MINISTRY OF TRANSPORT
ROADS DEPARTMENT

EXPERIMENTAL WORK ON ROADS

Report for 1936-37 of the Experimental Work on Highways (Technical) Committee

LONDON
HIS MAJESTY'S STATIONERY OFFICE
Price 2*s.* 0*d.* net

MINISTRY OF TRANSPORT
ROADS DEPARTMENT

EXPERIMENTAL WORK ON ROADS

Report for 1936-37 of the Experimental Work on Highways (Technical) Committee

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
26 York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff;
80 Chichester Street, Belfast;
or through any bookseller

1937

Price 2*s*. 0*d*. net

TABLE OF CONTENTS

PREFATORY NOTE.

The experimental work on roads dealt with in this Report is carried out by the Ministry of Transport with the advice of the Experimental Work on Highways (Technical) Committee.

Road research is carried out by the Department of Scientific and Industrial Research under the advice of the Road Research Board and is described in the Annual Reports of the Board.

The two branches of work are undertaken in close collaboration and the corresponding reports are complementary, together giving a complete picture of road research and experiment.

The following reports dealing with the Experimental Work of the Ministry of Transport, Roads Department, have been published by H.M. Stationery Office:—

1. " Technical Advisory Committee on Experimental Work. Report to 31st December, 1930." (5s. 6d. net.) (Out of print.)

2. " Experimental Work on Roads. Report for 1931 of the Technical Advisory Committee on Experimental Work." (1s. 6d. net.) (Out of print.)

3. " Experimental Work on Roads. Report for 1932 of the Technical Advisory Committee on Experimental Work." (1s. 6d. net.)

4. " Concrete in Road Construction." (1933.) (2s. 6d. net.)

5. " Experimental Work on Roads. Report for 1933 of the Experimental Work on Highways (Technical) Committee." (1s. 6d. net.)

6. " Experimental Work on Roads. Report for 1934 of the Experimental Work on Highways (Technical) Committee." (1s. 6d. net.)

7. " Experimental Work on Roads. Report for 1935-6 of the Experimental Work on Highways (Technical) Committee." (1s. net.)

Of these, Nos. 1, 2, 3, 5, 6 and 7 are referred to throughout this Report as " the Report for 193- " whilst the title of No. 4 is given in full.

Except where otherwise specifically stated, the expression " the Laboratory " refers to the Road Research Laboratory of the Department of Scientific and Industrial Research.

Except where otherwise stated, all skidding tests have been carried out at a speed of 30 m.p.h. and with a smooth tyre and when the surface was wet.

It is to be understood that observations are being continued on all experimental lengths unless otherwise stated.

THE EXPERIMENTAL WORK ON HIGHWAYS (TECHNICAL) COMMITTEE

Major F. C. Cook, C.B., D.S.O., M.C., M.Inst.C.E., F.S.I. (*Chairman*).

Professor R. G. C. Batson, A.K.C., M.Inst.C.E., M.Inst. Mech.E.

Professor R. G. H. Clements, M.C., M.Inst.C.E.

Mr. T. Peirson Frank, M.Inst.C.E., F.S.I.

Dr. W. H. Glanville, D.Sc., M.Inst.C.E.

Mr. W. J. Hadfield, C.B.E., M.Inst.C.E.

Mr. A. J. Lyddon, O.B.E., M.Inst.C.E.

Mr. E. S. Perrin, B.Sc., A.M.Inst.C.E., M.I.A.E.

Mr. W. P. Robinson, M.Inst.C.E

Dr. H. F. Gillbe, B.Sc., A.I.C. (*Secretary*).

EXPERIMENTAL WORK ON ROADS

REPORT FOR THE YEAR ENDED 31st MARCH, 1937, OF THE EXPERIMENTAL WORK ON HIGHWAYS (TECHNICAL) COMMITTEE

CHAPTER I.

To the Minister of Transport.

SIR,

We have the honour to submit to you our Report for the 12 months ended 31st March, 1937.

During the year Mr. Batson was appointed to the Chair of Civil Engineering at Liverpool University; we are, however, glad that he has found himself able to remain a member of this Committee. Dr. Glanville has been appointed Assistant Director of Road Research to succeed Professor Batson and has accepted your invitation to become a member of this Committee. We welcome this arrangement, particularly because of its importance in maintaining the close connection between full scale road experiments and the work of the Road Research Laboratory.

In the course of the year we have held seven meetings and made three inspections in connection with full scale experiments.

We have also continued the work which at your request we began during 1935, in connection with the preparation of a revised Memorandum dealing with "The Layout and Construction of Roads," and furnished a Report to your Chief Engineer. Our Report, with certain small amendments which you deemed necessary, was published in January, 1937, as Memorandum 483 (Roads), and forms a basis on which construction may be carried out with due regard to the amenities of the countryside, the convenience of traffic, and the greater safety of all persons using the roads.

In our Report for 1935-6 we drew attention to the amount of work involved in considering critically the results obtained from some 60 experiments which had been begun as part of our programme. A summarised review of the information forthcoming from these experiments which was prepared for our consideration is included as an Appendix to this Report. Especial attention has also been paid in the Report to the lessons which it is suggested may be learned from the different experiments. Further to our consideration of this aspect of our work we have had prepared, in tabular form, a statement of our conception of the problem of Experimental Work on Roads. (See Appendix 5 to this Report.) Although this table indicates that experiments are necessary in respect of many factors in road design and construction, no item was included until, after careful consideration, we came to the conclusion that there were such differences of opinion and such reasonable possibility of obtaining helpful information as to merit experiments being undertaken.

During the year there has been an increasing interest in our work on the part of those concerned in the road industry, as shown by an increasing desire to co-operate in experiments and research. The Asphalt Roads Association, in co-operation with whom we have already carried out a number of full scale experiments, have during the year made arrangements to undertake co-operative research with the Road Research Board, with which body we are of course very closely associated. Whilst it is difficult for us to accept a proposal that an experiment be undertaken in conjunction with any firm or individual, it is much easier when the proposal comes from a representative Association and we welcome this recent increased interest and co-operation in experiment.

We have given consideration recently to the use of bricks as a road surfacing material, in the light of a summary prepared for our information of the results of trial lengths laid in this country. The work already carried out has shown the importance of formulating a specification for brick intended for use as a road paving material, and representatives of the brick making industry have undertaken to deal with this matter. When an appropriate specification has been prepared we propose to give the question further consideration.

The Department's experimental concrete road at Harmondsworth was opened to traffic in December, 1929. The only maintenance work which has been necessary has been attention to the transverse cracks which have developed, though even this was discontinued in 1935 in order that any further lessons to be learned from the experiment might be brought out more rapidly. The traffic on this road, which is only 20 feet wide, has grown from 12,000 tons per day in 1930 to 16,000 tons per day in 1935. All the sections are still in useful condition notwithstanding the density of the traffic, the narrow carriageway, and the fact that even the most expensive of the designs adopted was cheaper than would normally be regarded as suitable for a road carrying fast and heavy traffic. The principal defects that have been experienced are extensive transverse cracking, particularly on the unreinforced sections, and deflection at the joints when a vehicle passes from one slab to another. It is worth mentioning in this connection that the joints are plain butt joints without dowels or sleepers. Throughout the construction of this road the utmost care was taken to ensure that the specifications were rigidly adhered to, a factor to which in our opinion the success of the work is mainly due. The information obtained from the road has been of great value, especially in demonstrating (i) the possibility of achieving economy in design if sufficient care is given to the execution of the work and (ii) the suitability of concrete as a wearing surface throughout a long period of years without the superimposition of other surfacing materials. As little further information of a purely experimental nature is likely to be obtained unless the tests are continued indefinitely, we are of opinion that no useful purpose would be served by continuing to keep the sections open to traffic.

Except on three sections, no repairs have been needed on the tar and bituminous test lengths laid on the Kingston By-pass in 1930. The exceptions are (i) the two tar macadam sections, on which a certain amount of patching was carried out during July, 1936, and (ii) the cold asphaltic concrete section, $1\frac{1}{2}$ in. thick, which is gradually deteriorating. The defects in the last-named section are occurring principally over the transverse joints in the underlying concrete and no satisfactory method of repairing the surface has yet been found. It is, however, noteworthy that with these exceptions, 11 different tar and bituminous materials have for nearly seven years carried the traffic of this road (17,000 tons per day) and retained a satisfactory resistance to skidding without any appreciable expenditure on maintenance.

The test lengths of tar and bituminous surfacing laid during 1934 on the Kirkham By-pass (Lancashire) have been kept under observation. The single-coat rolled asphalt has given much less satisfactory results than have been obtained with that section of the Kingston By-pass which was laid to the same British Standard Specification. In our view the former section needs surface treatment, and the causes of its comparative lack of success are now being investigated. The unsurfaced concrete section continues to give satisfactory results. The two-coat tar macadam section has deteriorated markedly in the two side traffic lanes, where surface treatment is necessary. The surface irregularity of the hot process tar macadam section is now being examined with a view to deciding upon the necessity or otherwise of surface treatment. Section H, which is a cold asphalt representing the same type of construction as Section No. 8 on the Kingston By-pass, has been so unsatisfactory that the two 10 ft. lanes adjacent to the kerbs have had to be replaced, and it seems as if further disintegration may take place on the 20 ft. width of original material remaining at the centre of the carriageway. The Road Emulsion and Cold Bituminous Roads Association, who selected the specification for, and undertook the construction of, this section, are of opinion that the failure was due in the first instance to the action of water from the adjacent section finding its way under the asphalt along the top of the concrete, and that the physical nature of the aggregate used in the base coat of the asphalt was a contributory factor. The result of laboratory examination of the materials used on the section leads us to the opinion that the primary cause of failure was the use in the base course of an aggregate which was lacking in crushing strength and unduly permeable to water.

The thin carpets laid in the late summer and early autumn of 1934 in Oxfordshire and Worcestershire continue to yield useful information. As reported last year, four of the Oxfordshire sections (each of which had a "sandpaper" surface texture) failed after only a few months: Sections Nos. 3, 6 and 10, each of which had a rather low percentage of binder for its grading, failed by disintegration; Section No. 1, which had rather a high percentage of binder with a limestone aggregate and filler, failed by becoming slippery. It has been noticed that the sideway force coefficients obtained on some of the other sections with fine-textured surfaces, e.g., Sections Nos. 13 and 19, have varied over a wider range than those for the medium and coarse-textured surfaces. These results lead to the conclusion that for fine-textured surfaces there is a comparatively small tolerance in the selection of the correct amount of binder; a small excess may produce a low resistance to skidding whilst a small deficiency may result in lack of durability.

There are only three "sandpaper" surfaces in the Worcestershire test length, viz., Sections E, F and H. As mentioned in our Report last year, repairs were necessary to Section E after it had been subjected to traffic for a few months. Although Section F had a low resistance to skidding in March, 1935, it is sound and durable. Section H, as reported a year ago, was burnt off after a few months and replaced by material to a similar specification; the failure of the first material was attributed by the manufacturers to unsuitable binder. The replacement has so far given satisfactory results. The question of the relation between the surface textures of the sections in these experiments and their resistance to skidding is discussed at greater length in Chapter V of this Report.

With the co-operation of the Surrey County Council a comprehensive investigation into the factors attending the design of thin carpets was begun during the year. The factors being investigated in the first set of experiments are (*a*) nature of aggregate, (*b*) nature of binder, and (*c*) proportion of binder. Trial mixes were made and tested at the Laboratory to obtain information regarding suitable gradings of aggregate and proportions of binder, and the carpets laid on the road were based on the results of these tests. We have referred in a previous Report to the difficulty of obtaining gravel to a reasonably close specification as regards grading, and even, in some cases, of obtaining bulk deliveries to samples supplied as representing normal output. The difficulty was experienced again in carrying out these tests, with the result that it was impossible to complete the programme prepared for 1936 and at the end of October it was decided to cease experimental work for the year on account of weather conditions.

With the co-operation of the Buckinghamshire County Council some surface dressing experiments were carried out with the purpose of assessing the relative value of various materials with regard to road visibility. We have inspected these experimental sections at night accompanied by representatives of the Royal Automobile Club and the Automobile Association. There was general agreement as to which sections were likely to be preferred by motorists. There was, however, considerable doubt as to the reasons for the preferences expressed which it was recognised involved factors of a physiological and psychological nature which are not yet fully understood.

Continued use has been made of the machines for drilling cores from concrete roads, frequently at the request of local highway authorities. We welcome this recognition of the value of these machines in determining the quality of concrete as used in road construction.

The motor cycle and side-car, stationed at Leeds, have been in constant use for testing the resistance of roads to skidding. We have previously reported that we should like to see several more machines provided and used regularly in all parts of the country. We were therefore glad to learn that you have ordered four more machines, to be stationed at London, Edinburgh, Manchester and Exeter respectively, where they will be available for general use.

We are increasingly impressed with the desirability of having instruments with which measurements may be made to enable the results of experimental lengths to be compared on a quantitative basis as regards visibility, riding qualities, durability and the traffic carried. We are particularly interested therefore in the work being done in these directions at the Laboratory, as the production of simple and cheap measuring apparatus which can be used on any road, whether experimental or otherwise, will be a definite step forward in the advancement of the science of road engineering.

The Department of Scientific and Industrial Research and your Roads Department have continued their work of jointly compiling "Road Abstracts." These have again been published in full as a supplement to the Journal of the Institution of Municipal and County Engineers, and we desire to record our appreciation of the continued co-operation of the Institution in this matter.

CHAPTER II.

CONCRETE.

(*a*) *The Experimental Road, Harmondsworth.*

Previous references:—*Report for* 1930, *pp.* 14-24.
"*Concrete in Road Construction,*" *pp.* 5-15.
Report for 1933, *pp.* 9-13.
Report for 1934, *pp.* 8-12.
Report for 1935-6, *pp.* 10-11.

The factors to be investigated in this experiment were:—

(*a*) The economic value of reinforcement in 6-in. and 8-in. slabs.

(*b*) The effect of laying 8-in. slabs on subgrades of dry clinker, wet clinker or clinker covered with waterproof paper.

(*c*) The effect of using concrete of dry, wet or medium consistency.

(*d*) The relative merits of slabs laid in lengths of 30 ft. and 45 ft.

(*e*) The effect of the treatment of a concrete surface with silicate of soda after curing.

(*f*) The effect of laying concrete in consecutive or alternate slabs.

The length of the road is 450 yds. and the width between kerbs 20 ft. The average daily traffic is 16,258 tons (1935 census) (7,826 vehicles).

Until the end of 1934 careful maintenance was carried out on cracks and joints to prevent fraying of arrises and possible consequent disintegration of the concrete. Since the beginning of 1935 maintenance has been reduced to the minimum necessary in the interests of public safety, in order to obtain information as to the deterioration which would occur on a concrete road in such circumstances. In view of the facts that the earlier maintenance had involved the sealing of all the joints and all but one of the cracks to prevent the ingress of water, and that the ballast embankment carrying the road afforded excellent drainage, it is not surprising that on this road the deterioration has been very small indeed.

There has been little change in the condition of the concrete during the last two or three years and the road appears capable of continuing to carry the traffic for an indefinite period. It has been decided, however, that no additional information bearing on experimental work is likely to be obtained by further use of the road, and that it should be closed to traffic as soon as the experimental sections now under construction on the adjacent length of the Colnbrook By-pass have been completed. It is expected that this will be in the autumn of 1937, when the experimental concrete road will have carried traffic for nearly eight years.

No development has occurred during the year to vary the interim conclusions which have been drawn from these experiments and published in previous Reports. It is, however, intended, when the road is closed to traffic, to drill a number of cores and to examine them in order to obtain information on the uniformity of the concrete as regards composition, density and thickness in different parts of slabs, and to compare slabs made to different specifications. On completion of this examination it is proposed to review the whole of the information relating to this experiment and for convenience to issue a separate and final Report.

(*b*) GLOUCESTERSHIRE.

Gloucester-Newport Road (*A*.48).

Previous references:—*Report for* 1932, *pp*. 14-16.
Report for 1933, *pp*. 25-26.
Report for 1934, *pp*. 19-20.
Report for 1935-6, *pp*. 16-17.

Experimental concrete sections were constructed in June, 1932, on the above road, which is 20 ft. wide and carries an average daily traffic of 4,224 tons (1935 census) (2,251 vehicles). The objects of the experiment were:—

(*a*) To compare concrete made with four different aggregates.

