material Clayey Sd Soil & Gr.
N-17	"	7	A-2-6	86	77	11.5	86	76	34	11	22	12	4	100	-	0.3	Native Material Clayey Sd Soil & Gr.
N-18	"	7	A-2-6	92	100	11.6	77	66	25	10	27	15	3	140		0.7	Native Material Clayey Sand
N-19	"	4	A-2-4	94	80	10.9	100	98	28	13	18	8	19	61	0.2	0.7	Native Material Sandy Soil
N-20	"	4	A-2-4	95	70	10.0	100	98	26	12	18	8	46	61	0.2	0.7	Native Material Sandy Soil
N-21	"	1	A-2-6	80	90	11.0	73	69	19	9	28	17	7	93	0.0	0.9	Native Material Clayey Sand
N-22, 26	"	1	A-2-4	88	57	9.7	92	89	24	9	21	8	13	88	0.2	0.5	Native Material Clayey Sand
N-23, 25	VII-Ora 60-C	7	A-2-4	95	45	8.3	99	99	17	8	NP	NP	27	42	0.3	0.3	Native Material Sand
O-1, 2,3	XI-SD-12-G	3	A-1-b	95	58	6.1	99	83	14	5	24	3	75	76	0.5	0.3	Native Material D.G.
O-4	"	2	A-1-b	95	43	6.6	97	76	11	4	NP	NP	54	81	0.3	0.3	Native Material D.G.
O-5,6	"	2	A-1-b	97	47	6.6	96	74	9	4	NP	NP	73	81	0.3	0.3	Native Material D.G.
O-7	XI-SD-12-F	4	A-2-4	94	74	10.1	98	89	21	5	NP	NP	38	90	0.0	0.3	Native Material D.G.
O-8	"	4	A-1-b	87	62	11.7	98	83	17	5	NP	NP	9	81	0.1	0.3	Native Material D.G.

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (1)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi.	Liquid Limit	Plastic Index	Calif. Bear. Ratio, 0.1" Pen. Compt. at: Field M&D	Calif. Bear. Ratio, 0.1" Pen. Compt. at: Opt. Cond.	Expan. During Soaking: Fld	Expan. During Soaking: Opt	Remarks
0-9,10 11,41	XI-SD-12-F	1	A-2-4	96	72	9.9	97	88	27	8	NP	NP	40	34	0.7	0.8	Native Material Loam & D.G.
0-12, 14	XI-SD-12-E	4	A-2-4	91	52	8.2	97	88	22	4	NP	NP	35	90	0.6	0.3	Native Material Loam & D.G.
0-13	"	4	A-2-4	90	43	7.5	100	89	22	5	NP	NP	18	90	0.6	0.3	Native Material Loam & D.G.
0-15, 16,21	"	3	A-2-4	92	74	11.5	98	92	32	8	NP	NP	23	29	0.8	1.1	Imp. Sg. Material Sandy Soil
0-17,18 23	"	3	A-2-4	94	50	7.5	99	84	26	7	NP	NP	50	56	1.1	0.8	Imp. Sg. Material Loam & D.G.
0-19, 20	XI-SD-12-D	5	A-2-4	93	64	9.7	95	82	25	7	NP	NP	13	56	0.6	0.8	Imp. Sg. Material D.G.
0-22, 28	"	5	A-2-4	88	73	13.5	85	78	32	11	29	6	10	25	0.3	1.5	Imp. Sg. Material D.G.
0-29, 30,31	"	4	A-2-4	85	54	10.2	100	92	22	7	NP	NP	8	21	0.7	1.1	Native Material Micaceous Loamy D.G.
0-32, 33	"	5	A-6	81	85	18.8	100	95	49	21	29	13	9	5	0.7	1.2	Native Material Clayey D.G. Soil
0-34, 35	XI-SD-12-C	5	A-2-4	88	48	8.5	100	94	23	7	NP	NP	17	45	0.5	0.8	Native Material D.G. Soil
0-36, 37,38	"	5	A-1-b	92	83	11.3	98	78	17	6	NP	NP	21	62	0.1	0.2	Native Material D.G. Cushion Course
0-39	"	5	A-4	97	64	9.7	100	98	40	11	NP	NP	29	31	0.3	0.4	Native Material Loamy Soil
0-40	"	5	A-4	88	51	10.3	100	98	39	11	NP	NP	5(-)	31	-	0.4	Native Material Loamy Soil
P-1,2, 13	XI-Riv 26-G	6	A-1-a	101	53	4.9	52	46	8	2	NP	NP	135	108	0.1	0.1	Imp. Select Mat'l. Coarse Sd. & Gravel
P-3,4, 15,18	XI-Riv 26-G	5	A-4	78	46	20.0	99	99	47	4	NP	NP	5(-)	14	-	1.1	Micaceous Sandy Silt Cushion Course
P-5,6 14	"	5	A-1-a	-	-	2.0	54	45	4	1	NP	NP	-	100	-	0.1	Imp. Select Mat'l. Coarse Sd. & Gravel
P-7	"	4	A-1-b	89	40	8.6	91	82	9	3	NP	NP	8	68	0.0	0.2	Imp. Sg. Mat'l. Coarse Sand Cushion course
P-8	"	4	A-1-b	104	53	6.9	87	80	10	3	NP	NP	150	68	0.2	0.2	Imp.Sg.M. Coarse Sand Cushion Course

