spacing varying from 120 to 800 ft, which, to put it mildly, throws some doubt on the validity of this indication.

Expansion Joints. There has been a progressive closing of the expansion joints as the pavement gets older. However, the magnitudes of the closure in the joints of the various sections at any particular time, are such that the spacing of expansion joints is indicated to have little effect on the amount of closure. On the other hand spacing of contraction joints had an effect. For expansion joint spacing of 120 ft, the residual joint closure is smaller with 60-ft. than with 25-ft contraction joint spacing.

CONDITION SURVEY

As a whole the pavement is in excellent condition. To date there is no evident difference between the conditions of the various test sections. Warping of most of the slabs has been so small as to be barely measurable, with negligible effects on the pavement riding qualities The maximum warping observed on any slab at any time measurements were made was 0.28 in. Joint faulting has not yet developed to any extent. The maximum observed faulting has been 0.25 in., but the great majority of the joints of all sections show less than 0.14 in. difference in elevation between the two sides of the joints.

There are no longitudinal cracks, except short checks, nor any corner-breaks in any of the test sections. Also the transverse cracking has been so slight in amount that no trends are evident Table 3 shows the location, description, date of initial observance and date of observance of latest progression of all transverse cracks.

All joints in general are in good condition; faulting is infrequent and slight, spalling is infrequent and generally confined to the lip curbs, condition of filler is good, and no joints evidence any "pumping" action thus far.

CONCLUSION

This pavement is as yet too young and has been subjected to too little traffic to indicate the relative merits of the various designs used.

INVESTIGATIONAL CONCRETE PAVEMENT IN OREGON

By G S. Paxon, *Bridge Engineer, Oregon State Highway Department*

This is the second progress report on the experimental concrete pavement project begun in 1941 under cooperative agreement with the Public Roads Administration. This project parallels similar projects in five other states. The object and scope of the project were given in detail in Mr. Kelley's report at the 1940 annual meeting of the Highway Research Board.[1] In general the program is designed to furnish information concerning the necessity for the spacing, the arrangement, and the type of transverse joints in concrete pavements.

In the first progress report, made at the 1941 annual meeting of the Highway Research Board,[2] construction details, instrumentation, and results of the subgrade soil survey were given. For convenient reference, Table 1 from the first progress report is repeated. This table gives the designation, pavement section, and joint spacings included in the project.

This project is now four years old and sufficient data have been gathered to show several interesting trends Whether the trends shown to date will continue over the life of the pavement or will reverse themselves can be told only after further observation.

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[1] E. F. Kelley, "History and Scope of Co-operative Studies of Joint Spacing in Concrete Pavements," *Proceedings*, Highway Research Board, Vol. 20, p 333.

[2] G. S. Paxson, "Investigational Concrete Pavement in Oregon," *Proceedings*, Highway Research Board, Vol 21, p 147

EXPANSION JOINT MOVEMENT

The arrangement of the project gives an opportunity to compare the movements at the expansion joints of sections having widely differing expansion joint spacing. Section 1 is continuous for 5,280 ft. without an expansion joint Sections 3 have subsections 405 ft. without expansion joints Sections 4, 5, and 7 have subsections 120 ft long without expansion joints All of these sections have contraction joints at 15-ft. intervals Sections 6 are reinforced pavement with expansion joints at 120-ft. intervals and contraction joints midway between expansion joints, making 60-ft. continuous slabs. Under the program of instrumentation, measuring stations to determine the movement relative to the subgrade were installed at each end, at the midpoint, and at the quarter-points of Section No. 1, at each end and at the midpoint of two of the subsections of each of Sections No 3; at each end of five of the subsections in Sections No 4, 5, 6, and 7. Gauge points were placed to measure the opening and closing of all expansion joints in the subsections listed above. Gauge points were also placed at selected contraction joints in Sections No. 1 and 3, at all contraction joints in two subsections of Sections No. 4, 5, and 7; and at the single contraction joint in five subsections of Section 6.

TABLE 1
ARRANGEMENT OF EXPERIMENTAL SECTIONS

Section No	Length	Thickness	Metal Reinforcement	Expansion Joints		Contraction Joints	
				Spacing	Load Transfer	Spacing	Load Transfer
	ft	*in.*		*ft*		*ft*	
1	5,280	9-7-9	None	At ends	Dowels	15	None
3W	2,430	9-7-9	None	405	Dowels	15	None
3E	2,430	9-7-9	None	405	Dowels	15	None
4W	1,200	9-7-9	None	120	Dowels	15	None
4E	1,200	9-7-9	None	120	Dowels	15	None
5W	1,200	9-7-9	None	120	Dowels	15	Dowels
5E	1,200	9-7-9	None	120	Dowels	15	Dowels
6W	1,200	9-7-9	Mesh	120	Dowels	60	Dowels
6E	1,200	9-7-9	Mesh	120	Dowels	60	Dowels
7W	1,200	8 uniform	None	120	None	15	None
7E	1,260	8 uniform	None	120	None	15	None

