P. M Tebbs I want to make one comment before I go into the information as indicated by our studies in Pennsylvania Mr. Kirk has just remarked that he had more corner breaks on sections where there were no longitudinal cracks. It seems to me that this is explained by the phenomenon of curling of the edges and that it justifies the placing of a center joint to check the curling Where you have a longitudinal crack or construction joint, the edge is allowed to rest more uniformly on the subgrade, and there should be less corner breaking

EFFECT OF REINFORCEMENT IN PENNSYLVANIA STATE HIGHWAYS

SUMMARY OF REPORT

By P M Tebbs

Pennsylvania State Highway Department, Harrisburg, Pennsylvania

This information was furnished by condition surveys covering about 1,500 miles of concrete road

The relative effect of various weights of reinforcement are given by average slab length and cracking in Table 8, and the variation of crack (in 5-7-5 by 16 feet, No 25 mesh) with age, in Figure 89.

From these surveys the following conclusions are offered

1. Transverse cracking occurred mainly in the first and second years, with no considerable increase after the third year.
2. Average spacing of transverse cracks in short slabs was less than in long sections
3. Total number of cracks increased with age of road
4. Cracking was considerably reduced by increasing the weight of mesh reinforcement from 25 to 56 and 65 pounds per 100 sq ft
5. A four-year-old 6-8-6 by 18-foot plain concrete surface laid on gravel subgrade showed exceptionally few cracks, having an average slab length of 70 feet The same design on other subgrades had average slab length of 28 feet

W L Blaum I will confine myself to a few comments on Mr Hogentogler's paper, following which Mr Acheson will give a report on the Syracuse Resurfacing Experiment built under his direction

In connection with this report and with the conclusions drawn, I believe that most of our highway engineers in New York will be in accord The following conclusions of Mr Hogentogler seem to be especially well established

Plain concrete surface in widths greater than 10 feet have developed longitudinal cracks This condition is now very largely eliminated by the use of the longitudinal construction joint