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (j)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi	Liquid Limit	Plastic Index	Calif. Bear. Ratio: 0.1" Pen Comptd at Field M&D	Calif. Bear. Ratio: 0.1" Pen Comptd at Opt. Cond	Calif. Bear. Ratio: Expan. During Soaking Fld	Calif. Bear. Ratio: Expan. During Soaking Opt	Remarks
P-9,10,11 12,16,17	XI-Riv 26-G	6	A-4	80	73	25.6	100	99	60	7	NP	NP	5(+)	21	-	1.1	Micaceous Sandy Silt Cushion Course
R-1,2, 3	V-SB-2-D	NJ (19)	A-2-4	101	100	14.5	90	82	35	14	26	7	23	64	0.4	1.0	Native Material Silty Sd. & Gravel
R-4,5, 6	V-SB-2-D	4	A-1-a	94	94	12.1	64	50	12	4	23	4	21	83	0.0	0.3	Imp. Sg. Mat'l. Sand and Gravel
R-7,8, 9	"	1	A-1-a	104	100	11.3	58	50	13	4	23	4	6	85	0.0	0.4	Imp. Sg. Mat'l. Sand and Gravel
R-10	"	4	A-1-b	87	79	13.3	61	51	10	4	23	4	9	83	0.1	0.3	Imp. Sg. Mat'l. Sand and Gravel
R-11, 12,13	V-SB-2-E	7	A-4	84	86	18.1	100	99	45	16	23	8	2	41	0.0	0.7	Native Material Silty Sand
S-1	VII-Ora 171-A	2	A-4	79	69	16.7	100	98	43	21	28	8	3	9	-	3.0	Imp. Sg. Mat'l. Clayey Sand
S-2,4	"	2	A-4	88	63	12.6	99	98	40	22	27	8	25	11	2.5	2.7	Imp. Sg. Mat'l. Clayey Sand
S-3,6	"	2	A-6	79	62	14.3	100	99	52	29	29	12	14	7	3.0	4.2	Imp. Sg. Mat'l. Silty Clayey Sand
S-5	"	2	A-6	82	94	19.0	100	98	53	33	29	16	4	4	-	2.5	Imp. Sg. Mat'l. Silty Clayey Sand
S-7,9	"	1	A-4	96	66	9.8	98	95	43	13	17	3	30	60	0.6	0.7	Native Material Clayey Sand
S-8	"	1	A-4	83	40	9.1	100	98	56	13	17	3	5	60	0.5	0.7	Native Material Clayey Sand
S-10	"	1	A-4	93	66	10.7	100	98	57	15	17	3	16	60	0.5	0.7	Native Material Clayey Sand
S-11, 12	"	2	A-6	91	69	13.1	99	97	40	12	27	11	16	11	0.8	2.8	Imp. Sg. Mat'l. Silty Clayey Sand
S-13, 14	VII-Ora 184-A	4	A-6	99	94	8.2	92	88	49	26	31	17	91	58	1.0	1.5	Imp. Sg. Mat'l. Sandy Clay, Gr. & DG
S-15	"	4	A-2-6	97	77	8.3	74	67	19	9	27	23	53	122	0.2	0.7	Imp. Sg. Mat'l. Sandy Clay, Gr. & DG
S-16, 17,18	"	3	A-2-5	-	60	8.5	70	60	13	6	50	9	14	-	0.1	-	Imp. Sg. Mat'l. Sandy Clay, Gr. & DG
T-1, 12	VIII-SBd 26-D	6	A-1-a	107	35	2.4	48	37	4	2	NP	NP	273	135	0.1	0.1	Imp. Sg. Mat'l. Coarse Sd. and Gravel

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 29 (k)

SUBGRADE SOILS: CLASSIFICATION AND TEST DATA

Job Letter and Sample Number	Dist. County Route Section	Faulting Group Number	H.R.B. Soil Class	Mat'l. in Place: Rel. Comp. (%)	Mat'l. in Place: Degree Satur. (%)	Mat'l. in Place: Moist. Cont. (%)	Grading (% Passing): # 4	Grading (% Passing): # 10	Grading (% Passing): # 200	Grading (% Passing): 5 Mi.	Liquid Limit	Plastic. Index	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Field M&D	Calif. Bear. Ratio: 0.1" Pen. Comptd. at Opt Cond.	Calif. Bear. Ratio: Expan. During Soaking Fld	Calif. Bear. Ratio: Expan. During Soaking Opt	Remarks
T-2, 3,4	VIII-SBd 26-D	5	A-1-a	108	61	3.5	54	44	12	3	NP	NP	288	115	0.2	0.1	Imp. Sg. Mat'l. Clayey Sd & Gravel
T-5, 6,7	"	1	A-2-4	101	74	10.5	84	80	17	3	19	.8	66	72	0.5	0.2	Imp. Sg. Mat'l. Sand & Gravel
T-8, 9	"	6	A-1-a	109	38	2.2	52	42	6	2	NP	NP	330	122	0.2	0.6	Imp. Sg. Mat'l. Clayey Sand & Gravel
T-10, 11	"	3	A-2-4	104	53	7.6	92	88	25	4	NP	NP	87	67	0.4	0.3	Imp. Sg. Mat'l. Clayey Sand & Gravel
V-1, 2,3	VII-Ala Street	2	A-2-6	103	62	6.2	94	81	19	7	26	13	196	133	1.2	0.2	Imp. Sg. Mat'l. D.G.
V-4, 5,6	"	2	A-2-4	105	65	5.5	93	77	16	5	22	9	221	127	0.3	0.3	Imp. Sg. Mat'l. D.G.
W-1, 2,3	VII-LA-Bev.Blvd	4	A-6	84	57	12.4	92	91	51	7	30	16	10	23	1.0	2.0	Native Material Sandy Silty Soil
X-1, 2,3	VII-LA-Pico Blvd	3	A-6	88	94	14.4	100	99	50	23	29	18	12	6	1.0	4.2	Native Material Silty Clay

Relative Compaction Based on Maximum Density, (at Optimum Conditions as used in CBR Test), as equal to 100%

Moisture Content in place expressed as % of Dry Weight of the soil

#Samples from Areas of pavement which had no joints (NJ), or were Second Story (2nd S) or were blanketed (B) with Asphaltic Mixtures.

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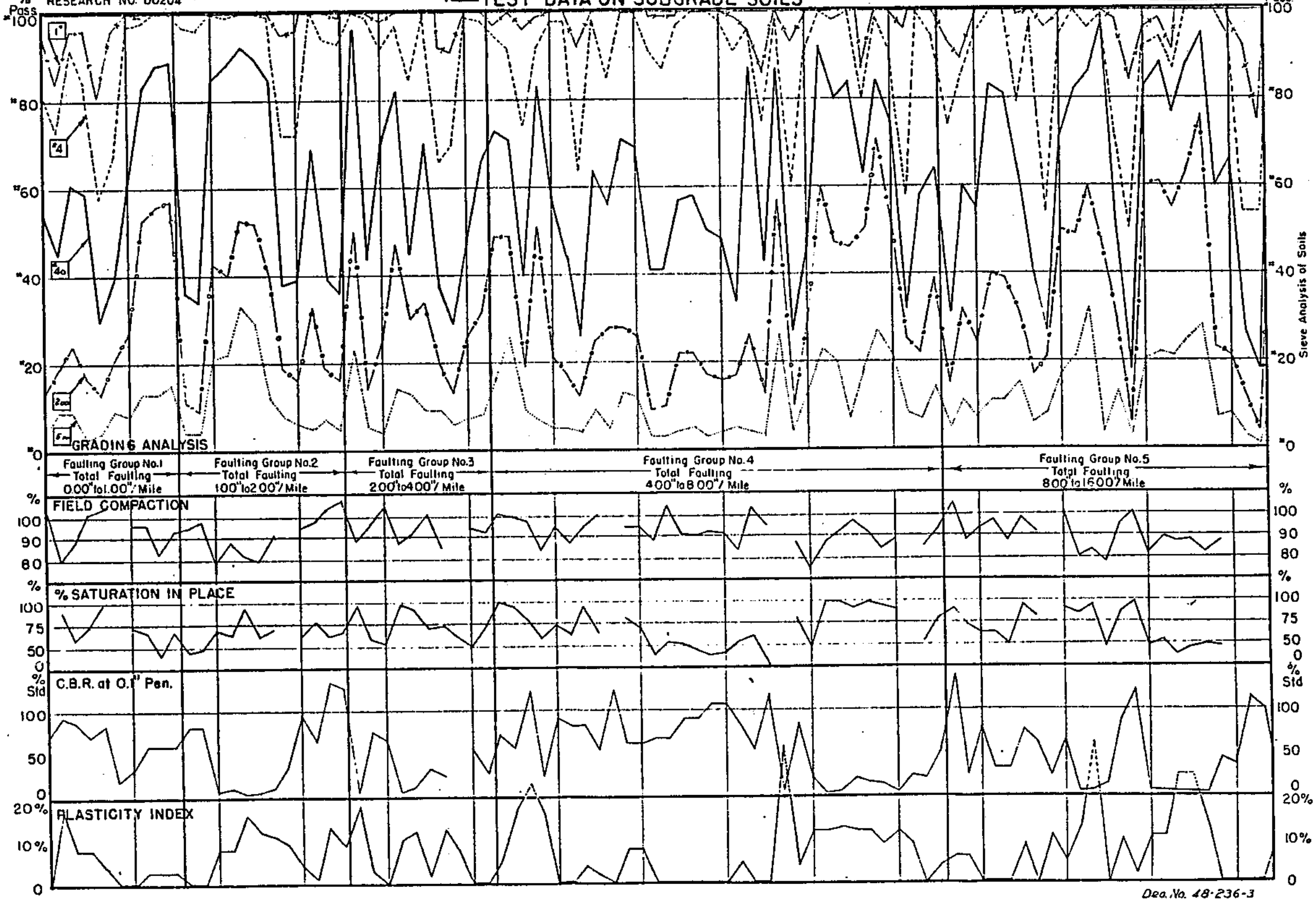
RESEARCH NO. 00204