TABLE 2
ELONGATION OF SUBSECTIONS

Section No	Length Between Expansion Joints	Total Elongation of Subsection in Inches							
		April 1942	July 1942	March 1943	July 1943	April 1944	July 1944	April 1945	
	ft								
1	5,280	0.130 (63°F)	0.210 (74°F)	0.280 (48°F)	0.270 (78°F)	0.280 (74°F)	0.240 (73°F)	0.230 (65°F)	
3W	405	0.081 (63°F)	0.207 (73°F)	0.154 (48°F)	0.230 (78°F)	0.173 (66°F)	0.327 (04°F)	0.282 (65°F)	Average of 2 subsections
3E	405	0.147 (56°F)	0.309 (77°F)	0.258 (53°F)	0.350 (98°F)	0.335 (54°F)	0.402 (91°F)	0.366 (53°F)	Average of 2 subsections
4E	120	0.109 (54°F)	0.171 (77°F)	0.156 (46°F)	0.202 (78°F)	0.198 (56°F)	0.237 (87°F)	0.228 (57°F)	Average of 5 subsections
5W	120	0.089 (54°F)	0.184 (78°F)	0.137 (53°F)	0.224 (82°F)	0.208 (54°F)	0.243 (75°F)	0.254 (54°F)	Average of 5 subsections
6W	120	−0.001 (58°F)	0.083 (81°F)	−0.001 (55°F)	0.080 (75°F)	0.058 (68°F)	0.137 (92°F)	0.032 (57°F)	Average of 5 subsections
7W	120	0.104 (50°F)	0.198 (76°F)	0.162 (50°F)	0.241 (78°F)	0.223 (54°F)	0.230 (72°F)	0.237 (52°F)	Average of 5 subsections

Since the measurements of the movements at the expansion joints are made from fixed points in the subgrade, the total elongation of the subsections can be observed. The total elongation of the measured subsections is given in Table 2.

It is unfortunate that measurements could not be made during comparable months of each successive year with the concrete at the same temperature Because of the change in concrete temperature from hour to hour, the number of measurements required in each series made this impractical Examination of the data given in Table 2 fails to show any significant relationship between the elongation of the subsection and the length between expansion joints. The data from Section 6 are interesting in showing the effect of the 60-ft contraction joint spacing as contrasted with the 15-ft contraction joint spacing of the other sections The data from Sections 3 appear out of line with those from the other sections No reason is apparent for this discrepancy.

The data given in Table 2 for Section 6 show the effect of the 60-ft spacing of contraction joints in the reinforced pavement on the total subsection elongation With but one intermediate contraction joint in each 120-ft subsection, the expansion joint movement is only a fraction of the movement in the unreinforced sections

As noted, measurement stations were placed at the mid-point and quarter-points of Section 1 and at the mid-points of each subsection of Sections 3 At all of these measurement stations slight movements back and forth from the original positions were noted There were no movements of significant magnitude, nor was there any trend toward movement in a definite direction. These observations at the quarter-points of Section 1 indicate that there is little, if any, movement of the slabs in the central portion of the mile-long section between expansion joints The thermal change, therefore, must have been accommodated by elastic distortion of the slabs.

The average closure of the expansion joints within the sections is, of course, the same as the average elongation of the subsections. The average closure for each section is given in Table 2 for two months in each year that the experimental project has been in use. The measurements of total elongation of the subsections were made from reference lines across the pavement and were taken at intervals of approximately three months Measurements of the actual openings of the joints were taken each month from the time the pavement was laid in June of 1941 until September, 1942, and at intervals of three months thereafter. Typical expansion joint movement patterns are shown in Figures 1 and 2 In Figure 1, the average opening of the two joints at each end of the mile-long Section 1 is shown The joint openings shown are due to the elongation of Section 1 on one side of the joint and the 405-ft. subsection of Section 3 on the other side The figure is thus not truly representative of a joint between the two mile-long sections. It does, however, give a typical illustration of joint movement Figure 2 shows a joint movement pattern which is the average of two joints within a section which has 120-ft. spacing of expansion joints The movements of the expansion joints in these two sections, one of which has a joint spacing of 5,280 ft. and the other a joint spacing of 120 ft, are similar As would be expected, considerable closure occurred in the first year. The additional closure during the next two seasons has been small The 5,280-ft section shows an additional closure of 0 032 in., while the 120-ft section shows an additional closure of 0 038 in. The small difference in the action of the two sections indicates that the length between expansion joints has but little effect on the joint closure

OPENING OF CONTRACTION JOINTS

During the first four days after the concrete was placed, no appreciable movement of the contraction joints was observed. After this period, a slow but steady opening of these joints occurred for a period of two weeks. From this time on, the movement of the contraction joints followed the changes in temperature of the concrete. The joints open as the temperature drops and close as the temperature rises. It is interesting to note that with each successive temperature maximum the closure of the joints is less complete This indicates that dirt from the pavement surface has worked into the joint, or that the slabs are slightly out of line Figure 3 shows the average movement of the contraction joints in Section 4E during the first 4 yr The openings shown are the summation of the openings of the seven contraction joints in a 120-ft subsection

NET CHANGE IN LENGTH OF CONCRETE SLABS

An interesting point in the joint measurements is the change in length of the concrete slabs themselves This can be determined by subtracting the total opening of the contraction joints in a subsection from the elongation of the subsection. Data on all contraction joints are available for two 120-ft. subsections in Sections 4E, 5W, and 7W, and for five 120-ft. subsections in Section 6W. Data are also available for 18 of the 26 contraction joints in a 405-ft. subsection in Sections 3W and 3E. In these two subsections the contraction joint openings, measured across the 18 joints, were proportionately increased to cover the 26 joints in the subsections During the winter the contraction joints are open and no compression is applied to the slabs. The change in length, after correcting for any temperature difference, is an actual growth or shrinkage due to physical changes in the concrete. Table 3 shows the data for the subsections for which data are available. The data shown have been adjusted to a temperature of 40 deg. F., using a coefficient of thermal expansion of 0.0000065. In applying the adjustment to the elongation of the subsection, only the half lengths of each end slab were used, as the intermediate contraction joints render the interior slabs ineffective. In