(*b*) To compare two types of "jointless" concrete.

(*c*) To test bitumen emulsion as a means of curing concrete.

(*d*) To test silicate of soda for the surface treatment of concrete.

(*a*) Sections were laid to compare concrete made with Frampton gravel, Clee Hill granite, Malvern granite and local mountain limestone, the slabs being in each case 9 in. thick and reinforced with a single layer of high tensile steel weighing $5\frac{1}{2}$ lb./sq. yd. The Frampton gravel was mixed with cement in the proportion of $4\frac{1}{2}:1$, whilst the mixes used on the other three sections contained three parts of aggregate, $1\frac{1}{2}$ parts of Holm sand and 1 part of cement. No longitudinal joint was provided, the slabs being laid to the full 20-ft. width of the carriageway. The transverse joints were formed at 15-ft. intervals, and $\frac{3}{8}$-in. cellular rubber expansion jointing material was used at every third joint. All four sections are in excellent condition and no difference is to be observed in their behaviour. The running surface of all sections is good, but the expansion joints required attention at the end of the year. The experiment has shown that Frampton gravel, which has been regarded as suitable only for bottom-course concrete in two-course work is, in fact, capable of providing a satisfactory running surface.

(*b*) The two types of "jointless" concrete were laid in lengths of 120 ft., with a central longitudinal joint. The first section was provided with steel hoops of 16-gauge strip, 30 in. in diameter and 3 in. deep, spaced at a minimum distance of 6 in., with 3-in. top and bottom cover. The second section was laid in two courses, of which the lower was 7¼ in. and the upper 1¾ in. thick. The top course contained a metal structure in the form of a mesh 9 in. square composed of steel strip 1 in. deep laid upon the lower course. No new cracks have been noted since last year in the former type of construction, although the transverse cracks previously reported have opened slightly. The section constructed with square mesh has remained practically the same and the only additional defect a longitudinal hair crack 18 in. long. The experiment has shown that there is no advantage to be gained in using either of the special methods of construction; it was claimed that in slabs 120 ft. long only very fine or hair cracks would occur, but visible cracks have developed, particularly with the "hoop" construction. Difficulty was experienced by the workmen in getting a good finish, and the labour costs were greater than with the usual method of construction.

For experiments (*c*) and (*d*) sections 120 ft. long were constructed to the County Surveyor's normal specification.

(*c*) The use of bitumen emulsion for curing was satisfactory as regards the provision of a durable concrete. It resulted, however, in a slippery road. This was brought to the notice of the industry, who explained that the result was due to the emulsion having been applied without a subsequent dressing of sand. It is proposed to make further experiments to investigate this point.

(*d*) The experiment shows that whilst silicate of soda can be used without disadvantage for surface treatment of concrete, there is no advantage in doing so and the extra cost is not justified.

(*c*) Gloucestershire.

Thornbury By-pass (*A*.38).

Previous references:—*Report for* 1933, *pp*. 26-30.
Report for 1934, *pp*. 20-21.
Report for 1935-6, *pp*. 17-18.

Five sections, each consisting of six bays 45 ft. long, with a central longitudinal joint, making 12 slabs per section, were laid on the above road in the summer of 1933 to determine what economies could be effected

(*a*) by the use of a local gravel in the running surface; and

(*b*) by the use of single-course concrete, 6 in. and 7 in. thick, instead of the County Surveyor's normal two-course concrete, 9 in. thick.

The carriageway is 30 ft. wide and carries an average daily traffic of 9,600 tons (1935 census) (5,217 vehicles). The sections are as follows:—

Section No. 1.

7 in. thick; two-course work; 2 in. of 3:1½:1 mix of Clee Hill granite, Holm sand and cement, on 5 in. of 6:1 mix of Frampton gravel and cement.

Section No. 2.

7 in. thick single-course work; 4:2:1 mix of granite, sand and cement.

Section No. 3.

7 in. thick single-course work; 6:1 mix of gravel and cement.

Section No. 4.

6 in. thick single-course work; 4:2:1 mix of granite, sand and cement.

Section No. 5.

6 in. thick single-course work; 6:1 mix of gravel and cement.

The slabs were reinforced at the top and bottom with 5½ lb./sq. yd. of high tensile steel in each layer, and on Sections Nos. 4 and 5 additional reinforcement was provided at the corners. For comparative purposes a further section of two bays, each 50 ft. long, was laid according to the County Surveyor's normal specification (i.e. 9 in. thick; two-course work with Frampton gravel in the bottom course (7 in.), Clee Hill granite in the top course (2 in.) and with bottom reinforcement of high tensile steel weighing 5½ lb./sq. yd.).

Early in 1937 the running surface on all sections was in very good condition. Impact due to traffic was felt at several transverse joints, particularly at one slab on Section No. 3. Fretting and spalling was occurring at both the transverse and the longitudinal joints. The spalling was particularly noticeable on Section No. 3. During the year a corner crack developed on

Section No. 3 and new transverse cracks were observed on Section No. 5, bringing up the total length of cracks on this section from 12 ft. to 60 ft. The sections of single-course concrete composed of 6 parts of Frampton gravel and 1 part of cement are the only ones which have developed cracks, but the difference between these sections and the others is small. The single-course gravel section, 6 in. thick, has cracked more than the section 7 in. thick, but is still in very good condition. The single-course granite section, 6 in. thick, is in excellent condition.

This experiment, particularly when considered in association with the 6 in. concrete on the Leatherhead By-pass, confirms the result obtained on the Experimental Road, Harmondsworth, viz., that on a reasonably good foundation carefully constructed concrete 6 in. thick, suitably reinforced, will satisfactorily carry heavy, fast traffic for at least five years, even when a comparatively cheap local gravel is used in the normal 4:2:1 mix or its equivalent.

(*d*) City of Gloucester.

Ring Road (*A*.40).

Cheltenham Road (*A*.40) *to Barnwood Road* (*A*.419).

Previous references:—*Report for* 1934, *pp*. 30-34.
Report for 1935-6, *pp*. 25-26.

Seven experimental sections, having a total length of 275 yards, were completed in August, 1934. The object of the work was to determine the most suitable thickness and to compare the merits of three types of aggregate for the top course of concrete slabs. The experiment was extended to compare the " bridge " method of tamping with the normal method and to compare various types of expansion jointing material.

The carriageway is 40 ft. wide and the average daily traffic (1935 census) is 4,445 tons (2,505 vehicles). Each section consists of unreinforced concrete 8 in. thick, the bottom course in each case being composed of 6:1 mix of Frampton gravel and cement. Rapid-hardening cement was used throughout. On Sections A and B there is no longitudinal joint; the slabs extend one foot beyond the face of the kerb, making a total width of 42 ft. Transverse joints were formed at intervals of 9 ft. and 18 ft. alternately. On Sections D, E and F there is a longitudinal joint and the transverse joints are spaced 40 ft. apart; on Sections C and G random bays were constructed to suit the road junctions.

The work was described in detail in the Report for 1934, but for convenience brief particulars are given in the following table:—

Method of Construction.	Section.	Thickness of bottom course (in.).	Top course.			Expansion jointing material.
			Thickness (in.).	Nominal mix.	Coarse aggregate.	
Alternate bay for full width.	A	5	3	3 : 1½ : 1	Limestone	½-in. bituminous sheet.
As A	B	7	1	4½ : 1	Cornish grit.	½-in. bituminous sheet reinforced with canvas.
As A (random lengths).	C	6½	1½	4½ : 1	Cornish grit.	None.
Continuous slab, for half width, 'Bridge' tamping.	D	6	2	4½ : 1	Cornish grit.	½-in. bituminous sheet loaded with granulated cork.
As D	E1	5	3	3 : 1½ : 1	Limestone	⅜-in. compressed cork.
As D	E2	5	3	3 : 1½ : 1	Granite	⅜-in. compressed cork.
As D	F	5	3	3 : 1½ : 1	Limestone	¼-in. sponge rubber loaded with granulated cork.
As C	G	6	2	4½ : 1	Cornish grit.	½-in. bituminous sheet loaded with granulated cork.

Inspections have been made periodically, the latest in April 1937. No crack was observed on Sections A and G. The approximate length of cracks transverse to the major axis of the slabs on the other sections was as follows:—

Section.	*Length of Crack. (ft.)*
B	27
C	60
D	190
E1	80
E2	40
F	70

Sections A and F, and Sections D and G, respectively, are similar as regards the thickness and composition of the concrete, but the method of constructing the slabs was different. As Sections A and G were free from cracking, it appears so far that the alternate bay construction with normal tamping is superior to the continuous slab construction with "bridge" tamping. Some of the cracks on Sections E1, E2 and F may have been due to a slight settlement in the foundation, as these sections were constructed on an embankment.

The joints were still in very good condition, there being no sign of fretting, and the running surface was excellent. At present there is no indication that a greater thickness than 1 in.

is necessary for the top course if care is taken to ensure thorough bond between the two courses. The results confirm those of other experiments, viz., that aggregate of a low crushing strength may give satisfactory results in a concrete running surface provided that proper care is exercised to ensure that the aggregate is clean and the concrete well constructed. The experiment shows also that there is no advantage in using the "bridge" method of tamping.

(*e*) West Riding of Yorkshire.

Wakefield—Goole Road at Rawcliffe (*A*. 614).

Previous References:—*Report for* 1933, *pp*. 35-36.
Report for 1934, *pp*. 25-27.
Report for 1935-6, *pp*. 20-22.

The experiments on this road, of which the carriageway is 30 ft. wide and carries an average daily traffic of 7,356 tons (1935 census) (3,400 vehicles), were undertaken to investigate the most suitable dimensions of concrete road slabs and to compare the following types of transverse joints:—

(1) Sleeper joints;
(2) Dowel joints;
(3) A proprietary interlocking joint;
(4) Construction joints (which may conveniently be considered as another type of joint) which were formed in the longer slabs, the reinforcement being continuous across the joint.

The experimental length is divided into three sections, as shown in the following table:—

Section No.	Aggregate.	No. of longitudinal joints.	Slab width. (ft.).	No. of bays.	Length of slabs. (ft.).
1A and 1B (970 yds.).	Quartzite bottom course, granite top course.	None	33	{ 7 7	54 40½
		1	16½	{ 10 15	54 40½
		2	12 & 10½	{ 6 10 6	60 50 40
2A (720 yds.)	Two-course work; quartzite in both courses.	None	33	38	54
		1	16½	2	54
2B (486 yds.).	Single-course work; quartzite	None	33	8	54
		1	16½	9	54
		2	12 & 10½	10	54

The concrete in Sections 1A, 1B and 2A is of two-course construction, the bottom course being 7 in. thick, of 4:2:1 mix, and the top 3 in. thick, of 3:1½:1 mix; on Section No. 2B the concrete is single-course work 10 in. thick, of 4:2:1 mix, and the slabs extend 18 in. beyond each kerb, giving a total concrete width of 33 ft. The experiments included lengths with (*a*) no longitudinal joint; (*b*) a central longitudinal joint, and (*c*) two longitudinal joints, the central slab being 12 ft. wide and the two side slabs each 10 ft. 6 in. The work was begun in August, 1933, but owing to delays not connected with the experiment, was not finished until April, 1935. Parts of the road were opened to traffic at various dates from December, 1933, to April, 1935.

Twenty-four hours after construction, very fine cracking over the reinforcement was observed, of which the position and the amount were carefully recorded. The cracks disappeared, however, when the surface was rubbed over with pumice and water. The most probable cause of the cracking would appear to be that the spacer bars and the concrete already cast at the construction joints where the reinforcement was continuous held the two layers of reinforcement too rigidly to permit them to conform to the shrinkage of the concrete.

The road has been inspected at intervals. The condition in April, 1936, was as follows:—

The concrete surface was in excellent condition, being marred only by slight fraying at the joints. The fine cracking noted twenty-four hours after construction was very difficult to trace. A few cracks of sufficient width to be easily visible had occurred (including two corner cracks on Section No. 1A, five transverse cracks on Section No. 2A and two cracks in continuation of the longitudinal joint on either side of a manhole cover on Section No. 2B), but they were so few in number that it was not possible to relate their incidence to the type of construction employed. Little difference was to be observed between the behaviour of the different joints.

The most recent inspection was in April, 1937, when the following observations were made:—

Section No. 1A.

No new cracking had occurred but slight crazing was visible. The transverse and longitudinal joints were generally tight and in good condition, with the exception of the southern longitudinal joint, which was slightly open and was spalling along the north arris.

Section No. 1B.

No new cracking had taken place and there was no apparent change in the cracks previously noted. The condition of the longitudinal joints was similar to those on Section No. 1A.

Section No. 2A.

No new cracking had occurred and the cracks already recorded were in general very faint and in many instances difficult to detect. There was slight crazing on individual slabs, but this was hardly noticeable. There was occasional very slight fraying at the expansion joints but none at the construction joints, although there were very slight inequalities at some of the latter. At some of the expansion joints the filling material had been extruded and had broken off about $\frac{1}{4}$ in. below the surface of the concrete.

Section No. 2B.

There were several small holes in the surface where aggregate up to 1 in. in diameter had been picked out. The longitudinal joints were similar to those on Sections Nos. 1A and 1B but there was slightly more unevenness at the construction joints.

Skidding Tests.

Tests of the resistance to skidding were made on the experimental sections with the motor-cycle skidding apparatus. The curves of sideway force coefficient obtained at speeds between 5 and 30 m.p.h. on 9th March, 1936, 6th August, 1936, 17th November, 1936, and 22nd January, 1937, appear at the end of this Report. From the curves for the four sections it will be seen that the quartzite aggregate gives higher coefficients than the granite aggregate, probably because the quartzite surface is slightly rougher as a result of the picking out of the finer particles of the quartzite from the surface. The reason for the difference in the sideway force coefficients obtained on Sections Nos. 1A and 1B is not apparent.

General.

The concrete was generally in very good condition, Section No. 2A having the best appearance. Most of the cracking previously recorded is very fine. Little difference was to be observed between the behaviour of the different joints, but slight deflection at some of them could be felt when heavy vehicles were passing.

This experiment has shown that very satisfactory results as regards durability may be obtained from several different dimensions of slabs, which covered a range of widths from 10 ft. 6 in. to 33 ft. and of lengths from 13 ft. 6 in. to 60 ft. Since deflection could be felt at the joints when heavy vehicles passed, it might be concluded that none of the types of joint construction included in this experiment is entirely satisfactory, though none of them is giving unusual trouble. This confirms the deduction from other experiments that an entirely satisfactory type of joint has yet to be designed.

(*f*) NEWPORT (MONMOUTHSHIRE).

Dock Street By-pass (*A*.48).

Previous references:—*Report for* 1933, *pp*. 45-46.
Report for 1934, *pp*. 34-37.
Report for 1935-6, *pp*. 27-28.

This experiment was undertaken in view of the freedom from cracking of two-course 9-in. unreinforced concrete laid in the City of Cardiff. In this work limestone up to 2 in. gauge is used in the top course, and the slabs are 12 ft. long. It was decided to investigate whether the freedom from cracking was attributable to (*a*) the length of the slabs or (*b*) the use of large aggregate in the surface.

Three sections each 90 yds. long were laid as follows:—

Section No. 1.—12-ft. bays using large aggregate (2 in.-1½ in.).

Section No. 2.—30-ft. bays using large aggregate (2 in.-1½ in.).

Section No. 3.—12-ft. bays using small aggregate (¾ in.).

The concrete was 9-in. unreinforced single-course work throughout, and was laid in bays divided by a single longitudinal joint with transverse joints at right angles to the kerb. Both joints were of the plain butt type, whilst expansion joints were provided along each kerb line. Dolomitic limestone was used for the coarse aggregate in each case, the fine aggregate being Bristol Channel gravel for Sections Nos. 1 and 2 and Holm sand for Section No. 3. The construction was carried out during the periods 19th January to 10th April and 16th August to 21st September, 1934. The carriageway is 30 ft. wide and carries an average daily traffic (1935) of about 12,444 tons (5,302 vehicles).