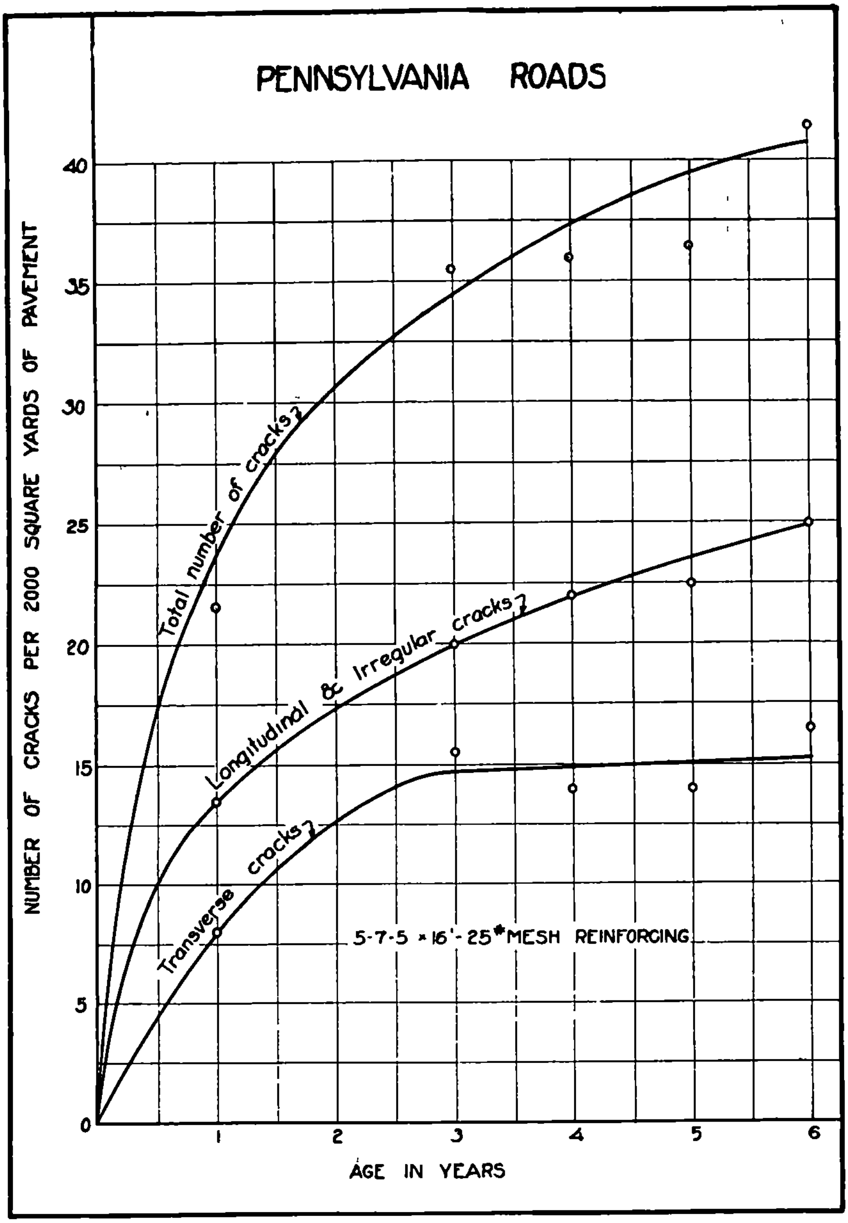

Figure 89—Influence of age on crack development—Pennsylvania roads

TABLE 10 —Pennsylvania Roads

Condition of Slab per 2000 Sq Yds Surface Area																				
Cross-Section	Width	Type	Reinforcement		No Trabs Grs		Av Length of Slab				No Long & Irreg Crs				Total No Crs & Joints					
					Age		Age-Years				Age-Years				Age-Years					
			Kind	Weight	1	3	1	2	3	4	1	2	3	4	1	2	3	4		
5-7-5	16	R	Mesh	25	33 4	44 5	35 3	31 5	25 9	27 2	13 4	17 5	20 2	22 0	46 8		64 7	64 4		
6-8-6	16	R			33 3	37 1		32 9	29 5	27 9		13 2	24 3	14 7		47 4	63 1	55 8		
6-8-6	18	R	Mesh	25	26 2	26 5	35 4	44 6	38 8		7 0	3 6	9 1	2 9	33 8	27 9	36 2	29 1		
7-7-7	18	R	Bars	76	24 0		43 5				0 5				23 4					
6-8-6	18	R	Mesh	56	22 5		48 8	47 0			1 6	2 9			18 1	20 3				
6-8-6	18	R	Mesh	65	15 5		81 6	57 2			08				15 9					

Plain concrete surfaces have developed transverse cracks There are some exceptions, however, to this general conclusion, as, for instance, such portions of the South Glens Falls-Gansevoort Highway in New York State, mentioned in the report, that were laid on pure sand subgrade in 1915 and which are almost free from cracks of any kind Such cracks can be reduced by using proper reinforcement

Cracking has been greatly influenced by character of aggregate In some cases at least, other conditions being equal, pavements in which certain uncrushed gravels have been used as the coarse aggregate developed more transverse cracks than where broken stone was used

Light mesh reinforcement placed with primary members perpendicular to the center line of the road has, in the same thickness of concrete, afforded a considerable reduction in transverse, longitudinal and corner cracks May not this conclusion suggest the benefit to be derived from the more extended use of bar mat reinforcement of such cross sectional areas as may be effective and yet feasible to have fabricated at the mill as well as in the field

Probably the greatest effect from reinforcing occurred after cracks had formed, in that it held the pieces together, reduced ravelling and kept the surface even and reduced impact Nearly all of these benefits were predicted when the use of steel reinforcement was first advocated for use in connection with concrete pavements The effects actually obtained, as well as the essential qualities of steel reinforcement, *i e*, the advisability of using a steel with a relatively high elastic limit to hold the pavement together

In conclusion, we might state that we may be, and often are, criticized for devoting so much time to the study of pavement failures From such studies and investigations, however, many valuable lessons may be learned, especially with reference to the inherent and acquired weaknesses of concrete pavements However, our successful highways should also be studied in like manner Pavement failures may be divided into three main classes

1 Those due to poor or unsuitable materials
2 Those due to poor or careless workmanship
3 Those due to incorrect or inadequate design

Under each one of these main classes are several divisions and numerous sub-divisions, all of which must be considered in the solution of our problems A similar method may, of course, also be used with reference to successful pavements

To be able to select the particular factor or set of factors or variables which would, for instance, make a good reinforced concrete pavement under given conditions is a task of great magnitude, and it is gratifying to note that progress is being made