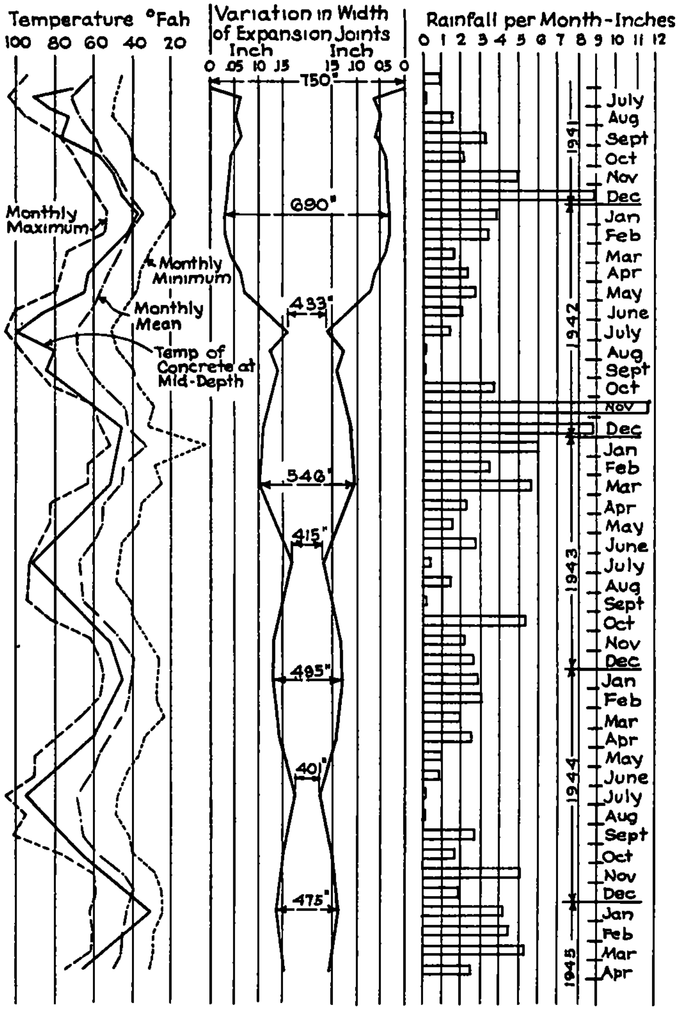

Figure 1. Expansion Joint Movement—Section No. 1

applying the adjustment to the contraction joint openings, however, the entire length of the subsection, except these half lengths, was used.

It will be noted that during the 25-month period between the cold weather measurements of December 1942 and January 1945, the changes in length of the concrete slabs themselves are, in all cases, very small. In general the nonreinforced sections show a slight tendency to decrease in net length Some of the reinforced subsections in Section No. 6 show a slight increase in net length, while others show a decrease. It is probable that the metal reinforcement acts to restrain the shrinkage shown by the unreinforced sections. The length changes are all of such small magnitude that for practical purposes they can be disregarded. The characteristics of the cement used in the pavement, as shown by the standard autoclave test, may be of interest in this connection. The cement used in Section 4E showed a swell of 0.091 percent, and the cement used in the other sections showed a shrinkage of 0.062 per cent. Cement with such characteristics can be regarded as exceptionally sound

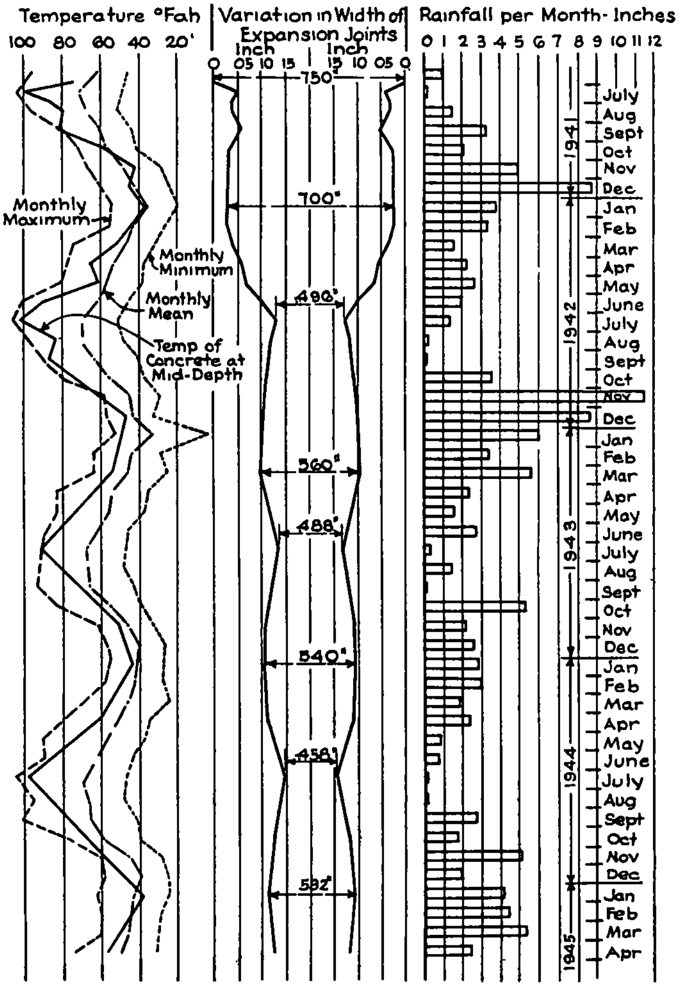

Figure 2. Expansion Joint Movement—Section 4E

The installations for measuring the contraction joint openings are arranged so that a comparison can be made between the action of the joints near the center of the subsections and the joints near the ends. There is evidence that the subgrade friction restrains the movement of the central slabs to some extent. Table 4 shows the contraction joint openings at the ends and center of Sections 1, 3, 4, 5, and 7. Measurements shown for Section 1 are the average of the seven joints at each end and the 19 joints at the center. Measurements shown for Sections 3 are the average of four joints at each end and four joints at the center. Measurements shown for Sections 4, 5, and 7 are the average of two joints at each end of the single joint at the center