The road was inspected in March, 1937, when all three sections were in good condition generally. The running surface was excellent but slight spalling was noticed at some of the joints. All the sections have so far given quite satisfactory results without cracking. The number of sections included in the experiment is not sufficient to enable the influence of all the variables involved to be determined, but the results show that if unreinforced concrete is laid in 12-ft. slabs, a comparatively cheap construction (viz., single-course 9-in. concrete of a 4:2:1 mix with dolomitic limestone of either ¾-in. or 2-in. maximum gauge) can be used without risk of cracks and that even 30-ft. bays with limestone up to 2-in. gauge will not crack. It appears therefore that there is a wide range of specifications which may be used for 12-ft. slabs without risk of cracking. This method involves, however, correspondingly large numbers of joints, which are a source of potential weakness and tend to give poor riding qualities. It is proposed therefore to carry out experiments to determine the effect of different kinds of large aggregate, especially in the surface, in reducing or eliminating the tendency to crack in slabs of more usual length (say 40-60 ft.), even when unreinforced.

(*g*) Surrey.

Leatherhead By-pass (*A*.24).

Previous references:—"*Concrete in Road Construction,*" *pp*. 34-40.
Report for 1932, *pp*. 10-14.
Report for 1933, *pp*. 18-24.
Report for 1934, *pp*. 15-19.
Report for 1935-6, *pp*. 15-16.

Section No. 1.

Slabs of different lengths and widths were laid on this section in order to determine the relative advantages of various slab dimensions. The work was completed in August, 1932. The carriageway is 30 ft. wide and the average daily traffic (1935 census) is 3,809 tons (2,670 vehicles).

A large number of cracks have developed. They are of three types, viz.:—

(*a*) Short transverse cracks commencing at the longitudinal joint.

(*b*) Transverse cracks of considerably greater length, in some cases extending for the full width of the slab.

(*c*) Transverse cracks in continuation of the transverse joints.

The longitudinal joint was constructed with a semi-circular tongue and groove joint, with $\frac{3}{4}$-in. diameter mild steel dowels 3 ft. long at 12-in centres. The dowels were ungreased in order to resist any tendency for the longitudinal joint to open, but the restraint they have exercised on the movement of the concrete has undoubtedly caused the small transverse cracks which commenced at the longitudinal joint. No crack occurred at the transverse joints where the dowel bars were greased at one end.

Section No. 2a.

The work on this section, which was completed at the end of 1932, was concerned with three types of "jointless" concrete designed to localise shrinkage effects, each type being constructed in 120-ft. lengths and of 6-in., 7-in. and 8-in. thicknesses.

Extensive cracking has occurred on all three sections. In Type 1, where the essential feature was the provision of steel hoops set in the concrete, the cracking consisted of transverse cracks the full width of the slab. In Type 2 the concrete was laid as two-course work, the top course containing a metal structure composed of steel strips, fastened with pins or clips. Extensive cracking, crazing and spalling occurred on this type of construction and it has been necessary to carry out a considerable amount of repair work. In Type 3, which consisted of single-course work with metal strips inserted to form planes of weakness, the concrete cracked along all the planes.

The experiment shows that these three types of construction compare unfavourably with 8 in. unreinforced slabs of normal design, and do not possess sufficient merit to justify their use in normal concrete road construction.

Section No. 2b.

Slabs of three different thicknesses were laid to determine the extent to which the cost of increasing the richness of the concrete might be offset by reducing the thickness of the slab. The work was carried out in May and June 1933. Numerous fine, short cracks have occurred in three slabs of thickness 7 in., mix 3 : 1½ : 1, and in two slabs of thickness 6 in., mix 4 : 2 : 1. None of these has called for any repair work and it is noteworthy that in the circumstances of this experiment, viz., good subsoil and medium traffic, the weakest concrete (6 in. thick, 4 : 2 : 1 mix, reinforced at the top with 7 lb./sq. yd. at the sides and 10½ lb./sq. yd. in the middle third of the slabs) has satisfactorily carried the traffic for four years without expenditure on maintenance.

(*h*) CHESHIRE.

Shotwick—Frodsham Road (*A*.5117).

Previous references:—*Report for* 1933, *pp.* 36-38.
Report for 1934, *p.* 27.
Report for 1935-6, *pp.* 22-23.

The carriageway of this road is 30 ft. wide and the traffic on the experimental length, which amounted to 2,738 tons (1,438 vehicles) in 1935, has increased considerably since the remaining portion of the road was opened in July, 1936. Experimental work was undertaken in 1933 with the object of determining the most efficient position for reinforcement, slabs without reinforcement being included for comparison. The work was arranged in three sections with slabs 8 in., 9 in. and 10 in. thick, each section being divided into five sub-sections as follows:—

1. With top and bottom reinforcement.
2. With top reinforcement.
3. With reinforcement at mid-depth.
4. With bottom reinforcement.
5. Unreinforced.

The slabs were constructed in two courses, the bottom being 6 in., 7 in. or 8 in. thick (4:2:1 mix) and the top course, which was laid before the concrete in the bottom course had set, 2 in. thick (3:1½:1 mix) in all cases. The slabs were 60 ft. long and either 10 ft. or 11 ft. 6 in. wide, there being two longitudinal joints. The maximum size of the granite aggregate was 1½ in. for the bottom course and ¾ in. for the top course. The mild steel reinforcement at both top and bottom was placed with 2 in. cover, the total weight of steel in all the reinforced slabs being approximately 14 lb. per square yard.

The road has been inspected periodically, the latest inspection being made in April, 1937. Part of the road was built over the bed of two streams which had drained from the east and west into a pond. The slab constructed over the site of this pond had subsided about ⅝ in. but was raised during the year by pressure grouting; the bituminous macadam which was laid on the surface has now been taken off. Subsidence has occurred at the longitudinal joints of three other slabs (the resulting unevenness necessitating correction with bituminous macadam), and at the east end of the road five slabs built over the bed of the stream have also subsided slightly.

Generally the road surface and joints were in excellent condition, but it is not yet possible to draw definite conclusions regarding the most efficient position of the reinforcement. The defects noted so far have been caused by subsidence in the foundations, as mentioned above. It is noteworthy, however, that even the cheapest form of construction, viz., 8-in. unreinforced concrete, is still, four years after construction, in excellent (uncracked) condition, having satisfactorily carried the traffic of this road without any expenditure on repairs.

(*i*) LANCASHIRE.

Maghull Diversion (*A*.59).

Previous references:—*Report for* 1933, *pp*. 34-35.
Report for 1934, *pp*. 22-25.
Report for 1935-6, *pp*. 19-20.

Arrangements were made with the Lancashire County Council for a series of tests on concrete road construction to be carried out on the Maghull Diversion of the Ormskirk—Liverpool Road. The width of the carriageway is 30 ft. and the average daily traffic is 9,643 tons (1935 census) (3,402 vehicles). The objects of the experiment were:—

(1) To compare the relative merits of single-course work and two-course work with (*a*) leaner concrete in the bottom

course than in the top course, or (*b*) cheaper aggregate in the bottom course than in the top course.

(2) To determine how far reinforcement may be used to compensate for a reduction in thickness of the concrete.

Particulars of the 14 sections, each of which is 450 ft. long, are given in the following table:—

Section.	Thickness (in.).	Aggregate.	Nominal Mix.	Reinforcement.
A	8	Granite	4 : 2 : 1	Top and Bottom.
B	8	,, ...	3 : 1½ : 1	,, ,, ,,
C & D	8	,, ...	Top 3 : 1½ : 1 Bottom 5 : 3 : 1	,, ,, ,,
E	8	,, ...	Top 4 : 2 : 1 Bottom 5 : 3 : 1	,, ,, ,,
F	10	,, ...	4 : 2 : 1	Bottom.
G	10	,, ...	4 : 2 : 1	None.
H	10	,, ...	3 : 1½ : 1	Bottom.
J	10	,, ...	3 : 1½ : 1	None.
K	12	,, ...	4 : 2 : 1	,,
L	8	Limestone ...	4 : 2 : 1	Top and Bottom.
M & N	8	Top: Granite. Bottom: Grit-stone.	4 : 2 : 1 4 : 2 : 1	,, ,, ,,
O	8	Gravel	4 : 2 : 1	,, ,, ,,

Concreting of the carriageway was completed in October, 1934, and the road was opened to traffic in the following December.

The road has been inspected at intervals, the latest inspection being made in April, 1937. The surface of the concrete was uncracked and in excellent condition. The only section which could be said to differ from the others was Section L, in which limestone aggregate was used, which was slightly lighter in colour.

The longitudinal joints were close and in good condition. There was slight fraying of all the transverse joints, both expansion and construction, but it was not sufficient to call for a detailed report.

Owing to the low cost of the granite and the relatively high cost of the lower grade materials on this road, the cost of the sections varied only from 9s. 10d. to 10s. 11d. per sq. yd. It is noteworthy, however, that the weakest types of construction, namely, 10 in. thick unreinforced, 4:2:1 mix, and 8 in. thick with double reinforcement, 4:2:1 mix, have satisfactorily carried the traffic on this road for two and a half years without any cost being incurred for repairs.

(*j*) SURREY.

Chertsey Arterial Road (*A*.316).

Previous references:—*Report for* 1930, *pp.* 24-28.
" *Concrete in Road Construction* ", *pp.* 15-17.
Report for 1933, *pp.* 13-16.
Report for 1934, *pp.* 12-13.
Report for 1935-6, *pp.* 11-13.

The object of the experiment on this road was to compare the merits of six different types of transverse joint. The work was carried out in the summer of 1930. Details of the joints, which are enumerated in the table below, were given in Figure 10 of the Report for 1930. The carriageway is 40 ft. wide and is divided by a central longitudinal joint. The average daily traffic is 11,516 tons (1935 census) (4,932 vehicles). The slabs are 21 ft. wide and 20 ft. long (except for one slab which is 120 ft. long) and project 1 ft. beyond the precast concrete kerbs on each side of the road.

The slabs were constructed with each type of transverse joint inclined at (1) 75° or 80° and (2) at 90° to the centre line of the road. The inclined joints are staggered by a length of 5 ft. on the longitudinal centre line, whereas the right-angled joints meet at the longitudinal joint.

The following table gives the length and number of the cracks which have developed at the transverse joints:—

Type of Joint.	Inclination of Joint.	No. of Cracks.	Total Length of Cracks.
	(°)		(ft.)
(A) Butt joint	90	3	8
	75	7	31
(B) Butt joint with granolithic arrises	90	2	7
	75	1	5
(C) " V " joint	90	0	0
	75	1	4
(D) Semi-circular tongue and groove joint.	90	1	2
	75	0	0
(E) Steel dowel joint ...	90	2	7
	75	1	5
(F) Sleeper joint	90	0	0
	80	5	18

The unjointed slab 120 ft. long developed 37 ft. of transverse cracks.

All the cracks referred to above were very fine and could be traced only with difficulty. The concrete surface was in very good condition. It will be seen from the table that cracking was more prevalent on slabs having butt and sleeper joints at inclinations of 75° and 80° respectively, but the reason for this is not apparent. The construction of the slabs and joints where the cracks have occurred was normal.

So far as the durability of the concrete is concerned, there is little difference between the different types of joints tested.

In previous reports information has been given regarding the relative deflections of adjacent slabs when a test vehicle was driven across selected joints. To verify these results, deflection measurements have been made during the year on every joint, and the records are being examined statistically.

The interim conclusion from this experiment is that on a well consolidated foundation there is little to choose, during the first few years in the life of the road, between the six types of joint tested, but the two tongue and groove joints (Types C and D) give the best results, having regard to both freedom from cracking of the slabs and deflection at the joints.

(*k*) SURREY.

Hampton Court-Esher Road (*A*.309).

Previous references:—"*Concrete in Road Construction,*" *pp.* 17-34.
Report for 1933, *pp.* 16-17.
Report for 1934, *pp.* 13-15.
Report for 1935-6, *pp.* 13-15.

The main object of the experimental work on this road, the construction of which was completed in March, 1932, was to compare the relative merits of a number of different types of transverse joint. The width of the carriageway is 30 ft. and the average daily traffic is 8,833 tons (1935 census) (4,726 vehicles). Details of the joints were given in "Concrete in Road Construction" (Fig. 3, p. 18) and for convenience a brief description is given below:—

Type A.—Flat dowel joint (close jointed).
Type B.—Bracket joint (with ⅜-in. or ⅛-in. bituminous jointing material).
Type C1.—Dummy joint without dowel bars.
Type C2.—Dummy joint with dowel bars.
Type D.—Vertical butt joint with ¼-in. cellular rubber filling.
Type E.—Sleeper joint with ¼-in. cellular rubber filling.

Type F.—Butt joint with thickened edges (close jointed or with ⅜-in. bituminous jointing material).

Type G.—Semi-circular tongue and groove joint alternating every 2 ft. 6 in. (close jointed).

Type H.—Semi-circular tongue and groove joint with dowel bars (close jointed).

Type I.—A proprietary interlocking joint (close jointed).

Type J.—Butt joint reinforced with surface mesh (with ⅜-in. or ⅛-in. bituminous jointing material).

Type K.—Dowel joint (close jointed).

The majority of the slabs are 20 ft. or 30 ft. long, but six slabs 120 ft. long, two of which were covered with 2-in. steam-rolled asphalt, were included in the experimental lengths.

In addition three sections designed to localise shrinkage effects were laid. One of these sections, referred to below as Type 1, was 240 ft. long and was constructed in two courses with grooves 2 in. deep and 6 in. wide in the upper surface of the bottom course to localise shrinkage in the top course. The other two sections were laid in lengths of 120 ft. and contained steel hoops either 2 ft. or 2 ft. 6 in. in diameter. One of these sections was laid as single-course work (Type 2) and the other as two-course work (Type 3).

The work was carried out in two sections. Section No. 1 was constructed in May and June, 1931, and Section No. 2 between November, 1931, and March, 1932. The length of transverse cracks noted in February, 1937, is given below:—

Type of Slab.	Thickness. (in.).	Date of Construction.	No. of Slabs.	Total length of Slabs. (ft.).	Total length of Transverse Cracks. (ft.).	Length of Transverse Cracks per 100 lin. ft. of Slab. (ft.).
Section No. 1.						
20 ft.	9	Summer, 1931	96	1,920	34	1·77
30 ft. ...	9	do.	96	2,880	70	2·43
Section No. 2.						
20 ft. ...	9	Winter, 1931/32	32	640	5	0·77
30 ft. ...	9	do.	24	720	0	0
20 ft. ...	10	do.	18	360	0	0
30 ft. ...	10	do.	50	1,500	52	3·47
120 ft. slab	9	Winter, 1931/32	2	240	4	1·67
120 ft. slab	10	do.	2	240	46	19·30
Type 1 ...	10	Winter, 1931/32	2	480	312	65·0
Type 2 ...	10	do.	2	240	50	20·8
Type 3 ...	10	do.	2	240	122	51·0

The following table gives the position of the various cracks:—

Type of Slab.	Transverse Cracks					Longitudinal cracks commencing at transverse joint (ft.).
	Full width of slab (ft.).	Commencing at longitudinal joint (ft.).	Commencing at kerb (ft.).	Commencing at centre of slab (ft.).	Continuation of transverse joint (ft.).	
20 ft. & 30 ft.	30	29	53	32	17	3
120 ft.	—	46	—	4	—	—
Type 1 ...	255	57	—	—	—	4
Type 2	—	43	7	—	—	—
Type 3 ...	105	10	—	7	—	—
Total Length.	390	185	60	43	17	7

On comparison of the 20-ft. and 30-ft. slabs, it will be noted that more cracking has occurred on the latter, both on Section No. 1 and on the 10-in. work on Section No. 2 constructed during the winter. The small amount of cracking on the 20-ft. slabs is still more than offset by the greater length of transverse joint to be maintained. A point of interest is the very small amount of cracking on the 120-ft. slabs, 9 in. thick, which is even less than on the corresponding slabs 10 in. thick.

All the types of joints are in good condition and have required very little maintenance.

Deflection Tests.

Information has been given in previous reports regarding the relative deflections of adjacent slabs when a test vehicle was driven across selected joints. To verify the tentative conclusions drawn from those tests deflection measurements have been made during the year on every joint and the records are being examined statistically.

From the information at present available, the following interim conclusions may be drawn:—

All the types of joint tested are still in good condition and the cost of maintenance has been negligible. There are no cracks attributable to restraint at the joints. Deflection at the joints has been small, the least having occurred at joints A, B and C, followed by H, I and K. Of these the bracket joint B was inconvenient and expensive to construct (8s. 9½d. per lin. ft.), whilst the dummy joints, although satisfactory as contraction joints, afford no provision for expansion. There is no evidence that oblique joints are superior to joints at right angles to the centre line of the road in the case of short slabs. In the case of long slabs laid in the winter with insufficient width of expansion joint, however, the inclination of the joint allowed the ends of the slabs to slide laterally and so relieved compression which might otherwise have led to a " blow-up " at the joint.