W M Acheson For some time, in fact since concrete roads have been resurfaced, there has been discussion as to whether or not a concrete road could be resurfaced with another thin layer of concrete Many reputable highway engineers have deemed it inadvisable to attempt it, while others, although believing it possible, hesitated about staking their professional reputation on the outcome of such a road To settle this question, which is becoming more pressing as our old concrete roads get more worn and cracked, the Experimental Highway, No 5470, was built

This highway is on the main route to the north from Syracuse to Watertown All traffic to the north from south, east and west, converges at Syracuse and pours over it in an endless and swelling stream, while almost all northern New York and Canadian visitors enter Central New York upon it.

Before describing the structural and construction details of New York State Experimental Highway No 5470, the type of the original roadway must be investigated

The old surface was built of first-class concrete, in 1914 and 1915 It was placed on a clay-loam subgrade and the general profile is one of easy grades over a rolling country No real cuts were encountered, and drainage was not a serious problem The old road metal had a section of 4¾-6¾-4¾ inches, being thickest in the middle, and built in blocks 16 ft wide and 30 ft long The sand used was one of a very fine character, and the concrete, as was then the practice, was placed very wet This resulted in a very wavy surface. The joints were placed at right angles to the center line, and were known as the "armor plate" type These consisted of two plates of 3-16″ metal, separated by a ¼″ layer of bituminous felt The plates were about 3 inches in depth and did not go to the bottom of the slab Each plate was set in its individual slab by means of anchors about 1 foot long and spaced about every 18 inches It is interesting to note that, while this type of joint is oboslete, very few breaks or spalls occur at the joint, with the exception of corner breaks The corner breaks are, doubtless, due to the fact that no reinforcement was used in the old pavement

It was determined to resurface approximately one mile of the northern end of S. H 5470 as an experiment, for several reasons One reason was that it is about the heaviest-traveled road in this section of the State, carrying over 7,500 vehicles in ten hours Another reason was that this portion was badly cracked and warped, and only by taking the worst conditions would the experiment prove of any value.

Some time in advance of construction a crack survey was made of the proposed experiment and every crack, joint, and disintegrated portion was carefully plotted to the scale of 1″=10′ This was done mainly to ascertain if any of the cracks in the old surface would affect the resurfacing It is proposed to repeat the crack survey at intervals and compare the most recent survey with the original It should be noted in connection with the crack survey that, while the old surface was built in blocks 16 ft wide, there was not a single block in a length of 5,310 ft that did not have a longitudinal crack very nearly in the center of the block. This would seem to justify our present system of laying pavement in two longitudinal strips The last 280 ft were covered with a layer of bituminous material, varying from ½″ to 2 inches in depth As this was not removed, the cracks under it remain indeterminate The concrete was placed directly on the bituminous carpet to ascertain if its presence had any effect on the resurfacing

To facilitate the keeping of records, each block was given a number consecutively from 1 to 176, instead of using the ordinary method of stations every 100 ft This is also true with the southerly 300 ft, which have been assigned alphabetical letters Henceforth all reference will be made to the number or letter of the block. As the numbers or letters were painted directly on the old pavement, the keeping of records was made much easier

In considering the design of the old pavement it must be borne in mind that no attempt was made to bond the old road with the new, in fact, this was not considered feasible, as the old road had become oil-soaked through nearly ten years of motor travel. However, block No 83, center strip, has no reinforcement, and under this block neat cement was sprinkled lightly on the old pavement. It will be interesting to observe what will happen to this portion

The thinnest section called for in the resurfacing is 3-2¾-3 inches, and the thickest section 5-4-5 inches, the middle figure referring to the center thickness in each case. These varied somewhat widely, and the pavement actually ran as deep as 6¾ inches in places where the old pavement was sagged and warped out of shape.

The reinforcement was of two types, wire mesh and bar mesh.

The sand used was a washed variety, and obtained near Cazenovia, Madison County. It is somewhat coarse, running about 60 per cent to 62 per cent by volume, through the No. 20 screen.

The stone was Onondaga limestone, and obtained at Jamesville. It consisted of No. 2 stone, containing about 25 per cent by weight of No. 1 stone.

The forms used were of wood and varied in thickness according to the different sections. They were fastened to the old pavement by means of pins which were driven in holes previously drilled by a pneumatic drill. To obtain a true, even surface, these forms were blocked up over depressions with wooden wedges. No theoretical grade was established, the forms merely being set by eye to follow, as nearly as possible, the old surface.