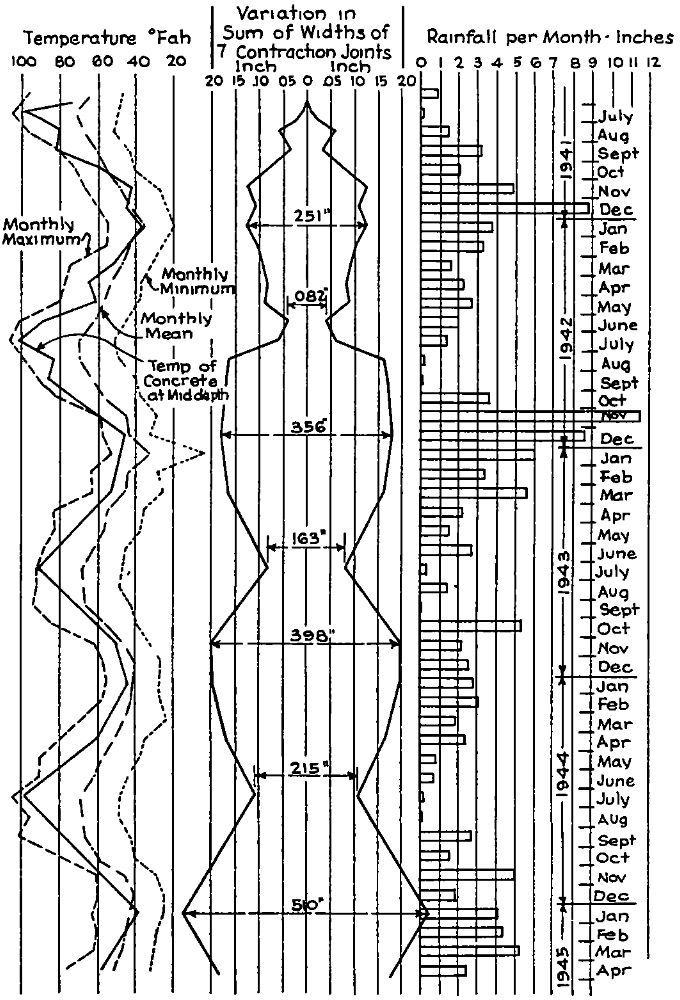

Figure 3. Contraction Joint Movement—Section 4E

TEMPERATURE CHANGE IN PAVEMENT SLABS

An attempt was made to secure a detailed record of temperature changes in the pavement slab Three stations were established in Sections 3W, 5W, and 7W Thermocouples were used in measuring the temperatures. These were cast into the concrete at each inch of depth of the pavement and at points 6 in. and 18 in below the lower surface of the pavement slab. The temperatures have been recorded at intervals since the concrete was placed Several hourly series of readings, continuous over 24 hours or more, have been made.

Figure 4 shows the concrete temperatures at 1 in., 4 in , and 6 in below the pavement surface for a period of 45 hours after the concrete was placed The rapid dissipation of heat by the thin slab is shown by the relatively slight temperature rise during the time the concrete was setting. In two days, enough heat had been lost that concrete temperatures followed air temperatures normally.

Figure 5 shows concrete temperatures at 1 in., 4 in., and 6 in. below the pavement surface during a normal autumn day. Concrete temperatures follow changes in air temperatures with the usual lag. Rapid air temperature changes are ironed out. Variations in temperature are greatest in the top of the slab.

Figure 6 shows temperature gradients through the slab at five different times during a 24-hr period The greatest temperature difference was at three o'clock p m when the top of the slab was 17 deg. F warmer than the bottom. The greatest differential in the opposite direction was at seven o'clock a.m. when the bottom of the slab was 5 1 deg. F warmer than the top. An examination of 129 sets of readings shows a maximum temperature difference of 21 5 deg. F with the top warmer than the bottom and a maximum

TABLE 3

CHANGE IN LENGTH OF CONCRETE SLAB

Section No	Length of Subsection	December 1942			January 1944			Change in Length in 13 Mo	January 1945			Change in Length in 25 Mo
		Contraction Joint Opening	Elongation of Subsection	Decrease in Length of Concrete	Contraction Joint Opening	Elongation of Subsection	Decrease in Length of Concrete		Contraction Joint Opening	Elongation of Subsection	Decrease in Length of Concrete	
	ft	*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*
3W	405	0 993	0 150	0 843	1 408	0 218	1 190	−0 347	1 354	0 225	1 129	−0 286
3E	405	1 025	0 295	0 730	1 132	0 310	0 822	−0 092	1 365	0 350	1 015	−0 285
4E	120	0 407	0 182	0 225	0 427	0 215	0 212	+0 013	0 494	0 143	0 351	−0 126
	120	0 417	0 225	0 192	0 438	0 233	0 205	−0 013	0 491	0 182	0 309	−0 117
5W	120	0 341	0 190	0 151	0 483	0 247	0 236	−0 085	0 497	0 230	0 267	−0 116
	120	0 309	0 185	0 124	0 419	0 205	0 214	−0 090	0 446	0 287	0 159	−0 035
6W	120	0 138	−0 038	0 176	0 167	0 034	0 133	+0 043	0 183	0 022	0 161	−0 015
	120	0 144	−0 058	0 202	0 141	0 033	0 108	+0 094	0 212	−0 041	0 253	+0 051
	120	0 144	−0 105	0 249	0 169	−0 102	0 271	+0 078	0 188	−0 125	0 313	−0 064
	120	0 150	−0 062	0 212	0 176	−0 049	0 225	−0 013	0 187	0 003	0 184	+0 028
	120	0 147	−0 097	0 244	0 167	−0 094	0 261	−0 017	0 178	−0 119	0 059	+0 185
7W	120	0 347	0 171	0 176	0 473	0 256	0 217	−0 041	0 464	0 162	0 302	−0 126
	120	0 335	0 169	0 166	0 453	0 189	0 264	−0 098	0 451	0 193	0 258	−0 112