INVESTIGATION OF P.C.C. PAVEMENT JOINTS
—TEST DATA ON SUBGRADE SOILS—

REFERENCE NO. 30 (a)
SKETCH NO. ______



Dwg. No. 48-236-3

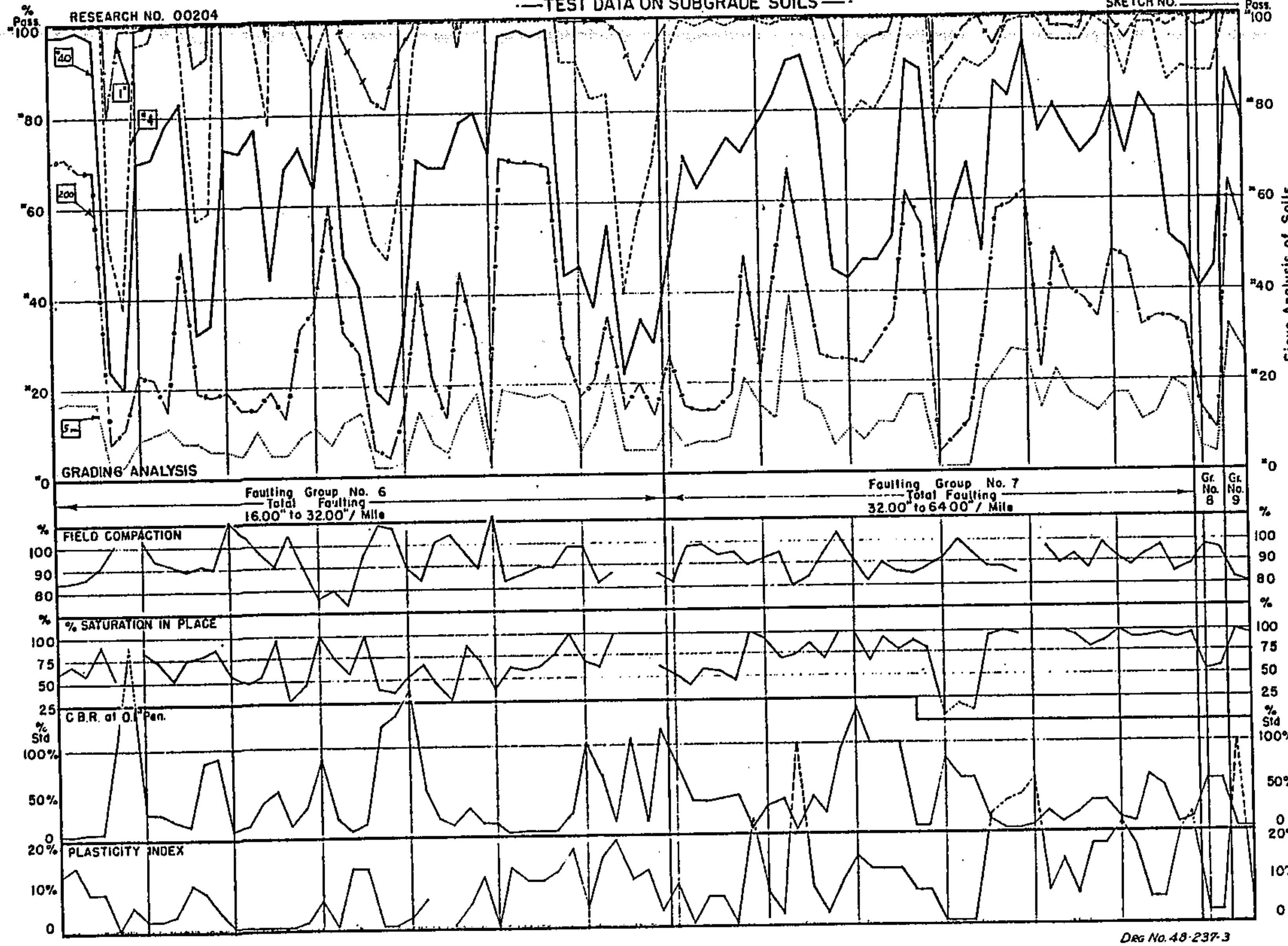
MATERIALS & RESEARCH DEPT.