CHAPTER III.

Cement-Bound Macadam.

(*a*) Wiltshire.

London-Exeter Road (*A*.30).

Previous references:—*Report for* 1933, *pp*. 42-45.
Report for 1934, *p*. 46.
Report for 1935-6, *p*. 32.

An experimental section 220 yards long was laid on the above road in August, 1933, to investigate the merits of the sandwich system of cement-bound macadam. The carriageway was 20 feet wide and the average daily traffic 4,510 tons (1935 census) (2,697 vehicles). The section was constructed in bays 30 ft. long and approximately 5 in. thick and consolidated by a 2½ ton roller. The transverse joints throughout were filled with bituminous sheeting.

When the road was inspected in March, 1936, it was noted that considerable cracking had taken place at the corners of the slabs. The road was inspected again in March, 1937. During the year under review there had been an increase in the amount of fine crazing of the surface, and a number of new cracks, often developments of previous ones, had occurred. Very little spalling was in evidence and the cracking had not had any apparent ill-effect on the durability of the surface. The riding qualities and appearance of the section as a whole, which have always been rather uneven, had not undergone any change since the previous inspection. It was noted that at the few places where the transverse joints in the two sides of the road were staggered, there was much less corner cracking than where the joints were opposite one another, and this observation, in conjunction with the similar result obtained in experiment No. 54 (near Cornhill in Radnorshire, A.44) indicates that staggering of the joints may lead to a reduction of cracking in this type of construction.

(*b*) Norfolk.

Route B.1145 *at Brisley*.

Previous references:—*Report for* 1934, *pp*. 46-52.
Report for 1935-6, *pp*. 32-33.

In August and September, 1934, trial lengths of three systems of cement-bound macadam, i.e., compressed concrete, sandwich and cement penetration were laid. The road is 20 feet wide and the average daily traffic in December, 1934, was 357 tons (139 vehicles).

Extensive cracking, spalling and crazing occurred on all three sections and in October, 1935, repair work became necessary. This was kept to a minimum in order to obtain further information by continued observation of the behaviour of the test sections; the crushed material was raked out and defects were made good with fine tar macadam.

The lengths have been inspected periodically during the year under review; a considerable amount of spalling has taken place along the longitudinal joint on the sandwich and penetration sections during the year. The sections however still provided a satisfactory riding surface in April, 1937. The compressed concrete section was the best of the three, the sandwich type coming next, and the cement penetration being the least satisfactory.

(*c*) Inverness-shire.

Cannich—Beauly—Milton Road (*A*.831) *at Cannich.*

Previous references:—*Report for* 1934 *pp.* 53-55.
Report for 1935-6 *pp.* 33-34.

An experiment was undertaken at the suggestion of the County Surveyor to compare the results obtained with the cement penetration system of construction, using grouts of different cement content, with those obtained with the sandwich system using a constant mix.

Four sections were laid on a water-bound macadam road, Nos. 1, 2 and 3, each being 220 yds. long and constructed on the penetration system with a sand-cement grout in the proportions of 2½:1, 1½:1 and 1:1 respectively. Section No. 4 is 330 yds. long and was constructed on the sandwich system with a 2:1 sand-cement mortar. The work was carried out in September, October and November, 1934. All the sections are 4 in. thick, the width of carriageway is 16 ft., and the average daily traffic (1935 census) is 223 tons (154 vehicles).

The sections were inspected in 1936. There was laitance on all sections—in some places as much as ¼ in. thick—which was being gradually removed by the traffic. This emphasized the importance of removing surplus mortar by brushing at the time of construction. At some of the joints the bituminous expansion material had been extruded and rolled flat by traffic. Although there were differences of level at a few of the transverse joints, the sections had good riding qualities. There was little difference in appearance between the three penetration sections. Section No. 4 (sandwich system) was free from the corner cracking which had occurred on other experimental lengths constructed by this method.

The sections were inspected again in May, 1937. There was on all sections a good deal of laitance which will probably take a long time to wear off owing to the small amount of traffic. No cracking had occurred on any of the sections; although there were inequalities of level at a few of the transverse joints, all sections had satisfactory riding qualities. The following notes were made:—

Section No. 1: Penetration system, 2½:1 sand-cement grout, cost, 5s. 2½d. per sq. yd.

The laitance is gradually flaking off, exposing the aggregate in the surface. There is very little abrasion at the joints, which are in better condition than on any other section.

Section No. 2: Penetration system, using 1½:1 sand-cement grout, cost, 5s. 1d. per sq. yd.

Some laitance has worn off, but some of the bays still have a crazed appearance. Abrasion is evident at several joints and a difference of level at some of the transverse joints could be felt when a car was driven over them. The surface finish is rougher than that on Section No. 4 but not so rough as that on Section No. 3.

Section No. 3: Penetration system, using 1:1 sand-cement grout, cost, 5s. 4½d. per sq. yd.

The laitance is gradually wearing off; a number of bays show the large aggregate in the surface; abrasion is evident at several joints; the surface is rougher than that on Section No. 4.

Section No. 4: Sandwich system, using 2:1 sand-cement mortar, cost, 5s. 11d. per sq. yd.

The laitance is wearing off slowly in several bays, a few of which now show a mosaic of small aggregate; most of the bays, however, still present a smooth appearance with very little aggregate showing. Abrasion had occurred at several joints.

(*d*) WIGTOWNSHIRE.

Newton Stewart—Girvan Road (A.714) at Knockville.

Previous references:—*Report for* 1934, *pp.* 55-57.
Report for 1935-6, *pp.* 34-35.

One section each of sandwich and cement penetration systems of cement-bound macadam, 240 and 210 yds. long respectively, were laid during September and October, 1934, for comparison with the County Surveyor's normal bitumen grouted macadam. The carriageway is 18 ft. wide and the average daily traffic (1935 census) is 580 tons (276 vehicles). The cost of the sandwich section was 3s. 7½d. per sq. yd., and that of the penetration section 3s. 9¾d. The bituminous macadam surfacing, with which the cement-bound macadam is to be compared, was constructed during March and April, 1935, under somewhat showery conditions. Its cost was 1s. 7½d. per sq. yd.

The road was inspected in April, 1936, and the following notes were made:—

Sandwich Section.

The aggregate was exposed uniformly in the surface; the jointing material had been extruded at a number of the joints. Spalling had occurred on some slabs at the centre joint, and, as a result, there was some loose stone lying in either channel; very little spalling was apparent at the transverse joints. The corner cracking experienced on previous experimental lengths of this type of construction had occurred on several of the slabs, and a number of small defects of this nature had been floated over with cement-mortar.

Penetration Section.

This section had the more closely grained mosaic appearance; the amount of laitance on the surface was greater than on the sandwich section, but nowhere excessive. Spalling at the centre joint was more extensive on this section, but the stone lying in the channels was less in quantity and of smaller gauge than on the sandwich section. Some longitudinal cracking was apparent, but the section was almost entirely free from corner cracking.

The road was inspected again in April, 1937. Both sections of cement-bound macadam were in substantially the same general condition as they were a year previously. The spalling had not increased to any extent except at the slab junctions. A considerable amount of further hair cracking had taken place, mainly over the line of the old road channels on both sides of the road, and particularly on the west side. A few potholes were beginning to appear in one slab and on the sandwich section the characteristic corner cracking was visible at nearly every joint.

The riding qualities of the surface, which were never very good, had not altered appreciably during the year, but otherwise the whole surface was in very good general condition.

The bituminous macadam was still in good condition, except near the north end where it adjoins the cement-bound macadam and where traffic from the adjacent roadside quarry is very heavy.

It is not yet possible to draw conclusions as to the respective merits of the two systems of cement-bound macadam in comparison with the bitumen grouted macadam.

(e) RADNORSHIRE.

(1) *Kington-Llangurig Road, A.44, near Cornhill.*

(2) *Knighton-Penybont Road, A.488, near Dolau.*

Previous references:—*Report for* 1934, *pp.* 57-60.
Report for 1935-6, *pp.* 35-36.

One section 220 yds. long was laid on each of the above roads in October and November, 1934, to compare two systems of cement-bound macadam, namely, sandwich on A.44 and compressed concrete on A.488, with the County Surveyor's normal tar macadam. The width of the carriageway is 20 ft. in each case and the average daily traffic (1935 census) is 464 tons (294 vehicles) at Dolau and approximately 1,300 tons (800 vehicles) at Cornhill. The slabs were laid in 30-ft. lengths with a central longitudinal joint, the thickness being 4 in. except near the transverse joints on the compressed concrete where it was increased to 8 in. For this section 12 and 5-ton rollers were used, whereas an 8-ton roller was employed on the sandwich section. An adjacent section of tar macadam 3 in. thick was laid on each road for comparison with the cement-bound macadam, the length of tar macadam on Route A.488 being 180 yds. and that on Route A.44, 345 yds.

The roads have been inspected periodically, the last inspection being made in April, 1937.

Sandwich Section.

In August, 1935, it was observed that at the joints between Slabs Nos. 33 and 34, and between Slabs Nos. 35 and 36, the concrete had lifted about 1 in. and ½ in. respectively. At the latter joint severe cracking had also taken place. The work which failed had been hand tamped and not rolled. The weather during laying was very cold, whereas the temperatures in the following summer were exceptionally high. Had the temperatures been normal it is probable that this trouble would not have been experienced. The defective material, for about 4 ft. on either side of the joint and to the full depth and width of the slab, was removed and made good with concrete of the same proportions as the cement-bound macadam, new jointing material being inserted to the full depth of the slab instead of only to three-quarter depth as in the original work.

At the beginning of 1936 this section had a more uneven surface than the compressed concrete. When this section was inspected in April, 1937, a considerable amount of spalling and cracking of the concrete was noticed, although the riding qualities of the road were still reasonably good. Eleven cases of spalling had occurred at the longitudinal joints, while the cracking consisted of (*a*) longitudinal cracks in two slabs, and (*b*) corner cracks along the centre of the road in several other slabs.

The adjacent section of tar macadam was greatly affected by wet and frosty weather during the preceding winter and had to be surface dressed at a cost of 3⅝d. per sq. yd.

Compressed Concrete Section.

An inspection early in 1936 showed that spalling had occurred at four of the joints, though not to a serious extent. On five slabs transverse cracks the full width of the slab had appeared at about 16 in. from the joint. The cracking had taken place at the change of cross section, which suggested that it was due to the inner faces of the ribs of the concrete tending to resist contraction in the cooler weather which followed the hot summer. No further case of spalling was noticed during the inspection of April, 1937, but short longitudinal cracks 16 in. long occurred in the space between the old crack and the expansion joint.

The adjacent tar macadam on this road had also greatly deteriorated and required extensive patching; it is to be surface dressed during 1937.

(*f*) BRECONSHIRE.

Neath-Abergavenny Road (*A*.464) *at Clydach.*

Previous reference:—*Report for* 1935-6, *pp.* 36-38.

The object of the experiment which was undertaken on this road, on which the average daily traffic (1935 census) is 2,216 tons (1,298 vehicles), was to compare the relative advantages of the sandwich system of cement-bound macadam and the County Surveyor's normal tar macadam surfacing. The experimental length is on a gradient which is 1 in 11 at the steepest part, and in these circumstances it was thought that cement-bound macadam, even though its first cost was 7s. 11d. per sq. yd. as compared with 2s. 9d. per sq. yd. for the County Surveyor's normal tar macadam, might be justified if it would provide a surface which would be more durable, and provide a better foothold for horses, than the tar macadam.

The cement-bound section, 255 yds. long, 20 ft. wide and 4 in. thick, was constructed in slabs 45 ft. long with a central longitudinal joint. The work was carried out in August and September, 1935.

The road was inspected in April, 1936. A pot-hole had occurred in one of the slabs and when the defective material was cut out it was found that the cement had not penetrated to the lower stone. Since the defect occurred in the first slab to be constructed it was attributed to the fact that the gang was not accustomed to concrete work. A diagonal crack had occurred near the joint with the tar macadam—due probably to a weakness in the foundation. Otherwise practically no cracking had occurred in the cement-bound macadam; the surface was rather uneven owing to the aggregate being very prominent, though this rather rough surface was, in the circumstances, an advantage. The transverse construction joints were visible as hair lines, and at their intersections with the longitudinal joint some of the aggregate had become detached along each joint line for a distance of approximately 2 ft.

The sections were inspected again in March, 1937. The cement-bound macadam had a good rough surface. The joints were in fairly good condition; although there was a number of small diagonal hair cracks at the junction of the longitudinal and transverse joints, these were of minor importance. The diagonal crack at the joint with the tar macadam, noticed when the inspection was made in April, 1936, had developed into a shattering of the material over a triangular area which will have to be cut out and replaced. Except for these defects the cement-bound macadam was in good condition, and the rough finish gave a good non-skid surface suitable for steep gradients. The tar macadam appeared to be in good condition.

CHAPTER IV.

TAR AND BITUMINOUS SURFACING.

(A) COMPARISON OF DIFFERENT TYPES OF SURFACING.

(*a*) SURREY.

Kingston By-Pass (*A*.3).

Previous References:—*Report for* 1930, *pp.* 58-80.
Report for 1931, *pp.* 9-13.
Report for 1932, *pp.* 22-26.
Report for 1933, *pp.* 49-52.
Report for 1934, *pp.* 65-68.
Report for 1935-6, *pp.* 39-41.

Eleven test lengths, each 220 yds. long, were laid on the above road in August and September, 1930, between Robin Hood Gate and Coombe Lane to compare the initial and maintenance costs, length of life and non-skid properties of a number of tar and bituminous surfacings. The road, of which the carriageway is 30 ft. wide, carried an average daily traffic of 17,245 tons (24 hour census, 1935) (12,127 vehicles).

A full report on the results of this experiment to date is in course of preparation. Most of the sections have changed little during the past year, but Sections Nos. 6 and 7 needed a certain amount of patching which was carried out during July. Section No. 11 is gradually deteriorating and several methods of patching the surface have been tried during the last few months. A satisfactory method has not yet been found for repairing the surface over the joints in the underlying concrete, where most of the defects have occurred.

It is noteworthy that so many tar and bituminous surfaces of varying specifications have proved capable of giving satisfactory results on a road carrying 17,000 tons per day for nearly seven years without any appreciable expenditure on maintenance.

The average skidding figures for those sections which gave good coefficients during their early life have since shown only a slight tendency to fall. Those which gave poor coefficients initially have improved from year to year.

(*b*) LANCASHIRE.

Kirkham By-pass (*A*.583).

Previous References:—*Report for* 1934, *pp.* 68-77.
Report for 1935-6, *pp.* 41-43.

During September, October and November, 1934, a series of experimental lengths were laid on the above road with the object of comparing the life, cost of maintenance and non-skid properties of well-known types of tar and bituminous surfaces.

The width of the carriageway is 40 ft. and the traffic amounted to 14,490 tons per day (1935 census) (7,756 vehicles).

The scheme was drawn up in collaboration with the Lancashire County Council, the Asphalt Roads Association, the British Road Tar Association and the Road Emulsion and Cold Bituminous Roads Association. For convenience a brief description of each section is given below:—

Section. *Specification supplied by*	*Description.*
Section A.—Asphalt Roads Association ...	1¼-in. mastic on 1¾-in. binder course.
Section B.—Asphalt Roads Association ...	Two-coat rolled asphalt: 1¼-in. wearing course on 1¾-in. binder course.
Section C.—Asphalt Roads Association ...	3-in. single-coat rolled asphalt.
Section D.—County Surveyor	12-in. unreinforced concrete.
Section E.—British Road Tar Association	Tar macadam: ½-in. wearing course on 2½-in. binder course.
Section F.—British Road Tar Association	2½-in. single-coat tar-concrete.
Section G.—Road Emulsion and Cold Bituminous Roads Association.	Two-coat cold asphalt: ½-in. wearing course on 2-in. binder course.
Section H.—Road Emulsion and Cold Bituminous Roads Association.	Two-coat cold asphalt: ½-in. wearing course on 1¼-in. binder course.
Section J.—Road Emulsion and Cold Bituminous Roads Association.	Two-coat cold (emulsion) asphalt: ½-in. wearing course on 2-in. binder course.
Section K.—County Surveyor	Two-coat cold bituminous macadam: ½-in. wearing course on 2½-in. binder course.