TABLE 4

CONTRACTION JOINT OPENINGS AT ENDS AND CENTER OF SECTIONS

(All Data Given in Inches)

	Section No 1		Section No 3W		Section No 3E	
Date	July 1944	Jan 1945	July 1944	Jan 1945	July 1944	Jan 1945
Conc Temp	93°	32°	93°	45°	102°	34°
West End	0 014	0 064	0 009	0 038	0 023	0 069
Center	0 006	0 051	0 011	0 040	0 006	0 053
East End	0 007	0 055	0 016	0 050	0 021	0 069

	Section No 4E		Section No 5W		Section No 7W	
Date	July 1944	Jan 1945	July 1944	Jan 1945	July 1944	Jan 1945
Conc Temp	98°	38°	89°	41°	89°	37°
West End	0 029	0 070	0 035	0 083	0 052	0 089
Center	0 012	0 050	0 021	0 055	0 023	0 060
East End	0 046	0 093	0 034	0 072	0 029	0 070

difference of 9.7 deg. F with the bottom warmer than the top.

MOISTURE DETERMINATION

An attempt was made to record the moisture content of the concrete. Resistance cells (consisting of a block of plaster of Paris in which bare electrodes spaced a constant distance apart were placed) were cast into the concrete slab at each inch of depth. It was expected that the moisture content of the cell would follow the moisture content of the surrounding concrete and that the resistance offered by the gap between the electrodes would vary inversely with the moisture content. The calibration of the cells was very unsatisfactory, principally because of the effect of changing temperature.

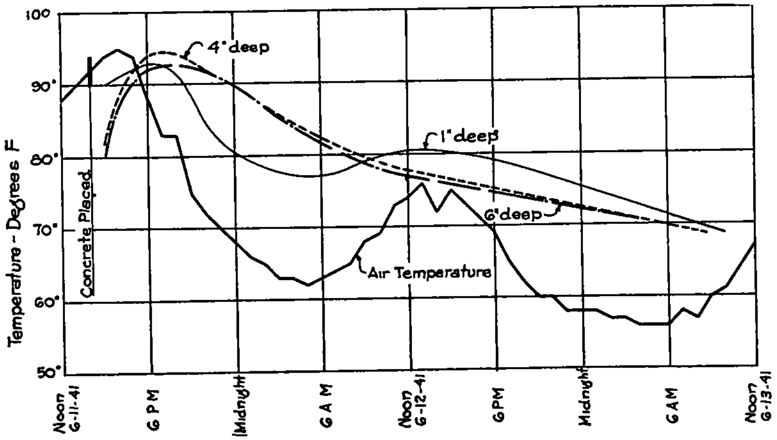

Figure 4. Curing Temperatures in Concrete Slab at Station 2, Section 5W, June 11 to 13, 1941

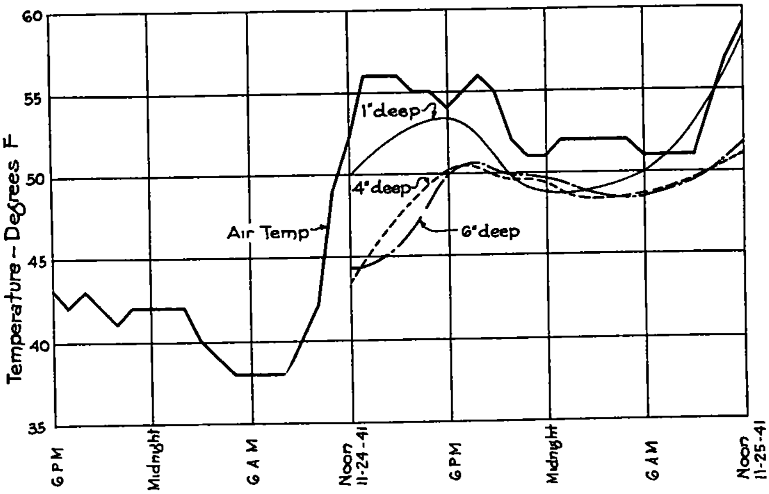

Figure 5. Temperatures in Concrete Slab at Station 2, Between Joints 21 & 22, Section 5W, Nov. 24 and 25, 1941.

The resistance of the cells dropped to approximately 100 ohms within an hour after they were cast in the fresh concrete. The moisture content of the saturated cell was 4.8 per cent by weight. The resistance of the oven dry cell was approximately 2,000,000 ohms. If it is assumed that an inverse linear relationship exists between the logarithm of the resistance and the moisture content, an approximate answer can be had

Figure 7 shows resistance readings and an estimate of the moisture content for the first year of service. The values given for moisture content are open to considerable question, but a trend is indicated. The upper part of the slab dried out quite rapidly to a moisture content of approximately 2 per cent and remained in that condition with only minor variations. The concrete in the center of the slab dried out more slowly, but, after a year, was approaching the moisture content of the top. The lower part of the slab dried out only slightly. No values are shown for the first inch of depth Resistance readings at this depth fluctuated widely from day to day and even from hour to hour, depending on the weather At a depth of 2 in , the daily fluctuation was not great enough to mask the general trend.