RESEARCH NO. 00204

INVESTIGATION OF P.C.C. PAVEMENT JOINTS
—TEST DATA ON SUBGRADE SOILS—

REFERENCE NO. 30 (b)

SKETCH NO. ______



DRG No. 48-237-3

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 31

Average and Extreme Values of Traffic and Soil Test Data as Related to Joint Condition

Faulting GROUP NO.	JOINT FAULTING - In Inches per mile		TRAFFIC Millions of 5000 Lb. EWLs		SUBGRADE SOIL TEST DATA: Soil in Place, % Relative Compact.		Soil in Place, % Saturated		Grading Percent Passing #4		#200		5 mi.		Plasticity Index		Calif. Bearing Ratio: 0.1" Pen. Standard Compact.		0.1" Pen Field D & M		Exp. in Soaking Std. Comp.	
	Min.	Max.	Min.	Max.	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	0.00	0.88	0.63	11.4	79	104	40	100	58	100	13	57	3	33	NP	18	4	164	1	104	0.1	4.2
2	1.06	1.94	0.60	101.8	79	105	40	99	72	100	9	57	4	33	NP	18	4	133	3	221	0.1	4.8
3	2.11	3.70	0.60	13.5	85	104	43	99	66	100	9	50	4	23	NP	18	6	90	3	87	0.1	4.8
4	4.05	7.92	0.63	13.5	74	109	25	100	48	100	4	71	2	27	NP	32	4	135	0	330	0.1	6.3
5	8.27	15.66	0.60	20.8	78	108	5	100	38	100	4	76	1	32	NP	32	3	214	0	288	0.1	6.0
6	16.19	31.70	0.60	20.8	74	112	26	100	38	100	4	71	2	22	NP	23	4	214	0	330	0.1	5.1
7	32.74	61.95	2.7	13.6	82	104	5	100	77	100	11	67	1	39	NP	40	3	140	0	82	0.1	6.5
8	72.16	72.16	2.7	2.7	95	97	54	56	88	88	9	14	4	5	2	2	58	58	24	38	0.1	0.1
9	102.14	163.39	8.2	8.2	80	82	94	100	100	100	52	64	26	32	10	40	3	4	4	6	6.0	6.5

Faulting GROUP NO.	JOINT FAULTING - In Inches per mile	TRAFFIC Millions of 5000 Lb. EWLs	SUBGRADE SOIL TEST DATA: Soil in Place, % Relative Compact.	Soil in Place, % Saturated	Grading Percent Passing #4	#200	5 Mi.	Plasticity Index	Calif. Bearing Ratio: 0.1" Pen Standard Compact.	0.1" Pen Field D & M	Exp. in Soaking Std. Comp
	Average	Average	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
1	0.53	2.909	90	70	90	31	12	7	57	25	1.3
2	1.47	9.100	93	68	97	31	12	7	46	40	1.4
3	2.99	4.723	93	67	90	25	8	4	51	37	1.2
4	5.72	4.869	92	68	86	28	9	6	61	49	1.2
5	11.70	6.197	93	64	81	32	10	6	62	45	1.5
6	22.29	8.370	92	70	80	30	9	7	50	31	1.2
7	47.00	6.918	90	77	93	35	14	12	43	16	1.8
8	72.16	2.7	96	55	88	12	5	2	58	31	0.1
9	132.27	8.2	81	100	100	58	29	25	3	5	6.2
All	17.6	6.540	91.8	69.1	86.6	30.9	10.5	7.2	53.3	35.4	1.7

The group of grading curves (32) which immediately follows are representative of the many subgrade soil samples taken during the investigation.

The grading curves are further illustrations of the lack of correlation between the type of subgrade soil and the performance of the pavement. The notes on pavement condition were made in the field at the time of sampling. In some cases, the grading curves indicate what is commonly considered an excellent type of subgrade soil but reference to the accompanying note classifies the pavement as being in poor condition. Conversely, in some cases, the curves indicate a subgrade soil that is considered very poor, but the notes classify the pavement as being in good condition.

Two pavements that are worth special attention are those on the 'C' and 'V' projects. Both pavements are quite old, but both are in good condition.

The 'C' project, X-SJ-4-C,D, was constructed, in part, in 1919 and the pavement placed directly over the old "dirt road" that had served as a traveled way for many years. Adjoining pavements placed in 1931 and 1938 over new subgrade are showing considerably more distress than the 1919 pavement. Comparison of the grading curves would classify the subgrade under the 1919 pavement as the most adverse of the three.

The 'V' project, VII-LA-Alameda Street, was constructed in part in 1921 - 1923 and pavement was placed over a subgrade which had been oil treated and maintained under traffic for a year previous to paving. The grading curves of the subgrade material indicate that the material was "good" subgrade soil. However, adjoining pavements put down much later than this pavement over a new subgrade of similar soil are showing more distress than the old pavement.

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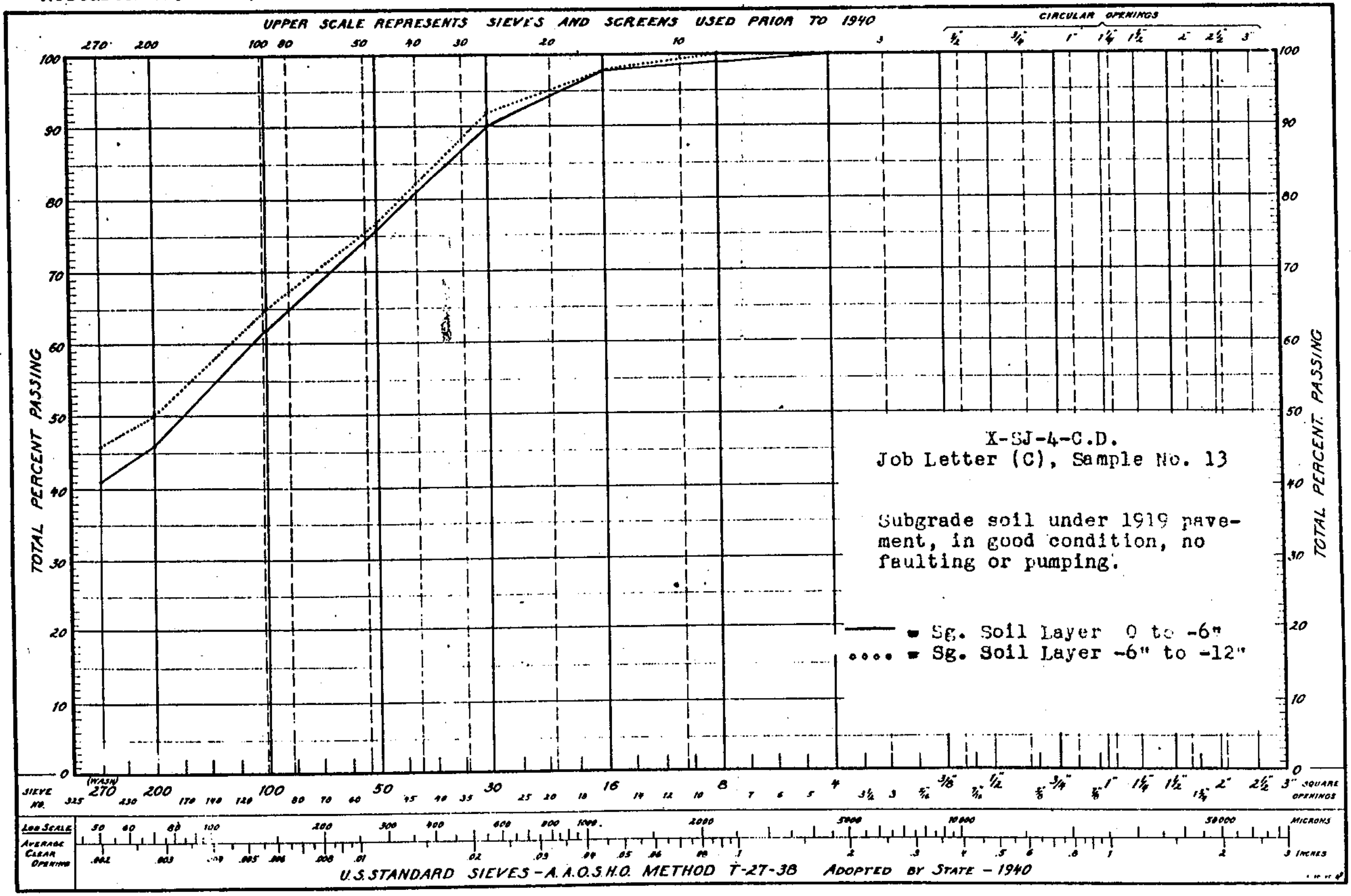
Research No. 00204