The following paragraphs indicate the condition of each section at the end of the year:—

Section A.

This section is in good condition and no appreciable change has taken place since it was laid. The lowest sideway force coefficient recorded was 0·54 in June, 1935, and February, 1937.

Section B.

This also remains in good condition, but some of the precoated chippings have been lost. The lowest coefficient was 0·63, recorded in June, 1935.

Section C.

A considerable amount of the precoated chippings has been lost and the riding qualities of the section are now unsatisfactory. It is thought that complete surface treatment will be necessary during 1937. The lowest coefficient was 0·65, recorded in June, 1935.

Section D.

This section is in good condition; there is a little fraying at the joints and one or two small defects at the corners of slabs. The satisfactory behaviour of this section in comparison with the others emphasises that where concrete is used as a road foundation it should also form the running surface. The lowest coefficient was 0·37, recorded in June, 1935.

Section E.

The 10 ft. side traffic lanes have deteriorated very markedly and it is considered necessary that they should receive surface treatment. The condition of the central 20 ft. is, by contrast, remarkably good, being appreciably the same as when the material was laid. The lowest coefficient was 0·55, recorded in February, 1937.

Section F.

This section lacks uniformity in both texture and shape and tests are to be made with the profilometer recently constructed at the Laboratory. The lowest coefficient was 0·53, recorded in February, 1937.

Section G.

This is in very good condition as regards durability and texture and has the additional merit of being light in colour. The lowest coefficient was 0·59, recorded in June, 1935.

Section H.

So much of this section has had to be replaced that it must be regarded as having failed (see pp. 8-9).

Section J.

Owing to disintegration of the surface, it was necessary to cover the whole of this section with a regulating coat in June, 1935. Part was covered with a $\frac{1}{2}$-in. carpet containing $\frac{3}{8}$-in. basalt as the maximum size, and the remainder with a sand carpet into which precoated basalt chippings were rolled; the finish of the latter was similar to that of Section No. 12 of the Oxford-Henley Road experiment. The section now has a satisfactory appearance, but the fact that these repairs were necessary must be borne in mind when assessing the results. In the opinion of the industry the early defects were due to the original carpet having been laid in wet weather and to traffic not having been admitted until some time after the material had been laid. The section was completed early in October and was not opened to traffic until December. The lowest coefficient was 0·59, recorded in February, 1937.

Section K.

This is in very good condition, no appreciable change having taken place since the surface was laid. The lowest coefficient was 0·69, recorded in June, 1936.

It will be seen from the above that all the skidding tests have given satisfactory results. Section K gives the highest average figures but there is only slight tendency for the non-skid properties of any of the sections to fall with age.

(B) INVESTIGATION OF VARIOUS FACTORS IN DESIGN.

(*a*) CITY OF LEICESTER.

Jarrom Street (*Unclassified*).

Previous references:—*Report for* 1932, *pp.* 32-33.
Report for 1933, *p.* 68.
Report for 1934, *p.* 87.
Report for 1935-6, *p.* 52.

Three sections of tar macadam 2 in. in thickness were laid during August and September, 1932,

(*a*) to compare the relative advantages of two different gradings of granite aggregate, graded 1-in. down and ⅝-in. down respectively;

(*b*) to compare the merits of the following binders: a 73/27 mixture of tar and bitumen; and a 90/10 mixture of tar and powdered rock asphalt.

The three sections are in poor condition and compare very unfavourably with the two experimental concrete sections in the same street laid in the summer of 1932. The two sections in which tar-bitumen binder was used are slightly better than the section in which tar-asphalt binder was used, and of the former sections, that containing ⅝-in. aggregate is the better.

From the experimental point of view the life of the sections is now finished and no further observations will be made.

(*b*) FLINTSHIRE.

Bangor-Chester Road (*A*.55).

Previous references:—*Report for* 1932, *pp.* 27-29.
Report for 1933, *p.* 52.
Report for 1934, *p.* 77.
Report for 1935-6, *pp.* 43-44.

Three experimental sections were laid on the above road between Northop and Holywell in August, 1932, to compare the suitability for tar macadam of different local aggregates, namely granite, slag and limestone. The carriageway is 20 ft. wide and the average daily traffic (1935 census) 5,168 tons (3,580 vehicles). The cost per sq. yd. of the three sections was 5s. 2d., 4s. 3½d. and 3s. 3½d. respectively. In July, 1934, all the sections showed signs of wear and they were surface dressed with a proprietary bitumen applied at the rate of 4 sq. yds. per gal. and ¾-in. granite chippings spread at the rate of 70 sq. yds. per ton, the cost being 4·1d. per sq. yd.

Early in 1936 all three sections again showed slight signs of wear. Bare strips had developed in the wheel tracks on the granite and limestone sections and there had been loss of chippings from the slag section, giving the surface a somewhat patchy appearance. The limestone section was the most economical of the three, despite renewal of the top coat in February, 1933, at a cost of 10d. per sq. yd., which was necessitated by disintegration causing exposure of the underlying aggregate. The failure was attributable to the low temperature of the material at the time of laying, which did not permit of satisfactory consolidation. The granite section was slightly better than the slag.

In March, 1937, all the sections had further deteriorated, and in numerous places areas up to 5 sq. ft. were devoid of chippings. The riding qualities of the road remain good, but the wheel tracks are polished. The order of merit of the sections remains unaltered, viz, (1) limestone, (2) granite, (3) slag.

(*c*) Lanarkshire.

Bathgate—Airdrie Road (*A*.89).

Previous references:—*Report for* 1932, *pp*. 31-32.
Report for 1933, *p*. 63.
Report for 1934, *pp*. 81-82.
Report for 1935-6, *pp*. 47-48.

Eight sections were laid, each 220 yds. long, to compare three different binders and three types of aggregate for single-course tar macadam. The average width of the carriageway is 26 ft. and the average daily traffic (1935 census), 1,625 tons (567 vehicles). The work was in progress between October and December, 1932; the weather was cold and rain fell on a number of days. The aggregates consisted of two types of 2¼ in.-1 in. whinstone and 2½ in.-1 in steel slag laid to a consolidated depth of 3 in.-3½ in.; the binders were coke-oven tar, a proprietary tar and a tar-bitumen mixture. Sealing coats of binder and ⅜-in. chippings were applied in each case except on Sections Nos. 2 and 3, which were blinded with a bituminous grit. This surface treatment was repeated in June, 1933, the same kinds of binders and chippings being used as for the first dressing. A brief description of the sections is given in the following table:—

Section No.	Surfacing Materials.		Sealing Coat.	
	Binder.	Aggregate.	Binder.	Chippings.
1	Coke-oven tar	Whinstone No. 1.	Tar-bitumen mixture.	Whinstone No. 1.
2	do.	do.	Bituminous sealing coat.	
3	do.	Steel slag	do.	do.
4	Proprietary tar.	Whinstone No. 1.	Proprietary tar.	Whinstone No. 1.
5	do.	do. No. 2	do.	do. No. 2.
6	do.	Steel slag	do.	Steel slag.
7	Tar-bitumen mixture.	Whinstone No. 1.	Tar-bitumen mixture.	Whinstone No. 1.
8	do.	Steel slag	do.	Steel slag.

The present position with regard to the sections is as follows:—

Of the coke-oven tar sections, Nos. 1 and 2 have suffered from bleeding, the latter to a considerable extent on the eastern half, although the remainder are in fairly good condition. Section No. 3 appears one of the best, although a little bleeding has occurred.

Of the proprietary-tar sections, No. 4 is in good condition on the north side, but the south side has deteriorated, being rather wavy, and some disintegration of the surface has occurred. Section No. 5 is in very good condition, this section and No. 3 being the best of all. Section No. 6 looks rather rough and open, but is otherwise satisfactory.

Sections Nos. 7 and 8, on which a tar-bitumen mixture was used, remain in sound condition. The surfaces are well sealed and are nearly as good as that of Section No. 5.

Comparing the aggregates, the whinstone No. 1 is giving better results with the tar-bitumen mixture than with coke-oven tar or the proprietary tar; the steel slag is rather less satisfactory when used with the proprietary tar than with the other binders; and the one section using whinstone No. 2 and proprietary tar remains satisfactory.

Two sets of skidding tests have been made during the year, giving on all the sections remarkably consistent and high results which, with one exception, lay between 0·6 and 0·7.

On nearly all the sections where the road was built on embankment the foundation appears to be weak and there is crazing of the surface which, in some cases, has been patched, particularly in the near-side wheel tracks. It appears that these parts of the road will fail first by fraying, but all the sections should last a considerable time longer before any major repairs become necessary.

(*d*) West Riding of Yorkshire.

Great North Road (*A*.1) *near Aberford.*

Previous references:—*Report for* 1932, *pp*. 29-30.
Report for 1933, *p*. 58.
Report for 1934, *pp*. 78-79.
Report for 1935-6, *pp*. 44-45.

Five sections were laid on the above road to compare five different aggregates for bituminous macadam, namely, Leicestershire granite, a local sedimentary rock, limestone, slag, and whinstone. Each of the sections was about 220 yds. long, except the whinstone section, which was 430 yds. long. The road, of which the carriageway is 30 ft. wide, carries an average daily traffic of 5,560 tons (1935 census) (3,142 vehicles). The work was carried out between August and October, 1932.

In each case the stone, graded 2¼ in. down, was mixed with a binder consisting of a proprietary bitumen and a small proportion of coal-tar oil; the percentages of binder and aggregate used on each section were given in the table on p. 72 of the Report for 1933. The materials were spread to give a final depth of 3 in. and after 14 days each section was surface sealed with a binder similar to that mentioned above and ½-in. chippings of the same stone as was used for the surfacing work, except that a bitumen emulsion binder was used for part of the slag section and for the whole of the whinstone section. It was necessary to surface dress these two lengths in August, 1933, using a hot bituminous binder and chippings of a type similar to the original aggregate. Part of the slag section was again surface dressed in the summer of 1935.

The road has been inspected regularly during the period covered by this Report. All the sections are still wearing well and there has been little noticeable change in the condition of the surfaces. There has been a slight tendency, however, for the defects previously noted to increase in number, and there are a few areas on Sections Nos. 1 (granite), 2 (sedimentary rock), and 5 (whinstone) where very slight crazing of the surface has occurred. The surfaces of Sections Nos. 1 and 5 have the most non-skid appearance whilst those of Sections Nos. 3 (limestone) and 4 (slag) are the smoothest.

Skidding tests were carried out in July and November, 1936, and January, 1937, when the road surface was wet; the values of the sideway force coefficient obtained are given in the following table, together with the corresponding values obtained in March, 1936.

Section.	Sideway force coefficients.				
	March, 1936.	July, 1936.	November, 1936.	January, 1937.	May, 1937.
No. 1 Granite ...	0·69	0·66	0·77	0·81	0·66
No. 2 Sedimentary rock.	0·57	0·58	0·56	0·79	0·48
No. 3. Limestone...	0·36	0·35	0·34	0·57	0·18
No. 4. Slag ...	0·32	0·37	0·35	0·61	0·27
No. 5. Whinstone	0·63	0·68	0·76	0·84	0·53

The marked increase in the values of the coefficient from November to January, particularly on Sections Nos. 2, 3 and 4, can probably be attributed to the fact that between the two tests the surface was abraded by grit applied to it during a prolonged spell of snow and frosty weather. In May, however, Section No. 3 gave a figure indicating that it might be very slippery under certain conditions and unless a substantial improvement is shown at the next test it is proposed to surface dress this section. Section No. 4 also gave a low figure and it may become necessary to surface dress this section. Sections Nos. 1 and 2 have so far needed no maintenance and may, therefore, be considered to be the best sections to date.

(*e*) CUMBERLAND.

Carlisle-Newcastle Road (*A*.69), *between Low Row and High Close Gill.*

Previous References:—*Report for* 1933, *pp.* 62-63.
Report for 1934, *pp.* 80-81.
Report for 1935-6, *pp.* 46-47.

For some time prior to 1933 the County Surveyor had used a local river gravel as aggregate for bitumen grouted macadam on secondary roads, and wished to see whether the same type of construction would prove successful under much heavier traffic. For this purpose six experimental sections, each 208 yds. long, were laid on the above road during September and November, 1933, a different type of binder being employed on each section for comparison. The width of the carriageway is 24 ft. and the average daily traffic (1935 census) 2,011 tons (757 vehicles). A 3-in. layer of 2¼ in.-¾ in. gravel was laid on a ½-in. cushion of sand and rolled with an 8-ton roller; the consolidated stone was grouted with binder at the rate of

1 sq. yd./gal. and blinded with sand. After rolling on the following day the work was surface dressed with the binder at the rate of 5 sq. yds./gal. and $\frac{3}{4}$ in.-$\frac{1}{4}$ in. clean gravel followed by a further sprinkling of sand.

The lengths have been inspected at intervals during the last $3\frac{1}{2}$ years, and except where bleeding has occurred, all the sections retain a good non-skid surface. The south side has still a better appearance than the north side, though the difference is not so marked as it was last year.

In certain places, usually near the haunches, there was some crazing of the surface. This was probably caused by settlement of the foundation, as the road was built on a peaty subsoil and had deep ditches on either side; moreover, clay was employed to bind the pitching used for widening the road. The surface of one section had become rather loose in places; on this section the viscosity of the binder was lower than for any of the other sections.

Appreciable bleeding occurs on all sections during hot weather. The section on which this is most pronounced was not completed until November, and owing to unsuitable weather the surface sealing coat could not be applied until the following February. It was thought that the bleeding might be due to failure of the bituminous grout to penetrate to the full depth of 3 in. The County Surveyor has therefore carried out similar work, 2 in. thick, with appropriate reductions in the size of the aggregate and in the quantity of binder, and has obtained successful results.

The experiment has shown that under suitable weather conditions the local river gravel can be used to produce a bitumen grouted macadam capable of carrying traffic of the order of 2,000 tons per day. As the object of the experiment has been attained, observation of the sections is to be discontinued.

(*f*) BERWICKSHIRE.

Earlston-Lauder Road (*A*.68).

Previous References:—*Report for* 1933, *pp.* 64-65.
Report for 1934, *pp.* 82-83.
Report for 1935-6, *pp.* 48-49.

The experiment on this road was undertaken to determine whether, and to what extent, the cost of construction and maintenance of tar macadam containing a local crusher-run whinstone could be lowered by reducing the thickness of the carpet.

The carriageway is 21 ft. wide and the average daily traffic (1935 census) 1,316 tons (624 vehicles). The work was carried out during August, September and October, 1933.

Sixteen sections, each 220 yds. long, were laid. The crusher-run aggregate was graded 1½ in.-⅛ in. except for the 3-in. work, for which 2 in.-⅛ in. aggregate was used. A 7-ton roller was employed throughout. Particulars of the thickness of each section, the binders used and the cost per sq. yd. are given in the following table.

Binder.	Scottish Tar No. 2.	Proprietary Binder No. 1.	Proprietary Binder No. 2.	Coke-oven Tar.	Scottish Tar No. 2.	Proprietary Binder No. 1.	Proprietary Binder No. 2.	Coke-Oven Tar.
Section No.	1	2	3	4	5	6	7	8
Thickness (in.)	2	2	2	2	2½	2½	2½	2½
Approx. Initial Cost per sq. yd.	*s. d.* 1 5	*s. d.* 1 6	*s. d.* 1 6	*s. d.* 1 4	*s. d.* 1 6	*s. d.* 1 9	*s. d.* 1 9	*s. d.* 1 7
Approx. Cost per sq. yd. to end of 1936.	2 1	1 10	1 10	1 8	1 10	2 1	2 1	2 1
Section No.	9	10	11	12	13	14	15	16
Thickness (in.)	3	3	3	3	1¾	1¾	1¾	1¾
Approx. Initial Cost per sq. yd.	*s. d.* 2 0	*s. d.* 2 4	*s. d.* 2 5	*s. d.* 2 3	*s. d.* 1 5	*s. d.* 1 5	*s. d.* 1 6	*s. d.* 1 6
Approx. Cost per sq. yd. to end of 1936.	2 4	2 4	2 5	2 3	1 9	1 5	1 6	1 7

Inspections early in 1936 showed that until then the crusher-run aggregate available locally had proved satisfactory without further grading and that the 1¾-in. tar macadam was sufficiently thick for the traffic carried by this road. These results are confirmed by recent inspections, but it was found necessary in comparing them to group the sections according to the surface treatment they had received, as follows:—

Sections Nos. 1-7 inclusive were surface dressed in 1934 with ½-in. whinstone chippings. Several potholes had appeared during the past year on Sections Nos. 2 and 3, chiefly where water from the foundation had previously been seen on the surface. Elsewhere all these sections were in good condition except where the dressing was becoming rather thin, whilst the underlying aggregate could be seen in places.