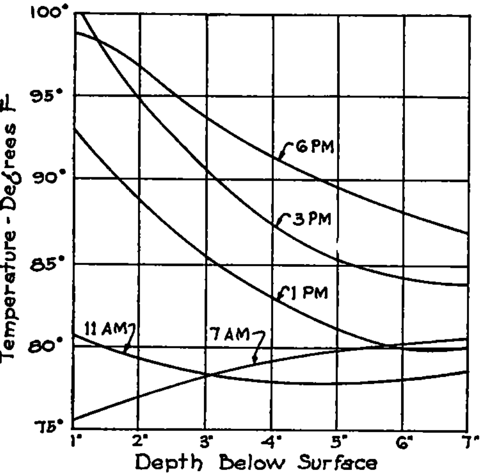

Figure 6. Temperature Gradient in Concrete Slab at Station 3 Between Joints 14 & 15, Section 3W, August 6, 1942.

A peculiar condition is indicated at the bottom of the slab by supplemental moisture cells placed in the subgrade, against the bottom of the slab, 6 in , 12 in., and 18 in. below the bottom of the slab. The cell at the lower surface of the pavement showed very little resistance change. The resistance change increased with the depth to a maximum at the deepest cell. At least two explanations are possible. The abrupt change in the capillarity of the two materials, concrete and soil, may form a layer of high moisture content at the junction The action may be similar to that resulting in the formation of frost boils Another possibility is that water may leak in along the plane between the concrete and the subsoil, either from the sides or through the joints Such water could probably only be dissipated by seepage through the slab and evaporation at the surface.

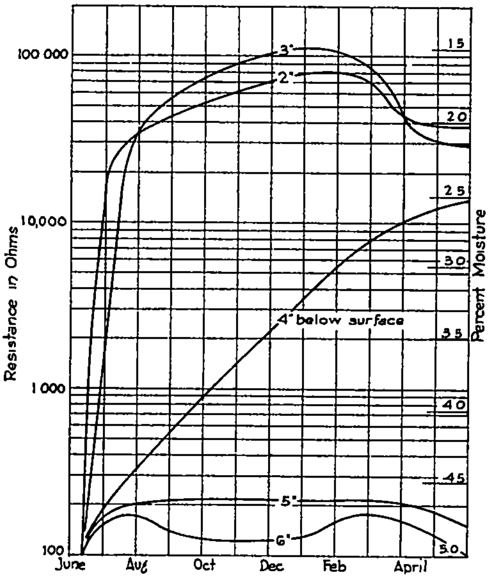

Figure 7. Resistance Across Moisture Cells and Approximate Moisture Content, Station 2, Section 5W.

SPALLING AT CONTRACTION JOINTS

The pavement surface was finished with a power-driven finishing machine which was run over the surface after the contraction joints were cut and the strips of asphalt-impregnated felt were placed Numerous instances have been observed where the felt strip has been pushed out of place by the operation of the machine. In some cases, the felt strip has been pushed down so that up to ¾ in. of concrete covers the upper edge. In these cases, this concrete has spalled off to the top of the felt strip and back into the surface of the concrete as much as 2 in. In other cases, the felt strip has been pulled away from the side form, leaving up to 2 in. of solid concrete along the form. Where this has occurred, the top 2 or 3 in. of the slab at the corner have spalled No instance has been observed where the corner broke through its entire depth. The spalls are generally confined to the concrete lying above the bottom of the felt strip. Figure 8 shows a typical corner spall of this kind.

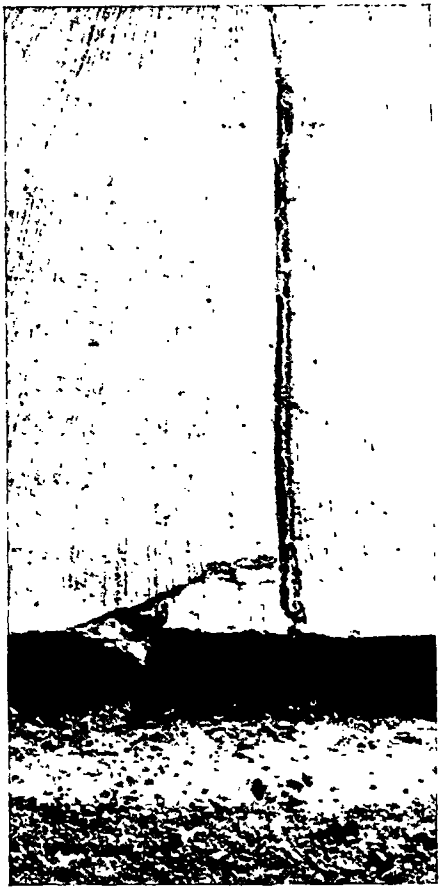

Figure 8. Typical Corner Spall at Contraction Joint.

Examination of this spalling indicates that it is not caused by loads. Breaks due to loads would extend through the entire depth of the slab. There is every indication that the spalling is caused by excessive pressure concentrated on the relatively small areas from which the felt strips have been removed The spalling is not confined to any one section, but is general throughout the project. The development of this trouble emphasizes the need for great care in placing the felt strips in contraction joints.