SEMI-LOG CHART FOR GRADING CURVES

?.C.C. Joint Investigation
Reference No. 32 (a)



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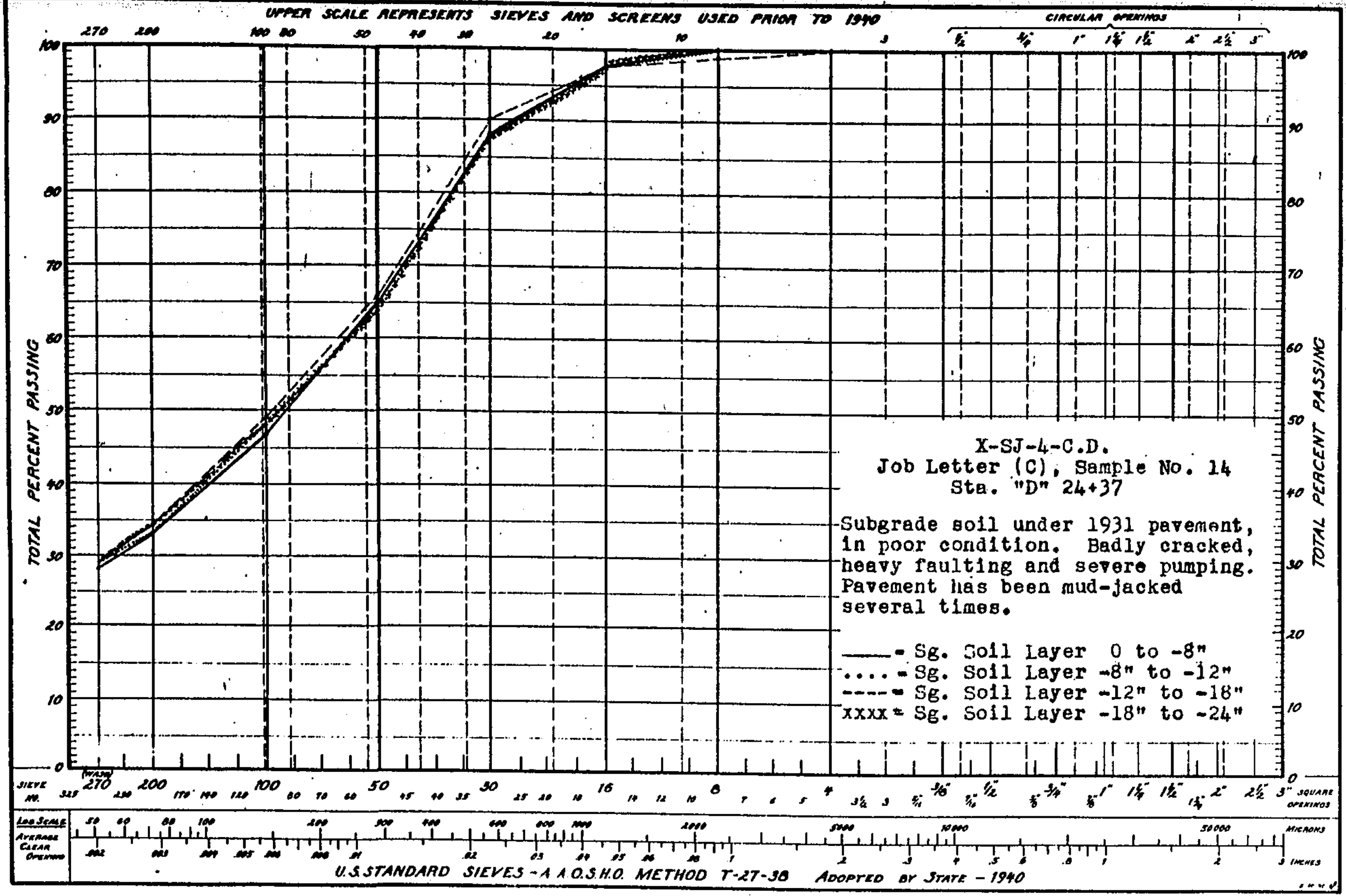
MATERIALS AND RESEARCH DEPARTMENT

Research No. 00204

SEMI-LOG CHART FOR GRADING CURVES

P.C.C. Joint Investigation
Reference No. 32 (b)