Sections Nos. 8, 9, 13 and part of No. 16 were surface dressed in June, 1936, as they were beginning to disintegrate. The dressing has held well in every case, giving these sections a very uniform light grey appearance. Thus only five sections now remain in their original condition, i.e. have not been surface dressed. Three of these are 3 in. and two 1¾ in. in thickness and with the exception of Section No. 14 which, at the south end on the west side, is very rough and beginning to fray, they are still in sound condition.

The proprietary binder No. 2 and the coke oven tar have held the aggregate best, whilst on each of the four sections on which the No. 2 tar was used surface dressing has become necessary.

The sections which were surface dressed have benefited considerably in appearance and riding qualities by this treatment. Skidding tests made in June and September showed that all the figures recorded were very satisfactory, the maximum and minimum coefficients being 0·88 and 0·64 respectively. It is of interest to note that the surface dressed sections, on which the chippings were of ½-in. gauge, all gave coefficients approximately 0·1 higher than the untreated sections, on which the aggregate in the surface was 2-in. to 1½-in. gauge; a coarse textured surface is thus not necessarily the most resistant to skidding.

The sealed sections appear to be in the soundest condition and least affected by damp. Where the 1934 dressing is beginning to wear off there is no sign of an excess of binder on the underlying aggregate. Thus the best result would appear to be obtained, when using this grading, by sealing the surface soon after construction and allowing the sealing coat to wear away completely before repeating the process.

Comparison of initial and maintenance costs up to 1937 shows that the 1¾-in. sections are proving the most economical. The saving in thickness has obviously resulted in less initial cost and at present this has not been offset by increase in the cost of maintenance.

(g) AYRSHIRE.

Glasgow-Kilmarnock Road (A.77), near Fenwick.

Previous references:—*Report for* 1933, *pp.* 65-66.
Report for 1934, *pp.* 83-85.
Report for 1935-6, *pp.* 49-51.

Twelve sections, each 220 yds. long, were laid to compare bituminous macadam containing crusher-run whinstone with the surfacing normally used by the County Surveyor, viz., bituminous macadam of graded whinstone blinded with clean chippings. To determine whether the former material would give a satisfactory surface at lower cost, six different binders were used with each of two gradings of aggregate. The binders used were a No. 2 tar, a proprietary tar and four proprietary bitumens. All the sections were 3½ in. thick except No. 1, which was 3 in. thick. The carriageway is approximately 40 ft. wide and the average daily traffic (1935 census) 7,540 tons (3,300 vehicles, largely fast and heavy). The work was carried out between August, 1933, and February, 1934. Particulars of the sections are given in the following table:—

Section No.	*Binder.*	*Aggregate.*
1	Proprietary tar	Crusher-run.
2	,, ,,	Graded.
3	Tar No. 2	Crusher-run
4	,, ,,	Graded.
5	Proprietary bitumen No. 1	Crusher-run.
6	,, ,, ,,	Graded.
7	,, ,, No. 2	,,
8	,, ,, ,,	Crusher-run.
9	,, ,, No. 3	,, ,,
10	,, ,, ,,	Graded.
11	,, ,, No. 4	,,
12	,, ,, ,,	Crusher-run.

Sections Nos. 1-4 were surface dressed in September, 1934, and again in October, 1936, whilst the remaining sections were surface dressed in May, 1935, ⅜-in. whinstone chippings being used in each case.

At an inspection early in 1937 the sections presented very much the same appearance as last year, with the following exceptions:—

Section No. 1 and the western 74 lineal yds. of Section No. 2 have been resurfaced with bituminous macadam owing to subsidence of the foundation and breaking up of the surface, and will consequently be excluded from observation in future.

On Sections Nos. 3 and 4 the recent surface dressing remains well held though there are a few bare patches.

Sections Nos. 5 and 6, on which the proprietary bitumen No. 1 was used, have a rather more uniform appearance than any of the others.

On Section No. 9 it was noted last year that oil dropped by parked vehicles had formed patches, which it was thought might damage the surface. Some of these places have been cut out in the course of repairs necessitated by reason of settlement of the foundation.

On Section No. 10 a small amount of patching has been done at the junction with a lane on the north side, where rough places were noted last year.

All the sections suffer to some extent from crazing of the surface, which is considered to be due to foundation weakness. The crazing is rather more prevalent on Sections Nos. 2-4, which are on the Fenwick By-pass and therefore on new foundation; otherwise there is little difference in appearance between these sections and Sections Nos. 5-12. Although the crazing is more noticeable in the near traffic lanes it can be seen at intervals over the whole width of the carriageway.

One series of skidding tests was made during the year and very satisfactory and uniform sideway force coefficients were obtained on all the sections.

It is still not possible to distinguish between the graded and crusher-run sections, the amount of patching necessary being fairly equally divided between the two types. The crusher-run aggregate, although slightly cheaper in initial cost than the graded aggregate, has in this experiment given equally good results. The gradings of the crusher-run and graded aggregates were given in the Report for 1934, p. 100, Table 4. Tests were made on single samples and no information is available regarding the uniformity of the gradings throughout the course of the work.

The road is constructed on ground which is a mixture of clay and peat, and (although the surfaces of Sections Nos. 2, 3 and 4 are good and show no sign of breaking up) the road foundation has failed to such an extent as to make reconstruction necessary during 1937, and these sections will then have to be excluded from the experiment.

(*h*) KIRKCUDBRIGHTSHIRE.

Dumfries—Stranraer Road (*A*.75).

Previous references:—*Report for* 1934, *pp.* 85-87.
Report for 1935-6, *pp.* 51-52.

Three experimental lengths were laid during October and November, 1934, to compare the merits of three gradings of a local whinstone for 2-in. bituminous macadam. With each specification two different liquid bitumen binders were used, giving in all six sections each 250 yds. long. The carriageway is 22 ft. wide and the average daily traffic (1935 census), 1,820 tons (822 vehicles). These experimental sections were compared with a length of surface-sealed two-coat bituminous macadam laid according to the County Surveyor's normal specification. The following table shows the gradings of the aggregates, the rates of spread of the materials and the proportions of the binder.

Section.	A	B		C	Normal.	
		Base coat.	Wearing coat.		Base coat.	Wearing coat.
Grading (%) :—						
Passing 2¼ in.	—	—	—	—	} 100	—
„ 1⅜ in. retained 1 in.	40	—	100	—		—
„ 1 in. „ ⅜ in.	50	75	—	75		} 100
„ ⅜ in. „ ¼ in.	10	12·5	—	12·5	—	
„ ¼ in. „ ⅛ in.	—	12·5	—	12·5	—	
Binder (gals./ton)	12	12	5	12	7	12
Rate of spread (sq. yds./ton).	12	12·2	100	13·5	9–10	25–30

When the road was inspected early in 1936 all the sections were in good condition despite the severe weather encountered during the previous winter and during construction.

A recent inspection showed that all the sections remain in substantially the same excellent condition as last year, except for isolated areas near the centre line where the surface is rather too open, and where sealing with fine bituminous grit may be necessary. Section B still has a coarser grained surface than the others but the contrast has become less noticeable during the past year; there is no difference in appearance between the respective sub-sections. The whole length has a very uniform non-skid appearance and this was borne out by the results of skidding tests made in June and September, which gave a minimum coefficient of 0·6. The shape and riding qualities of the road are also good. The colour of the surface is medium grey when wet and very light grey when dry.

The sections do not appear to have been affected by the severe winter of 1936-7. This is thought to be attributable to the use of a close-graded mixture, grading figures for the recovered aggregate being in close agreement with those giving the densest mix.

So far, the results from the different sections are so nearly alike that it is impossible to place them in order of merit. The experiment has shown, however, that in this instance three close-graded types of bituminous mixture (one of which had a wearing coat of $1\frac{3}{8}$ in.-1 in. precoated stone) have given a durable road surface which remains in exceptionally good condition after two and a half years' wear.

The Surveyor's normal surfacing has a more closely-grained matt finish as compared with the experimental sections. For this normal work the grading for the base coat was $2\frac{1}{4}$ in.-$\frac{3}{8}$ in. and for the wearing coat 1 in.-$\frac{1}{8}$ in. and the binders used were (*a*) a liquid bitumen, and (*b*) an 85/15 tar-bitumen mixture. This surfacing has become rather bare in a thin line in each wheel track and in places a certain amount of patching has become necessary. Elsewhere the sealing coat is well held and the shape of the road is still very good.

(*i*) Ayrshire.

Glasgow-Kilmarnock Road (*A.77*).

Previous reference:—*Report for* 1935-6, *pp.* 52-55.

The experiment on the above road was undertaken with the object of investigating two methods of providing a coarse-grained running surface which would be waterproof and would remain non-skid for long periods without needing surface dressing. The carriageway is 40 ft. wide, with four traffic lanes, and the average daily traffic (1935 census) was 7,540 tons (3,300 vehicles).

In the first method an asphalt sand carpet about 1 in. thick was laid on the roughened road surface and 1½ in.-¾ in. graded bituminous macadam was rolled into it. In the second method the graded macadam was laid and consolidated and after it had carried traffic for two to three weeks was sealed with asphalt mortar. A hot asphalt and a cold asphalt were associated with each method, giving four sections, each of which was divided into two sub-sections, 220 yds. long, so that two different binders could be used for the bituminous macadam. The experimental sections were adjacent to the 12 sections laid in 1933 (see p. 48) and were accordingly numbered from 13 to 16, viz.,

Section No. 13.—Cold asphalt sand carpet prepared and laid to B.S.S. No. 511 (1933) underlying a coat of graded bituminous macadam 1½ in. thick.

Section No. 14.—Hot asphalt sand carpet prepared and laid to B.S.S. No. 342 (1928) underlying a coat of graded bituminous macadam 1½ in. thick, as for Section No. 13.

Section No. 15.—Graded bituminous macadam 3 in. thick blinded with cold bituminous mortar.

Section No. 16.—Graded bituminous macadam 3 in. thick, as for Section No. 15, blinded with hot asphalt mortar prepared to B.S.S. No. 342 (1928).

An 8-ton roller was used on all the sections. The work was started in December, 1934, and completed, after some delay due to weather conditions, in May, 1935. The materials used and the laying of each section were described in detail in the Report for 1935-6.

The bituminous macadam used on Sections Nos. 15 and 16 contained 10 per cent. of ½-in. aggregate, but this grading was omitted from Sections Nos. 13 and 14 in order to provide voids into which the asphalt mortar could key during consolidation.

When the sections were inspected early in 1936, all were in very good condition, Section No. 14 having the best appearance, but on Section No. 16 too much mortar had been brushed on to the surface. The present position as regards the sections is as follows:—

Section No. 13.—This section is in very good condition but is not so well sealed as Section No. 14.

Section No. 14.—This is still the best of the four sections and remains in excellent and uniform condition.

Sections Nos. 13 and 14 are entirely free of the surface crazing which has occurred on Nos. 15 and 16.

Section No. 15.—Considerable crazing has taken place, particularly where the road is on embankment, and a good deal of patching has been carried out on the nearside traffic lanes. Otherwise, the section is in very good condition.

Section No. 16.—This section has crazed extensively, but has not needed quite so much patching as Section No. 15. The mortar has closed the surface still further and in many places obscures the roughness of the stone.

All the sections tend to hold the damp to some extent. One series of skidding tests was made during the year, and in all cases the results obtained were satisfactory, the sideway force coefficient being over 0·6. The excess of mortar on Section No. 16 did not cause any appreciable drop in coefficient as compared with the other sections.

The method of construction used on Section No. 13 has so far proved the most satisfactory, and all four sections retain coarse-grained safe surfaces. It is doubtful whether Sections Nos. 15 and 16 have remained entirely waterproof.

(*j*) Aberdeen County Council.

North Deeside Road (*A*.93).

The experiment on this road was undertaken to compare the suitability of the stone obtained from ten local quarries as aggregate for 2-in. single-coat bituminous macadam, as regards cost and durability. Each of the sections is 220 yds. long. The carriageway has an average width of 20 ft. and the average daily traffic is 1,691 tons (1935 census) (911 vehicles). The preliminary shaping was carried out between June and August, and the experimental surfacing was commenced on 20th July and completed on 14th September. The aggregate, crusher-run, passing $1\frac{1}{2}$ in. and retained $\frac{3}{8}$ in., was mixed with the bitumen binder at a quarry approximately 14 miles from the site. The road was surfaced in half widths and a coated grit screened from $\frac{1}{8}$ in. to $\frac{1}{16}$ in. was applied; whenever conditions permitted this was done the following day. A 10-ton Diesel roller was used for consolidation. There are at present no striking differences between the sections, particulars of which are given below, but most of the sections have a pleasing, light-coloured surface, the best being Nos. 4, 5 and 9. On most of the others there is evidence of crushing of the stone under the roller, accompanied either by fraying or by loss of the coated grit applied to fill the interstices.

Section No.	Mixed materials (sq. yds./ ton).	Coated grit (sq. yds./ ton).	Binder for mixed materials (gals./ ton).	Binder for coated grit (gals./ ton).	Voids (%).	Total cost of laying, per sq. yd.
						s. d.
1	11·7	257	9·1	9·6	46·37	1 6·73
2	10·1	220	12·5	10·9	44·26	2 0·23
3	13·4	206	12·0	13·7	47·60	1 8·45
4	11·6	179	9·6	8·3	46·11	1 8·61
5	9·8	154	7·6	6·1	49·48	1 8·31
6	12·3	200	7·8	6·3	46·00	1 8·56
7	11·9	198	7·5	7·4	47·69	1 8·75
8	12·0	177	8·0	7·2	43·33	1 8·34
9	10·2	154	7·6	6·3	48·09	1 7·84
10	9·7	158	6·5	6·7	47·43	1 11·02

Petrological classification of stone and abridged description of sample.

Section.	Classification and description.	Section.	Classification and description.
1	Mica Hornfels. Hard, dense, dark grey stone, nearly black when wet. Medium size of grain, crystalline surface texture.	6	Quartz Feldspar Granulite. Hard, dense stone, light grey, almost white in colour. Medium size grain, crystalline surface texture.
2	Feldspathic Quartzite. Hard, dense, light pinkish-coloured stone. Medium size of grain, crystalline surface texture.	7	Feldspathic Quartzite. Hard, dense, dark grey-coloured rock. Medium size of grain and crystalline surface texture.
3	Quartz Porphyry. Hard, dense, grey to light brown and slightly pinkish-coloured stone. Medium size of grain with granular surface texture. Appears sensitive to abrasion.	8	Quartz-Diorite. Hard, dense, rock containing about equal proportions of :— (*a*) a grey-coloured rock, flecked with white ; and (*b*) a brown, grey and white material. Medium to coarse grain, crystalline surface texture.
4	Hornfelsed Feldspathic Sandstone. Hard, dense rock. Colour very dark grey to light grey-brown. Medium size of grain with crystalline surface texture.	9	Norite. Hard, dense, dark grey-coloured rock. Medium size of grain. Crystalline surface texture.
5	Olivine Pyroxenite. A hard, dense rock. Colour dark grey, almost black when wet. Coarse-grained with crystalline surface texture.	10	Norite. Hard, dense, dark grey-coloured rock. Medium size of grain. Crystalline surface texture.

CHAPTER V.

THIN SURFACING COATS.

(*a*) WORCESTERSHIRE.

Worcester-Tewkesbury Road (*A*.38).

Previous References:—*Report for* 1934, *pp.* 94-96.
Report for 1935-6, *pp.* 57-58.

Thirteen sections of thin carpeting materials were laid on the above road in the autumn of 1934 to determine the relative merits of various thin surfacing coats. The carriageway is approximately 20 ft. wide and the average daily traffic (1935 census) 7,738 tons (4,312 vehicles). For convenience, some of the particulars of the sections are repeated in Table 1 of the Appendix to this chapter.

The present position with regard to each section is given in the following paragraphs. (It should be noted that, with the exceptions mentioned below, the lowest values of sideway force coefficient were all recorded during a test on 22nd September, 1936, when the weather conditions during the previous few days had been warm and dry.)

Section A.