CHANGE IN SURFACE IRREGULARITY

A graphic record of the surface irregularity of the entire project was made on August 13, 1941, approximately two months after the concrete was placed. In making this record a device known as a recording plane-o-meter was used. A photograph showing the device in operation is shown as Figure 9. The plane-o-meter consists of a rigid horizontal member carrying fixed wheels at each end 10 ft. apart Midway between the two fixed wheels is a third wheel which is free to move up and down and to follow the irregularities of the pavement surface. This wheel operates a lever to which is attached a pen which records the movement of the wheel on a roll of coordinate paper.

Figure 9. Plane-o-meter in Operation

The plane-o-meter was again run over the project on July 29, 1944, when the pavement was approximately three years old. The record was made on the same roll of paper that was used in making the first record. A comparison of the two graphs does not show any significant change. Some portions seem to have become rougher, while other portions seem to be smoother. There is no indication that any particular secion maintains its surface smoothness better than another section. In Figure 10 are shown graphs of the surface irregularity for 120-ft. subsections in Sections 1, 4W, and 6W, taken in 1941 and 1944.

The temperature differential across the pavement thickness has a considerable effect on the surface smoothness. In Figure 11 graphs are shown of the surface irregularity at different times between seven a.m. and three fifteen p.m. The surface seems to be considerably rougher in the morning, when the bottom of the slab is at a higher temperature than the top and the individual slabs are concave upward, than in the afternoon when the reverse conditions prevail.

GENERAL CONDITION SURVEY

This section of highway is in the suburban area of Portland and serves as a by-pass route for truck traffic entering Portland from the east A considerable volume of traffic has developed since the pavement was completed Many of the heavy trucks carry loads of 36,000 lbs. on two tandem axles. The average daily traffic during the first six months of 1945 has been as follows·

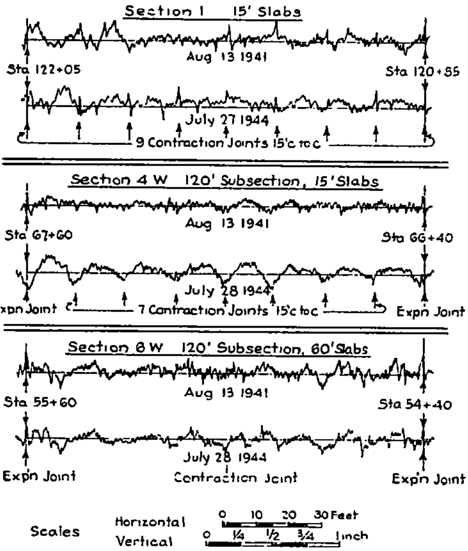

Figure 10. Change in Surface Irregularity, Aug. 13, 1941 to July 28, 1944.

Passenger cars	3,438
Light trucks	236
Heavy trucks	348
Trucks with semitrailers	18
Trucks with full trailers	25
Buses ..	80
Total	4,145

Immediately after the section had been opened to traffic, a detailed inspection of the pavement was made on September 12, 1941. There were no cracks in any of the slabs. The expansion joints were in practically perfect condition. The joint filler was in place and was slightly lower than the concrete surface on each side of the joint. No instance was observed where the joint filler had been squeezed out above the joint. Some of the contraction joints had opened to show a hairline crack Almost no spalling had as yet taken place at these joints.

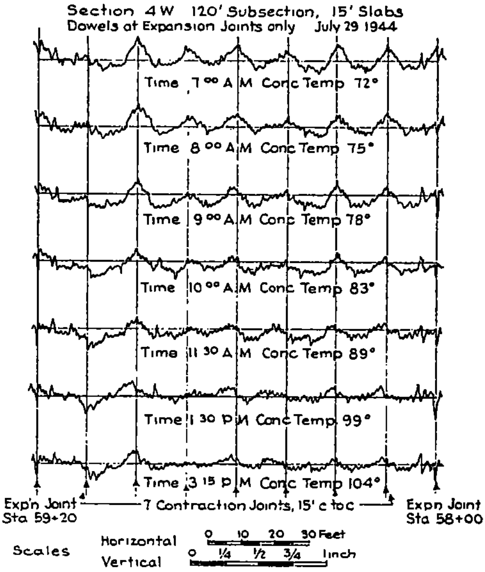

Figure 11. Effect of Slab Curl on Surface Irregularity.

On April 25, 1942, 7½ months later, a second survey was made. The service period between inspections covers the fall, winter, and early spring months. Slightly less than normal rainfall occurred during this period. The total rainfall during the period was 32 in. Temperatures were normal with a maximum of 80 deg. F and a minimum of 19 deg. F. No cracks in the pavement slabs were found. The expansion joints were in good condition, with no squeezing of the joint filler above the surface Some spalling of the surface and corners was noticed at contraction joints where the installation of the felt strips was faulty. A slight surface wear was noted at points of intersection with side roads. The surfaces of these side roads are generally of a low type, and the shoulders are gravel or crushed rock macadam. Considerable fine gravel and rock are carried onto the concrete pavement by incoming traffic. Surface wear is due to the abrasive action of these loose particles. Vehicles leave the main highway at high speeds, but, because of stop signs, enter the highway at low speeds. The wear is much greater in the outgoing lane.