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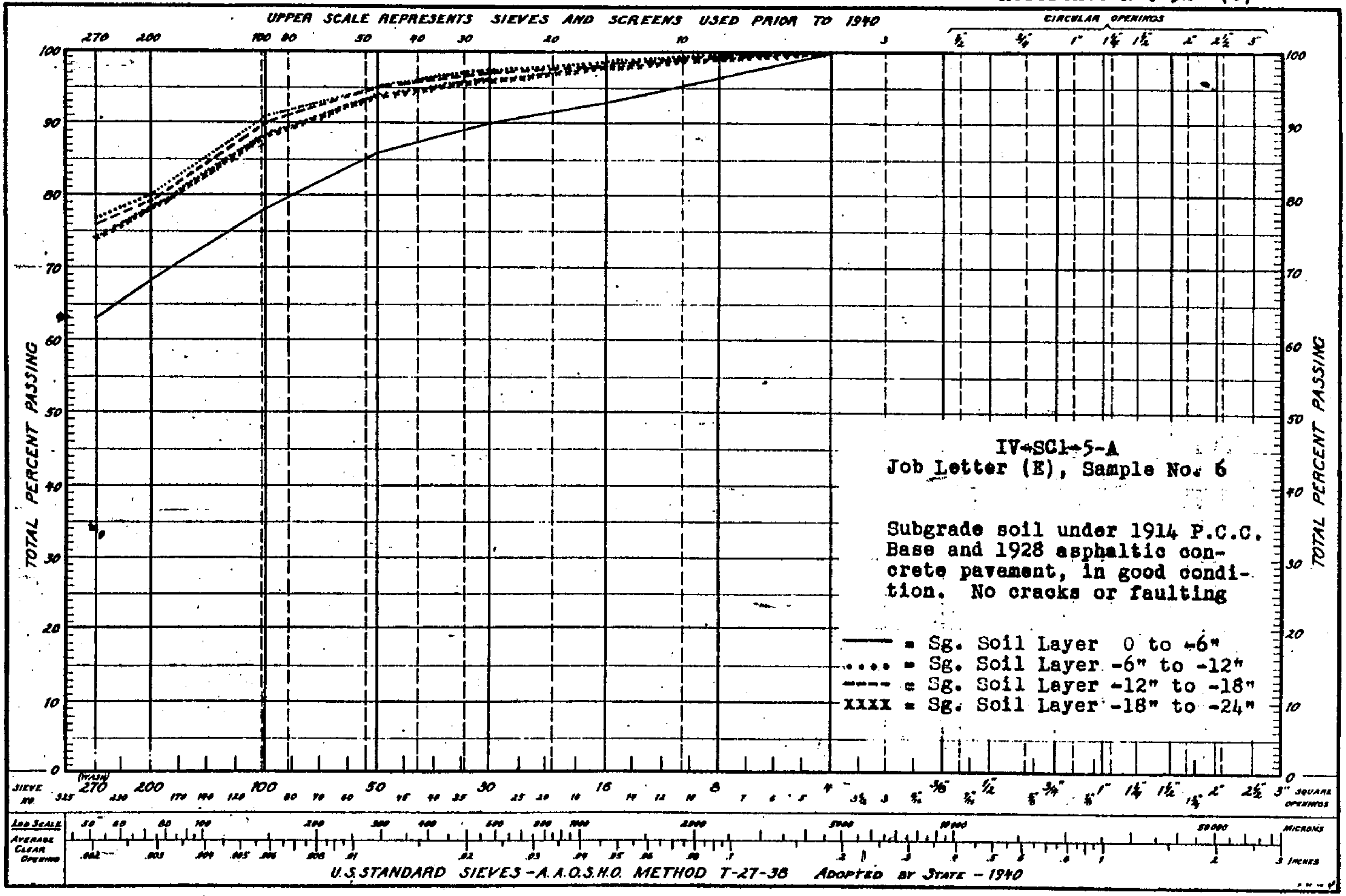
MATERIALS AND RESEARCH DEPARTMENT

Research No. 00204

SEMI-LOG CHART FOR GRADING CURVES

P.C.C. Joint Investigation
Reference No. 32 (c)



Research No. 00204

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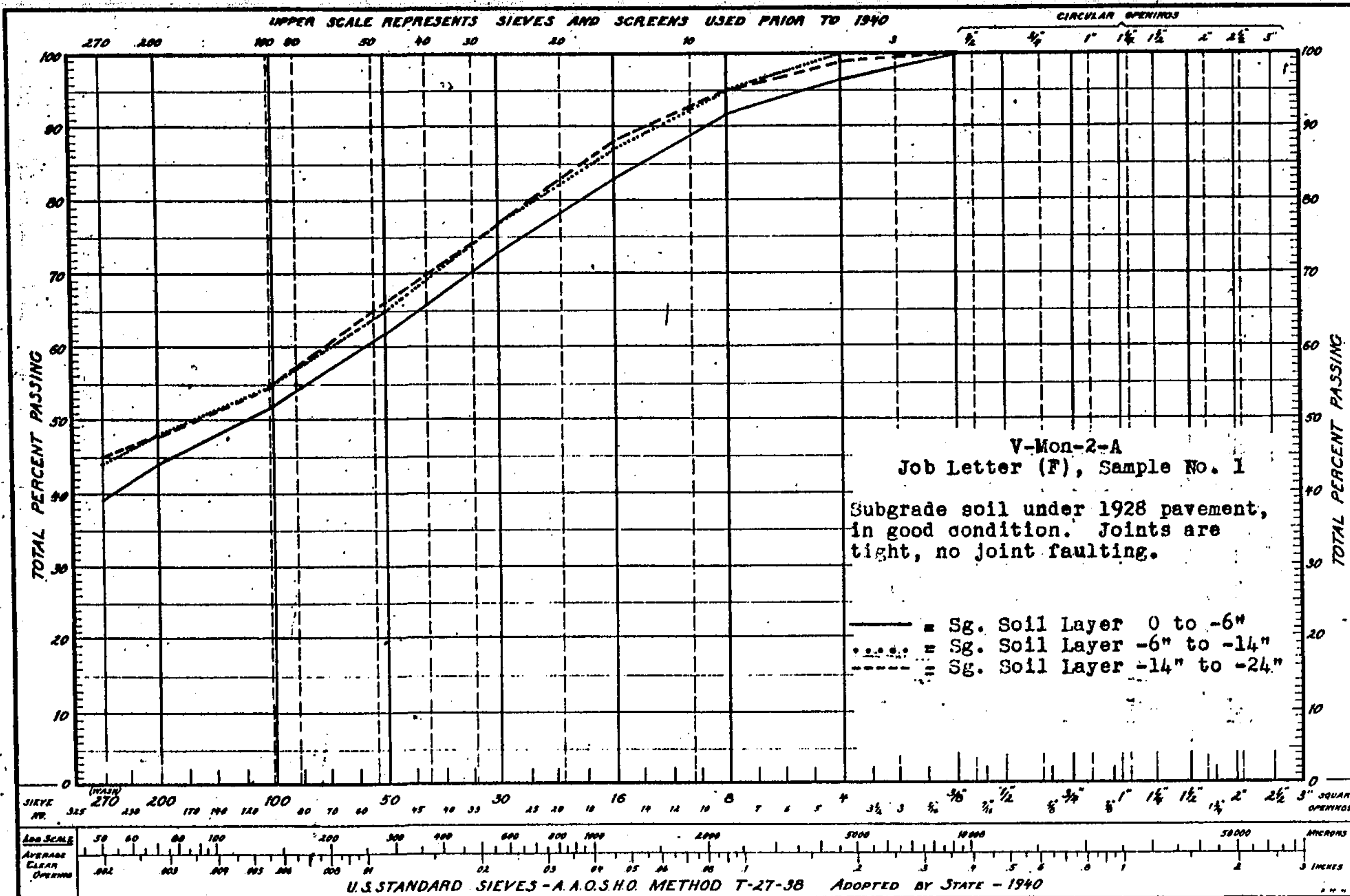
SEMI-LOG CHART FOR GRADING CURVES