Previous to resurfacing, all badly disintegrated portions were removed and replaced with new concrete. These patches were allowed to dry and cure, so that no bond might be established at these points.

Just prior to laying concrete, the old surface was swept clean and wet down thoroughly to aid the curing of the resurface slab as much as possible.

The types of joints used were poured and premoulded. Poured joints were used on all except the last eighteen joints, which were premoulded. A special device for cutting the joint material to fit the old road was devised, as all joints were set to grade, so that the screed could pass directly over them.

The laying of concrete followed closely the New York State specifications, which include the use of two screeds, or strike-off boards. The first of these is quite heavy, and shapes the concrete roughly. It is operated by four men. Two men follow with the second screed, which is lighter and is worked more rapidly than the first. In this manner the pavement has all surface voids filled quickly. The interior voids are closed by spading the concrete directly in front of the first screed. Behind the screeds two men operate what is known as the "belt." In this case a 14-inch cypress board ¼″ in thickness was used. As soon as the concrete had set sufficiently the road was broomed with an ordinary house broom, and the edges tooled. In curing, it was found that, due to the old road being more or less dry, the concrete dried out at an amazing rate, and, unless the burlap was applied almost as soon as the surface had been broomed, hair cracks would result This had to be adhered to at the risk of marring the surface with the burlap Moreover, the burlap had to be sprinkled constantly The constant sprinkling of the burlap is very important and cannot be over emphasized

Stress has been laid thus far on the resurfaced portion, as this is the real experiment However, mention must be made of the widening which ran the entire length and was eight feet wide, making a total of 24 feet of pavement The widening had stretches of 8, 7, and 6 inch depths, and is reinforced in a manner similar to the resurfacing, except that the southernmost 300 feet have wing-bar reinforcement, a new departure in this part of the State Aside from these points, the widening has no unusual features

"Twenty-four-hour cement" was used on the area in front of the proportioning plant, and with very good results, as loaded trucks were run over it 24 hours after it was placed

It is, of course, too early to give any definite results of the experiment, as frost and snow have yet to place an undetermined strain upon it However, a daily inspection shows no deterioration under the heavy traffic now going over it

My conclusions and reactions, from the charts, photographs, and data of Mr Hogentogler's paper, are that highways should always be constructed in longitudinal strips This method of construction would overcome, to a great extent, the longitudinal cracking which appears today in highways that were constructed in full-width slabs, and presents an entirely different aspect on the use of reinforcement in concrete pavements

V R Burton I was very much impressed with the last statement of the previous speaker (Mr Acheson) to the effect that the problem of reinforcing has become a new problem, in that its influence is bound to be somewhat different on the divided pavement than on the old single-slab pavement With this in mind, our study of pavements, which, with the associated soil surveys, is laid out practically along the lines suggested yesterday by Mr Older,[1] will be made with a view to getting all the information we can from our existing designs of pavements and the influence of soil on these various designs The information I have, therefore, is confined to the newer type of pavements which we have laid, because we felt we wanted to check up on the designs we are using at present or those which we had most recently used

One thing in Mr Hogentogler's paper that I think might be

[1] Proceedings of Fifth Annual Meeting, Highway Research Board, National Research Council, Part 1

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STUDY OF PAVEMENT REINFORCEMENT, MICHIGAN STATE HIGHWAY DEPARTMENT

SUMMARY OF REPORT

By V R Burton

Michigan State Highway Department Lansing Michigan

Information derived from general pavement survey carried on for determining influence of subbase, subgrade, drainage, reinforcement and pavement cross-section

Conclusions as to the effect of reinforcement are based on a limited number of comparisons in which steel was used only in sections laid on questionable subgrade

Transverse cracks

1 Were considerably reduced by ½″ bar reinforcement (30 lbs per sq ft each way)
2 Were slightly reduced by three ¾″ longitudinal bars (25 lb) and ½″ transverse rods (60 lb)
3 Were reduced more by eight ½″ longitudinal rods (30 longitudinal, 61 lb total) than by six ¾″ bars (50 longitudinal, 130 lb total)
4 Were reduced more by reinforcement in short slabs than in long slabs
5 Were of less width in reinforced sections than in adjoining plain sections