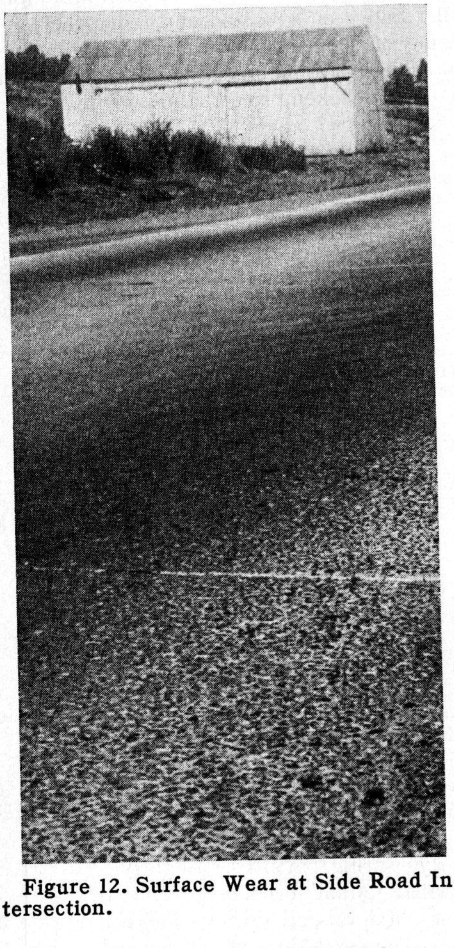

Figure 12. Surface Wear at Side Road Intersection.

Subsequent inspections were made on October 16, 1942, November 18, 1943, July 13, 1944, and April 24, 1945. There has been a gradual increase in the spalling of the surface and corners at contraction joints where the installation of the felt strips were faulty. There has been a marked increase in the surface wear where traffic turns off the pavement onto low-type side roads. Figure 12 is a photograph of one of these side road intersections and shows the difference in surface wear under incoming and outgoing traffic.

To date only two cracks have occurred in the entire project. Both of these are in Section 1. The first crack was noted while taking joint measurements on March 25, 1943. This crack is approximately one-fourth mile from the east end of Section No. 1 and is near the middle of a 15-ft. slab. It extends across the north lane, but does not enter the south one. A second crack was first observed during the inspection made on July 13, 1944. It is near the mid-point of Section No. 1 and is confined to the north lane, extending from the north or outer edge to about 2 or 3 ft. from the center joint between the two lanes. The cause of the cracking is not known. There are no peculiar conditions apparent which might explain them. There is no evidence that the distance between expansion joints or the type of joints used contributed in any way to the cracking.

SUMMARY

The general excellence of the pavement after four years' service makes it difficult to make comparisons between the different sections. The condition of all of the sections is satisfactory, and from data now at hand, it cannot be said that any section is better than another. There are, however, some observations and trends that are worth noting.

The distance between expansion joints does not seem to have any great effect on the expansion joint closure, at least when this distance is 120 ft. or more. The movement at all expansion joints is greater during the first year than in succeeding years because of the action of the contraction joints, which, having once opened, function as narrow expansion joints.

On this project the nonreinforced slabs show a slight tendency to shrink with age, while the reinforced slabs remain at approximately their original length. It is probable that the reinforcing steel restrains the normal tendency to shrink. The magnitude of the length change is not great enough to be of practical importance. The measurements indicate, however, that the concrete in this perimental project is not subject to the lume increase with age noted in many her pavements. Joint movements follow mperature changes fairly consistently, but e correlation between joint movement and infall, while probably present, is masked the greater temperature movement. here has been a progressive opening of ntraction joints. With each successive mperature maximum, the joint closure s been less complete.

Concrete temperatures follow air tempera-res with a considerable lag in time. Tem-ratures at the top of the slab show much der fluctuations than at the bottom. The mperature gradient is steeper when the top of the slab is hotter than the bottom than when the gradient is reversed. There is some evidence that the bottom part of the slab had not dried out to any great extent during the first year. There also seems to be a concentration of moisture at the plane between the slab and the subgrade.

Spalling at contraction joints has taken place due to displacement of the felt strips by the finishing machine. The need for great care in placing these strips and maintaining them in position during the placing and finishing of the concrete is emphasized. The two cracks that have occurred in the project do not appear to be related to any particular joint spacing or joint type.

STRUCTURAL EFFICIENCY OF TRANSVERSE WEAKENED-PLANE JOINTS

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SYNOPSIS

As part of the cooperative studies of the effects of varying the spacing of expansion joints in pavements containing closely spaced weakened-plane contraction joints, the Public Roads Administration conducted some special tests to determine the ability of the joints of the weakened-plane type to reduce critical load stresses These tests were made on six concrete test sections, each 30 ft long, 20 ft. wide and of 8-in. uniform thickness. Each section was divided longitudinally by a deformed metal center joint having ⅝ in diameter tie-bars at 60-in. intervals and transversely by a weakened-plane joint of a specific design. The technique of testing to determine the efficiency of the various joints was similar to that used in previous studies, that is, the critical strain was measured for a load of given magnitude acting successively at selected points at the joint edges, free edges and interiors of the panels of a section

Information was obtained on the structural behavior of weakened-plane joints as affected by. (1) type of coarse aggregate, (2) maximum size of coarse aggregate, (3) presence or absence of dowel bars, (4) method of producing fracture at the joint, (5) compressive forces acting to close the joint, and (6) width of joint opening

Briefly, the data obtained from this study indicate that (1) on the whole, all of the joints were more effective in controlling critical corner-load stresses than they were in controlling critical edge-load stresses, (2) in the presence of compression between the joint faces, all of the joints were effective in reducing critical stresses at both the edges and the corners, (3) without compression between the joint faces, aggregate interlock is an uncertain means of stress control regardless of type and size of coarse aggregate, (4) the presence of dowels improved the control of critical edge stresses to a limited extent but very definitely aided the control of of corner stresses, and (5) the presence of dowels greatly improved uniformity in stress reduction from point to point along the joint edge