P.C.C. Joint Investigation
Reference No. 32 (d)



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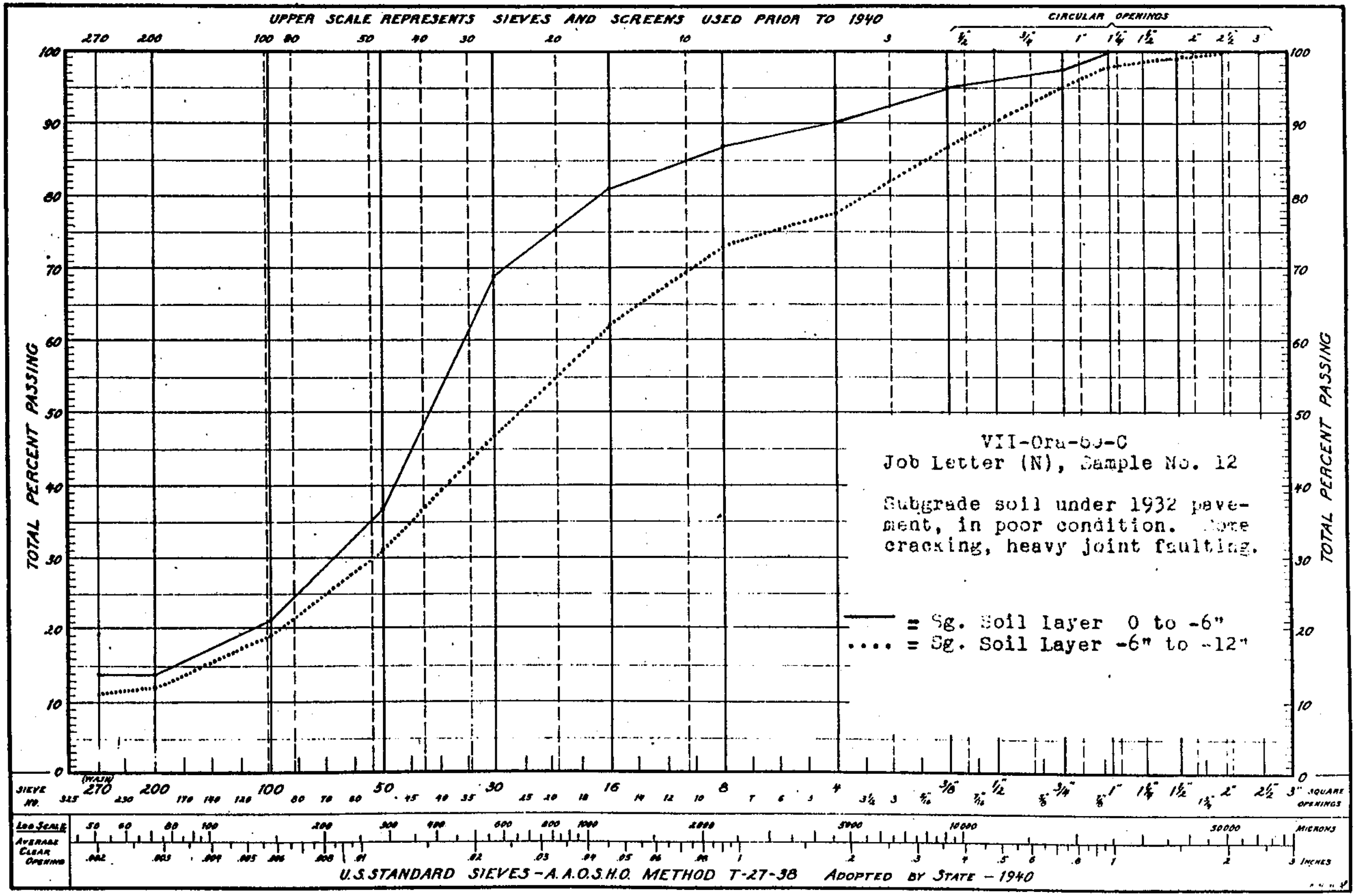
Research No. 00204

SEMI-LOG CHART FOR GRADING CURVES

P.C.C. Joint Investigation
Reference No. 32 (e)



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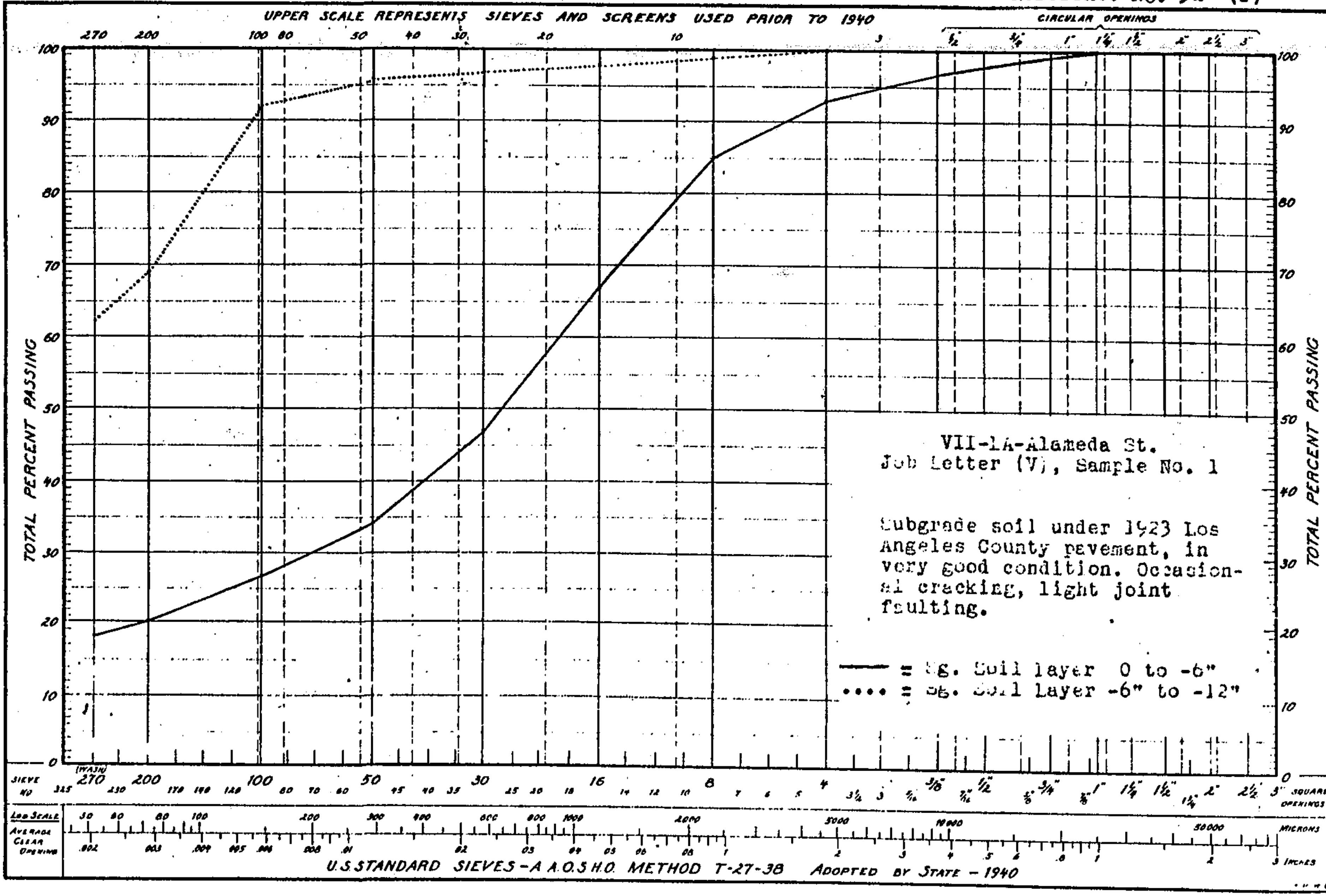
Research No. 00204