A good sound durable section with a satisfactory resistance to skidding, the lowest coefficient being 0·66.

Section B.

A sound section which appears likely to be durable; some excess of binder has come to the surface. The lowest coefficient obtained was 0·48.

Section C.

The interstices of the surface have closed up and there is more smoothing up in the wheel tracks than on most of the other sections. The lowest coefficient obtained was 0·32, in April 1937.

Section D.

This section was nearly as good as Section A, the difference being that it had faced up a little in the wheel tracks. The lowest coefficient obtained was 0·51.

Section E.

Twelve areas, all less than 18 in. square, had to be patched during 1935. No repairs were necessary during 1936, but the surface is more uneven than most. The lowest coefficient obtained was 0·32, in September, 1935.

Section F.

More smoothing or ironing has taken place on this section than on most; this may be to some extent due to oil droppings from vehicles. The section has a close-grained sandpaper texture and seems to be more affected by oil dropped from vehicles than does the open texture type of surface. Although this section is sound and durable, the non-skid qualities were poor, a coefficient of only 0·23 being recorded in March, 1935.

Section G.

Extensive patching had to be undertaken at the northern end of this section during 1935. Further repairs were necessary during 1936 at the southern end (particularly along the centre line and in the channels) as well as at the northern end. This section must be regarded as unsatisfactory. The conditions of test were a little more onerous than for most of the other sections since it was on a curved length of road and was more subject to droppings of manure. Despite these considerations the material must be regarded as having failed as regards durability. The lowest coefficient recorded was 0·68.

Section H.

The original material failed in 1935 as the binder used had deteriorated as a result of long storage. It was replaced by a material of the same specification and this has given a satisfactory result. The lowest coefficient obtained was 0·61.

Section J.

A good section, giving results similar to Section B. The lowest coefficient obtained was 0·52 in March, 1935.

Section K.

This section was one of the best. The lowest coefficient obtained was 0·52.

Section L.

Sound and durable, though there is more smoothing up than on most sections. In this respect it is similar to Sections C and F. The lowest coefficient obtained was 0·53.

Section M.

The results obtained are somewhat similar to those for Section C, but in warm weather patches of binder appear on the surface. The lowest coefficient obtained was 0·30.

Section N.

A very good section; it has a pleasant pinkish-brown colour, good texture and shape, was easy to lay and has a moderately satisfactory resistance to skidding. The lowest coefficient obtained was 0·37.

All the sections except E and G remain in good condition, although they are beginning to show signs of smoothing in the wheel tracks. The curves of sideway force coefficient obtained since the sections were laid are given at the end of this Report (see Figs D, E, F and H). The results obtained are discussed on pp. 59-60. It is too early to place the sections in a final order of merit.

(*b*) Oxfordshire.

Oxford-Henley Road (*A*.423).

Previous references:—*Report for* 1934, *pp*. 93-94.
Report for 1935-6, *pp*. 56-57.

In order to compare the relative durability, resistance to skidding and cost of thin surfacing coats, 20 sections, each 220 yds. long, were laid during September and October, 1934, on the above road between Dorchester and Nuneham Courtenay. The width of the carriageway is 20 ft. and the average daily traffic (1935 census) was 4,520 tons (2,603 vehicles). Details of the sections are given in Table 2 of the Appendix to this chapter.

Section No. 1 became slippery and in the winter of 1935-6 had to be surface dressed: this section was regarded as having failed. Sections Nos. 3, 6 and 10 failed by disintegration, and were replaced during February and March, 1935. Section No. 3 was replaced by similar material with a coarser grading than the original, and is now known as Section No. 3A; the results have been noted for comparison with the other sections. Section No. 6 was recarpeted with an entirely new material of fine grading; it is now referred to as Section No. 6A, and may reasonably be compared with the other sections. Section No. 10 is subject to more onerous conditions than are the other sections, since it is on a bend and at an intersection. It was replaced by material containing $\frac{3}{8}$-in. granite instead of the $\frac{3}{16}$-in. quartzite used previously; both materials were laid by the same firm. The section so resurfaced has been called No. 10A and is reasonably comparable with the other sections.

The following paragraphs describe the condition of each section in March, 1937. All the values of sideway force coefficient were obtained with a smooth tyre when the road was wet; except where otherwise noted, the lowest values were obtained on 22nd September, immediately after a spell of warm and dry weather.

Section No. 2.—The section had a light red colour and, with the exception of some roughness under trees and near the centre line, and some slight crushing of the aggregate, remained in very good condition. The lowest coefficient obtained was 0·59.

Section No. 3*A*.—This section had polished somewhat in the wheel tracks, otherwise it was in good condition over the northern half, but near the southern end the top surface had flaked off in places and some pot-holes, to the full depth of the carpet, have had to be filled. When this part of the section was relaid the gravel aggregate used was different in colour from the limestone on the remainder of the section. To obtain uniformity of appearance a veneer coat with limestone aggregate was applied to the new work; some of this has begun to flake off. The coefficients obtained in different tests were very irregular, varying between 0·70 and 0·34, the latter figure being recorded in September, 1936, and in April, 1937. The section has not given satisfactory results.

Section No. 4.—This remained a very good durable section; the shape and colour were good and the lowest coefficient recorded was 0·57.

Section No. 5.—This promises to be durable but is dark in appearance. Although there was an excess of binder on the surface in the wheel tracks the lowest coefficient obtained was 0·6, and the results obtained in the different tests did not vary unduly.

Section No. 6*A*.—Except for slight roughness where the damp was held between the wheel tracks and near the centre line of the road, the surface of this section was very close grained and of a very light colour. The coefficients obtained were exceptionally high and consistent at first, but showed a gradual tendency to fall and recently became more erratic, the minimum value obtained being 0·49.

Section No. 7.—Some fretting took place during the year in the west wheel tracks towards the northern end of the section; these defects were dressed with fine gravel and bitumen emulsion, which later gave the surface rather a rich appearance. Elsewhere the surface was in very good condition. The coefficients remained very consistent and high, the minimum value being 0·59.

Section No. 8.—The surface of this section had a rather mottled appearance and was becoming smooth in places. There was also some bleeding, presumably as a result of the extrusion of the tack coat which was laid prior to the surfacing materials. The section had a close-grained surface and the coefficients were very erratic, varying between 0·85 and 0·29, the latter being obtained in September, 1935.

Section No. 9.—This was in good general condition, but was beginning to become smooth in the wheel tracks. Numerous minute holes could be observed all over the section but these apparently had no ill effect. The coefficients were very consistent and never fell below 0·73, which was recorded on three occasions.

Section No. 10*A*.—The surface near the middle of the length had been interfered with in consequence of construction works at cross roads. There were some bare places near the southern end; elsewhere the section was in good condition, having a well-packed medium grained appearance, which, however, tended to hold the damp. The coefficients were remarkably high throughout, having a minimum value of 0·75, the last two recorded figures being 0·93

Section No. 11.—This section and No. 4 had surfaces which were more uniform in appearance than any of the others. They appeared likely to be durable and there were no signs of deformation. The coefficients for Section No. 11 were fairly consistent, the minimum value being 0·51.

Section No. 12.—This had much the same type of surface texture as Section No. 11 but was not quite so open. The shape was good and the surface promises to be durable. The coefficients were fairly consistent, and always satisfactory, though never very high, the minimum value being 0·47.

Section No. 13.—This section appeared likely to be durable and had fairly good riding qualities, although it looked rather smooth. Several small holes which had been noticed previously had practically healed up. The coefficients were irregular, varying between 0·73 and 0·37, but did not become undesirably low.

Section No. 14.—There was a number of very rich places in the wheel tracks on parts of the section, and it was noteworthy that for the most part they occurred where the materials had been laid on a wet road surface; otherwise the surface was sound. The coefficients were fairly high and consistent, the minimum value being 0·55.

Section No. 15.—Some fretting had taken place on parts of the section and a few rough areas were sealed with bitumen emulsion and chippings. Slight fatting up had occurred in places and variations in the richness of different loads of material were noticeable; otherwise the section was in good condition and has retained its light greenish-grey colour. The coefficients remained consistently good throughout, a minimum value of 0·62 being recorded in March, 1935, and September, 1936.

Section No. 16.—On the whole this was in good condition and had an open texture, except in the wheel tracks, where it looked rather smooth. The coefficients were fairly high and consistent, a minimum value of 0·54 being obtained.

Section No. 17.—The wheel tracks were becoming a little smooth, but otherwise the section had a uniform medium grained surface. A number of short ripples, which had been noticed previously, had persisted. The coefficients were inclined to be irregular but were generally satisfactory, the minimum value being 0·52.

Section No. 18.—This section was very rough in places between the wheel tracks and at the centre line, where some patching had been done. There were also cases of bleeding, particularly on the east side towards the northern end. A small transverse crack was noticed on the crest of the hill over the site of a crack in the underlying road surface; elsewhere the surface was well sealed. The coefficients were more irregular than for any of the coarse grained sections, minimum value being 0·37.

Section No. 19.—This had good riding qualities and a dense, even surface. A small pot-hole had been filled in at the northern end. The coefficients were very irregular, varying between 0·83 and 0·31.

Section No. 20.—This section had poor riding qualities, probably because the irregularities of the original road surface were not rectified by the application of the new material. A small amount of patching had been done near the west channel, where considerable fretting had taken place, sometimes down to the old road. In some places binder had come to the surface but elsewhere the surface was in good condition. The coefficients remained very consistent and had a minimum value of 0·58, obtained in June, 1936.

The sections which have remained most satisfactory in respect of durability, non-slipperiness and general appearance, are Nos. 2, 4, 5, 9 and 11. On each of these sections minimum values of sideway force coefficient of well over 0·5 were obtained.

The results of the tests made with the skidding machine are discussed below in conjunction with the corresponding results for the Worcester—Tewkesbury Road.

Notes on the results of skidding tests made on the Oxford-Henley Road and the Worcester-Tewkesbury Road.

Although the experimental sections on these two roads were laid only 2½ years ago, sufficient information has been obtained to indicate that the claim for thin carpets that " they do not need frequent surface treatment to keep them resistant to skidding " is in most cases justified.

The results have been examined to determine to what extent, if any, they are related to surface texture. For this purpose the sections on the two roads have been divided into three types, viz.,

Type A—coarse grained (⅞ in.-⅝ in.).

Type B—medium grained (⅝ in.-⅜ in.).

Type C—close grained (below ⅜ in.).

The results are shown in Figs. A, B, C, D, E and F (at the end of the Report) to which the following remarks apply. With few exceptions, all the three types of surface had very high resistance to skidding soon after being laid. There was a marked drop in coefficient during the next few months, after which there was a steady but comparatively small falling off except in the cases of types A and B on the Oxford-Henley Road, where the coefficients have remained substantially unaltered for two years.

Figs. G and H have been prepared to show the range of coefficients obtained. The two limits in each case represent the mean upper and lower values of the coefficients for the type concerned during the life of the road, e.g., on the Oxford-Henley Road the mean value of the maximum coefficients for Type A is 0·75, which is the height of the upper thickened line in Fig. G.

The diagrams for the two roads are very similar and the high minimum values of the coefficients for the type B materials are of particular interest.

(*c*) ROXBURGHSHIRE.

Melrose-Galashiels Road (*A*.6091).

Previous References:—*Report for* 1934, *pp.* 96-97.
Report for 1935-6, *pp.* 58-59.

Eight sections, each 220 yds. long, were laid during August and September, 1934, to compare the relative durability and the resistance to skidding of a number of thin surfacing coats laid on new bituminous macadam. The width of the carriageway is approximately 22 ft. and the average daily traffic (1935 census) 2,100 tons (1,092 vehicles). Brief particulars of the sections are given in the following table:—

Section No.	Aggregate.		Quantity of binder (gals./ton).	Rate of spread (sq. yds./ton).
	Nature.	Size (in.).		
1	Whinstone ...	$\frac{3}{8}$–$\frac{1}{8}$	12·3	27·8
2	,, ...	$\frac{7}{8}$–$\frac{3}{8}$	10·8	19·3
3	,, ...	$\frac{3}{4}$–$\frac{1}{4}$	11·8	19·7
4	,, ...	$\frac{7}{8}$–$\frac{1}{8}$	12·5	19·3
5	,, ...	$\frac{3}{4}$–$\frac{1}{8}$	8·5	20·1
6	Slag	$\frac{5}{8}$–$\frac{3}{8}$	10–10·5	21·6
7	Sand	—	—	39·6
8	Whinstone ...	$\frac{7}{8}$–$\frac{3}{8}$	13·8	19·6

Before the sections were laid the existing carriageway was shaped and surfaced with a 2-in. base coat of $1\frac{1}{2}$-$\frac{1}{2}$ in. whinstone using a tar-bitumen binder. All the processes made use of in this experiment were of a proprietary nature, except those for Section No. 8. The carpets were laid to a thickness of 1 in., except on Section No. 1 (¾ in.) and on Section No. 7 (½ in.). A 10-ton roller was used throughout. Although the weather was generally good rain caused suspension of the work on one or two occasions and the day and night temperatures fluctuated considerably. An inspection early in 1937 showed that an appreciable change in appearance had taken place during the past year, all the sections having deteriorated slightly, principally as a result of damp or frost during the winter of 1936-7, which was very severe. Section No. 2 and parts of Section No. 6 yielded the best results, and it is noteworthy that they are in the open, unaffected by overhanging trees. Skidding tests were made in June and September, 1936, and in April, 1937, and in every case a good sideway force coefficient was obtained, the lowest being 0·56 on Section No. 4 in April, 1937.

This experiment, together with other experiments on thin surfacing lengths elsewhere, indicates that mixing operations have not been controlled with sufficient accuracy. It is evident that in the case of future experimental work extra supervision will be necessary at the plant or more suitable equipment required to ensure the correct proportioning of materials. During last year, cases were noticeable of differences between areas, on the same section, corresponding to the spread of different loads of materials, certain of them being much darker and holding the damp more than others. Sufficient time has not yet elapsed, however, for the sections to be compared as regards ultimate cost.

(*d*) Wigtownshire.

Dumfries-Stranraer Road (*A*.75), *near Benfield Bridge*.

Previous reference:—*Report for* 1935-6, *pp*. 59-60.

The experiment on the above road was carried out to compare a thin surfacing coat with the County Surveyor's normal surface dressing as regards cost, durability and non-skid properties. The average width of the carriageway is 21 ft. and the average daily traffic (1935 census) 905 tons (404 vehicles). The thin surfacing coat, 576 yds. long, and the surface dressing, 440 yds. long, were applied in July, 1935. For the thin surfacing coat a ¾ in.-½ in. crusher-run whinstone was used, with a proprietary bitumen binder at the rate of 10 gals./cu. yd.; the materials were laid at approximately 26 sq. yds./ton. The cost of the thin surfacing coat was 9·5d. per sq. yd., as compared with 3·3d. per sq. yd. for the surface dressing.

When inspected early in 1936 the thin surfacing was in excellent condition, but the surface dressing had worn off in places near the centre line. At a further inspection early in 1937 considerable change in appearance had taken place on parts of the thin surfacing section. Where the road is curved the surface is very rough in the wheel tracks and in several cases pot-holes, extending the full depth of the carpet, have developed. Elsewhere the surface has a good uniform texture. The surface-dressed section has not deteriorated to any extent during the year, but it was still too early to decide which section would ultimately prove the more economical.

(*e*) West Lothian.

Edinburgh-Linlithgow Road (*A*.9), *near Kirkliston.*

Previous reference:—*Report for* 1935-6, *p.* 61.

Six sections each 220 yds. long were laid in September, 1935, to compare the merits of a coke-oven tar, a proprietary bitumen and a proprietary tar as binders for use with a local whinstone in the construction of thin surfacing coats. The carriageway is approximately 27 ft. wide and the daily traffic (1935 census) 5,280 tons (2,442 vehicles). Carpets were laid with each type of binder to thicknesses of 1 in. and ¾ in., the respective rates of spread being about 20 and 25 sq. yds./ton. A 12-ton roller was used throughout.

When the road was inspected early in 1936 the contour was quite satisfactory and all the sections were in very good condition. A further inspection early in 1937 showed that the first four sections were still in good condition, although they were rather closer in texture and a little smoother in the wheel tracks than they were a year previously. The difference in the results obtained on areas covered by separate loads of material has become much more noticeable during the past year, as on similar experimental thin carpet lengths elsewhere. All the sections have a dark grey appearance and the binder coating the surface aggregate has not worn off to any appreciable extent.