SEMI-LOG CHART FOR GRADING CURVES

P.C.C. Joint Investigation
Reference No. 32 (f)



CLASSIFICATION OF SUBGRADE SOILS

All subgrade soils encountered in the joint investigation were classified according to the method proposed by the subcommittee, representing the Highway Engineers, of the Highway Research Board "Committee on Classification of Material for Subgrades and Granular Type Roads."

The report of the subcommittee, D. J. Steele, Chairman, was presented at the 1945 Annual Meeting of the Highway Research Board. The proposed method retained the symbols A--1 to A--7 series, established by the Public Roads Administration some 16 years previous to the date of the report, with certain changes in test limits being specified.

All subgrade soils classifications in the investigation are based on the subcommittee's proposed Table No. 2, as published on page 377 of the Proceedings of the Twenty Fifth Annual Meeting of the Highway Reseach Board (33).

Materials & Research Department
Research No. 00204

P.C.C. Joint Investigation
Reference No. 33

Table No. 2
CLASSIFICATION OF HIGHWAY SUBGRADE MATERIALS
(With Suggested Subgroups)

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing: No. 10 No. 40 No. 200	50 Max. 30 Max. 15 Max.	50 Max. 25 Max.	51 Min. 10 Max.	35 Max.	35 Max.	35 Max.	35 Max.	36 Min	36 Min.	36 Min.	36 Min.
Characteristics of fraction passing No. 40 Liquid limit Plastic. Index	6 Max.		NP	40 Max. 10 Max.	41 Min. 10 Max.	40 Max. 11 Min.	41 Min. 11 Min.	40 Min 10 Max	41 Min 10 Max	40 Max. 11 Min.	41 Min. 11 Min*
Group Index**	0		0	0		4 Max.		8 Max	12 Max.	16 Max.	20 Max.
Usual Types of Significant Constituent Materials	Stone Fragments Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good					Fair to Poor					

Classification Procedure: With required test data available, proceed from left to right on above chart and correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification.

*Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30 (See figure 2).

Note: Above table taken from "Classification of Highway Subgrade Materials" published in Proceedings, Highway Research Board, Vol. 25, 1945.

COMPARISON OF DENSITY OF SUBGRADE AT DIFFERENT POINTS BENEATH A SLAB.

A limited number of samples indicates that the subgrade compaction as indicated by density is greater under the center of the slab than at the end of the slabs when cohesive types of soils are involved.

The data also show that the reverse condition is typical of cohesionless sand subgrades in that the density is greater near the joints and that the sand tends to settle leaving the end of the slabs unsupported. This condition is referred to in New Jersey as "Turtle Backing".

The accompanying sketch (34) is a diagrammatic drawing showing the relative positions of subgrade soil samples taken and a tabulation of densities encountered in various types of soil.

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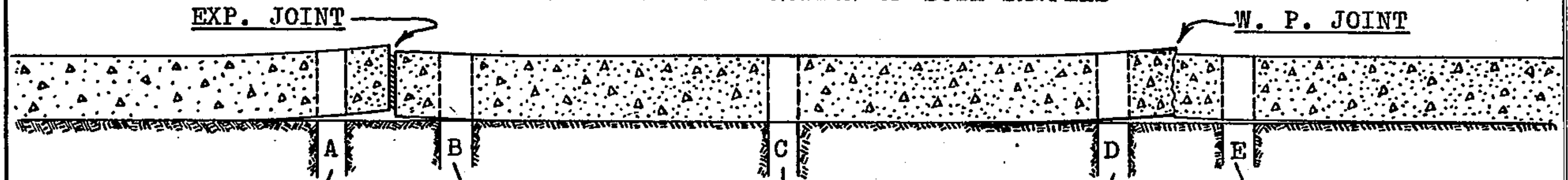
Research No. 00204

P.C.C. Joint Investigation
Reference No. 34

COMPARISON OF SUBGRADE SOIL COMPACTION BENEATH CENTER AND ENDS OF SLABS

SCHEMATIC PROFILE OF P.C.C. PAVEMENT SHOWING
TYPICAL RELATIVE LOCATION OF SOIL SAMPLES



COHESIVE SOIL SUBGRADES

AT EXPANSION JOINTS				CENTER OF SLAB (C)		AT WEAKENED PLANE JOINTS			
High Side (A) 17 samples		Low Side (B) 17 samples		31 samples		High Side (D) 12 samples		Low Side (E) 19 samples	
Wt. per Cu. Ft. #	Rel. Density *	Wt. per Cu. Ft. #	Rel. Density *	Wt. per Cu. Ft. #	Rel Density *	Wt. per Cu. Ft. #	Rel. Density *	Wt. Per Cu. Ft. #	Rel Density *
113.5	97.0	114.6	97.9	117.0	100	119.4	102.1	116.5	99.6

COHESIONLESS SAND SUBGRADES

AT EXPANSION JOINTS				CENTER OF SLAB (C)		AT WEAKENED PLANE JOINTS			
High Side (A) 18 samples		Low Side (B) 6 samples		16 samples		High Side (D) 7 samples		Low Side (E) 5 samples	
Wt. per Cu. Ft. #	Rel. Density *	Wt. per Cu. Ft. #	Rel Density *	Wt. per Cu. Ft. #	Rel Density *	Wt. per Cu. Ft. #	Rel. Density *	Wt. per Cu. Ft. #	Rel. Density *
110.8	101.2	112.0	102.3	109.5	100	113.2	103.4	107.3	98.0

NOTES:

#Weights per cubic foot are average weights for the number of samples indicated.

*Relative density figures are calculated with reference to the average weight per cubic foot of material under the center of the slab which is taken as equal to 100% for the purposes of this comparison