Sections Nos. 5 and 6, on which the proprietary tar was used, have a very different appearance from the others, being much darker in colour and more open in texture. In a number of places pot-holes have developed right down to the old road surface and a considerable amount of patching has been done. The weather conditions were favourable when these two sections were laid and the gradings of the recovered aggregate compared very well with those of the other sections, so these factors should not have influenced the sections adversely. It seems therefore that the proprietary tar may not have been suitable for use with the particular stone employed.

All the sections gave good sideway force coefficients when tests were made, viz., in June and September, 1936, and in April, 1937, when a minimum figure of 0·60 was obtained at 30 m.p.h. The coefficients obtained on the proprietary tar sections were little different from those obtained on the others. No deterioration has taken place on those areas on which, as noted last year, oil had been spilled. It is as yet too early to compare the sections as regards ultimate cost.

(*f*) Surrey.

Egham-Sunningdale Road (*A*.30) *and Woking-Chobham Road* (*B*.383).

During 1936 a number of experimental lengths were laid in co-operation with the Surrey County Council to investigate the effect of varying the factors involved in the design of thin surfacing coats. It was decided that the first series of experiments should be made on surfacing coats, approximately $\frac{3}{4}$-in. thick, designed to produce an open textured non-skid surface by using the maximum quantity of large aggregate with the minimum of smaller gradings and binder necessary to secure stability. The factors investigated in the series were:—

(*a*) Variation of aggregate (gravel, granite and slag).
(*b*) Nature of binder (6 different types).
(*c*) Proportion of binder (2 or 3 different proportions).

The experimental lengths were laid on:—

(1) The Woking-Chobham Road (B.383) which carries an average daily traffic of 3,169 tons (1936 census) (1,378 vehicles). On this road gravel aggregate was used, the required grading being obtained by mixing 2 types of Thames Valley gravel in the proportion of 2 parts of $\frac{1}{2}$ in.-$\frac{3}{8}$ in. gauge to 1 part of $\frac{3}{8}$ in.-$\frac{3}{16}$ in. gauge, with the addition of 5 per cent. by weight of limestone filler.

(2) The Egham-Sunningdale Road (A.30) which is part of the Great South West Road and carries an average daily traffic of 14,130 tons (1935 census) (7,827 vehicles). On this road Leicestershire granite was used, the required grading being obtained by mixing 5 parts of granite passing $\frac{1}{2}$-in. mesh sieve with 1 part of granite passing $\frac{1}{8}$-in. mesh sieve, with the addition of 5 per cent. by weight of limestone filler.

The proposals were discussed with the Asphalt Roads Association, the Road Emulsion and Cold Bituminous Roads Association and the British Road Tar Association; each Association suggested appropriate specifications for the binders in which it was interested. These binders were as follows:—

(1) Liquid bitumen (2) Fluxed lake asphalt	Recommended by the Asphalt Roads Association.
(3) Bitumen, cut back with light oil flux (4) Bitumen, cut back with tar oil flux	Recommended by the Road Emulsion and Cold Bituminous Roads Association.
(5) Tar, cold process (6) Tar, semi-hot process	Recommended by the British Road Tar Association.

Three different percentages of each of the first two and last two binders were used, namely, the optimum quantity of binder as determined by trial mixes, and quantities approximately ¾ gal. per ton of aggregate above and below this optimum quantity. Of the two remaining binders, only two quantities were used, differing by about 1 gal. per ton of aggregate.

The various binders were supplied to the following specifications:—

Liquid bitumen.—The binder shall consist of a pure asphaltic bitumen having a penetration of 90-110 at 77° F., fluxed with a suitable volatile oil to a viscosity (Redwood tar viscometer) of 300-400 secs. at 77° F.

Fluxed lake asphalt.—The binder shall consist of fluxed lake asphalt having the following proportions:—

70 per cent. of Lake asphalt, and
30 per cent. of liquid flux.

The penetration of the final asphalt cement (at 77°F.) to be 250.

Bitumen, cut back with light oil flux.—Asphalt cement complying with the definition in paragraph 1 (*e*) of British Standard Specification No. 510, 1933, and prepared from medium asphaltic bitumen complying with the limits set out in Table 1 of that Specification and the flux as defined in paragraph 5 (*b*).

Bitumen, cut back with tar oil flux.—Asphalt cement complying with the definition in paragraph 1 (*e*) of British Standard Specification No. 510, 1933, and prepared from medium asphaltic bitumen complying with the limits set out in Table I of that Specification and the flux as defined in paragraph 5 (*c*).

Tar binder, cold process.—A manufactured coal tar of a viscosity of 90-120 secs. at 30°C, prepared by distilling the crude tar to a viscosity of 25-30 secs. at 60°C, and oiling back with heavy creosote oil to the prescribed final viscosity. The heavy creosote oil was supplied to the following specification:—

Specific gravity at 38°C, 1·035 minimum
Distillation ranges (S.T.P.T.C. flask)

205°C	2 per cent. maximum
230°C	10 per cent. maximum
270°C	55 per cent. maximum
350°C	90 per cent. maximum
Water	1 per cent. maximum

Tar binder, semi-hot process.—A manufactured coal tar of a viscosity of 90-110 secs. at 35°C, prepared by distilling the crude tar to a viscosity of 10-20 secs. at 60°C, and oiling back with heavy creosote oil to the prescribed final viscosity. The heavy creosote oil was supplied to the specification used in the cold process.

Road machine tests were made at the Laboratory, before deciding on the detailed specifications, particularly with the gravel aggregate. From these preliminary tests specifications were prepared for the work on the road.

(a) *Woking-Chobham Road* (*B*.383).

The first part of the experiment consisted of the following 16 sections, each approximately 150 yards long, laid on Route B.383 from Chobham Village eastwards to Mim Bridge, Horsell Common:—

Section No.	Description.	Binder (gals./ton).	Approximate rate of spread (sq. yds./ton).	Temperature of materials immediately prior to laying.
1	Liquid Bitumen, medium mix.	9·75	25·2	110–150°F.
2	Liquid Bitumen, lean mix	9·11	26·7	120–145°F.
3	do. rich mix	10·42	25·7	135–145°F.
4	Lake Asphalt, medium mix.	14·7	23·6	135–150°F.
5	Lake Asphalt, lean mix	14·0	24·6	120–150°F.
6	do. rich mix	15·4	24·4	130–165°F.
7	Bitumen, cut back with Light Oil flux, rich mix.	11·55	25·5	120–145°F.
8	Bitumen, cut back with Light Oil flux, lean mix.	10·5	27·1	120–135°F.
9	Bitumen, cut back with Tar Oil flux, rich mix.	10·5	27·1	120–145°F.
10	Bitumen, cut back with Tar Oil flux, lean mix.	9·45	27·4	120–145°F.
11	Tar, cold process, medium mix.	9·8	27·2	100–120°F.
12	Tar, cold process, lean mix.	9·1	27·8	100–110°F.
13	Tar, cold process, rich mix.	10·5	27·2	100–120°F.
14	Tar, semi-hot process, medium mix.	10·5	27·2	120–150°F.
15	Tar, semi-hot process, lean mix.	9·8	27·2	115–125°F.
16	Tar, semi-hot process, rich mix.	11·2	27·0	100–125°F.

Bitumen emulsion was not used on this part of the experiment as the Road Emulsion and Cold Bituminous Roads Association did not recommend its use in conjunction with gravel of the grading it had been decided to adopt for the experiment.

The site of the experiment had been utilised some years previously for a variety of experimental bituminous macadam surfacings which had since been dressed. Before the new carpets were laid, the dressing was burned off, by means of a coke-fired road heater, the amount of burning depending upon the degree of deformation of the old surface. No further preparatory work was carried out, and generally the shape of the road was in reasonably good condition. Profiles of the road, both before the original dressing was burned off and after the new carpets were laid, have been taken by means of the profilometer designed and made at the Laboratory, to determine what improvement in riding qualities has been effected and the permanence of such improvement on the various sections.

The work was carried out by direct labour by the County Council and the materials were mixed at the Surrey County Council depot at Ewell about 20 miles from the site. Particulars of the temperatures of the materials when mixed are given in the above table.

The carriageway was 20 ft. wide with concrete kerbs on each side, except on Section No. 16 where there was no kerb over the last 120 yds. of the north side. The work was carried out in half-widths of the road. The existing surface was not heated nor was any preliminary coating applied before the new material was laid. Consolidation of the surfacing was effected by means of a 10-ton, 3-wheel, steam roller. The work was commenced on 15th July, suspended from 31st July to 10th August, and completed on 7th September, 1936. The men engaged on the work had had no previous experience in the laying of this class of material.

The cost of the sections and the results of skidding tests carried out in January and March, 1937, are given in Table 3 of the Appendix to this Chapter.

The sideway force coefficients at 30 m.p.h. for all the sections varied from 0·85 to 0·57 and were consistent and satisfactory.

Samples of the aggregates, binders and mixed materials used were forwarded to the Laboratory for examination.

Many of the gravel sections (on B.383) have begun to deteriorate. On Sections Nos. 1 and 2 (where the road is sharply curved) disintegration has gone so far as to necessitate repairs, but on the other sections there was only slight fretting in the wheel tracks and remedial treatment was not needed. Considerable surface wear has taken place at a bus stop on Section No. 15. No appreciable change is apparent on Sections Nos. 4, 5, 6 and 9.

(b) *Egham-Sunningdale Road* (*A*.30).

The second part of the experiment, in which granite aggregate was used, was carried out between 15th September and 31st October, 1936, on Route A.30 between Wentworth, Virginia Water and Englefield Green, Egham.

The following 16 sections, each approximately 150 yds. long and 30 ft. between kerbs, were laid:—

Section No.	Description.	Binder (gals./ton).	Approximate rate of spread (sq. yds./ton).	Temperature of materials immediately prior to laying.
1	Lake Asphalt, medium mix.	15·6	25·5	140–180°F.
2	do. lean mix	14·9	25·0	145–160°F.
3	do. rich mix	16·3	26·3	145–180°F.
4	Liquid bitumen, medium mix.	10·3	26·0	120–150°F.
5	do. lean mix	9·6	26·0	120–150°F.
6	do. rich mix	10·95	26·6	115–150°F.
7	Bitumen, cut back with Light Oil flux, rich mix.	11·3	25·4	100–135°F.
8	Bitumen, cut back with Light Oil flux, lean mix.	10·6	25·8	110–145°F.
9	Bitumen, cut back with Tar Oil flux, rich mix.	10·95	25·1	110–135°F.
10	Bitumen, cut back with Tar Oil flux, lean mix.	10·3	27·2	110–140°F.
11	Tar, cold process, medium mix.	9·95	27·1	110–130°F.
12	Tar, cold process, lean mix.	9·5	27·3	110–130°F.
13	Tar, cold process, rich mix.	10·6	27·6	110–135°F.
14	Tar, semi-hot process, medium mix.	9·95	27·3	145–170°F.
15	Tar, semi-hot process, lean mix.	9·3	26·6	140–170°F.
16	Tar, semi-hot process, rich mix.	10·6	27·4	150–170°F.
17	Bitumen emulsion, rich mix.	To be laid during 1937.		
18	Bitumen emulsion, lean mix.			

As for the first part of the experiment, the materials were mixed by the Surrey County Council at their Ewell depot. The carriageway was prepared by burning off excess binder and the residue from previous surface dressings; the camber of the road was also improved by spreading and rolling a hot sand carpet into depressions. The surface of the carriageway was preheated by the road heater to about 100-130° F., except on Section No. 1 and part of Section No. 2, on which the preparation of the surface was similar to that carried out on the Chobham sections. Where the haunches were of concrete they were brushed with bitumen emulsion to form a key, the rate of spread being 10 sq. yds./gal. of emulsion. As the weather was much cooler than when the gravel sections were laid, it was found difficult to spread the materials containing lake asphalt and tar (semi-hot process) as binders, and the temperatures of the mixtures were accordingly increased. The laying was carried out in half-widths of the road.

The costs of the sections, together with the results of skidding tests carried out in January and March, 1937, are given in Table 4 of the Appendix to this Chapter. As on the Chobham sections, the values of the sideway force coefficient at 30 m.p.h. were very satisfactory on all sections and ranged from 0·89 to 0·66.

Samples of the aggregates, binders and mixed materials used were forwarded to the Laboratory for examination.

The granite sections are at present in good condition with the exception of one or two minor defects. The third part of the experiment consists of 18 sections with slag as the aggregate and binders similar to those used with granite. These sections will be laid adjacent to the granite sections during 1937.

APPENDIX TO CHAPTER V.

TABLE I.

WORCESTER–TEWKESBURY ROAD.

Details of Experimental Sections.

Section.	Aggregate.		Nature of filler.
	Nature.	Size.	
A	Slag	$\frac{5}{8}$ in.–$\frac{1}{8}$ in. ...	None.
B	Slag	$\frac{3}{4}$ in.–$\frac{1}{4}$ in. ...	(Sealing coat only used.)
C	Granite ...	$1\frac{1}{8}$ in.–$\frac{1}{8}$ in. ...	Granite $\frac{1}{4}$ in.–dust.
D	Granite ...	$\frac{3}{4}$ in.–$\frac{3}{16}$ in. ...	Granite $\frac{3}{8}$ in.–dust.
E	Granite and Limestone.	$\frac{1}{4}$ in.–$\frac{1}{16}$ in. ...	Limestone.
F	Quartzite ...	$\frac{1}{8}$ in.–dust ...	Limestone.
G	Granite ...	$\frac{3}{4}$ in.–$\frac{1}{8}$ in. ...	None.
H	Slag	$\frac{3}{16}$ in.–200 mesh	As aggregate.
J	Granite ...	$\frac{5}{8}$ in.–$\frac{1}{4}$ in. ...	Granite ; $\frac{1}{8}$ in.–dust, limestone flour.
K	Granite and Quartzite.	$\frac{3}{4}$ in. ... } $\frac{5}{8}$ in. ... }	Limestone.
L	Sand	$\frac{1}{8}$ in.–100 mesh	Cement.
M	Basalt	$\frac{3}{4}$ in.–$\frac{1}{8}$ in. ...	Basalt and limestone dust.
N	Limestone ...	$\frac{3}{4}$ in.–$\frac{1}{2}$ in. ...	Limestone.

TABLE 2.

OXFORD–HENLEY ROAD.

Details of Experimental Sections.

Section No.	Aggregate.		Nature of Filler.	Binder (% by weight by analysis).	Cost per sq. yard.	Rate of application of emulsion to existing road surface (sq. yds./gal.).
	Nature.	Size.				
1 } 1a }	Limestone ...	$\frac{1}{8}$ in.–20 mesh (Failed in 1936.)	Limestone ...	7·2	2/0d.	14·5
2	Limestone	$\frac{5}{8}$ in.–$\frac{3}{8}$ in. ...	None	3·7	1/3d.	—
3	Limestone	$\frac{1}{8}$ in. down ...	Rock Asphalt ...	5·9	1/0d.	8·1
3a	Gravel	$\frac{1}{4}$ in.–down ...	Limestone and Rock Asphalt.	—	—	—
4	Granite and Quartzite ...	$\frac{3}{4}$ in. and $\frac{5}{8}$ in. ...	Gravel	5·4	2/0d.	—
5	Granite	$\frac{3}{4}$ in.–$\frac{1}{4}$ in. ...	Granite	4·4	1/6d.	—
6	Sand	$\frac{1}{8}$ in. down ...	Limestone ...	3·8	1/6d.	(Cut-back bitumen). 6·7
6a	Slag	$\frac{1}{8}$ in. down ...	As aggregate ...	4·6	2/0d.	—
7	Granite	$\frac{3}{8}$ in.–$\frac{1}{8}$ in. ...	None	5·3	1/11d.	11·2
8	Granite and Limestone...	$\frac{1}{4}$ in.–$\frac{1}{16}$ in. ...	Limestone ...	7·2	1/4d.	16·3
9	Slag	$\frac{5}{8}$ in.–$\frac{3}{8}$ in. ...	None	4·5	1/7d.	14·7
10	Quartzite	$\frac{3}{16}$ in. down ...	As aggregate ...	3·2	2/2d.	7·4
10a	Granite	$\frac{3}{8}$ in.–$\frac{1}{8}$ in. ...	None	4·1		
11	Granite	$\frac{3}{4}$ in.–$\frac{1}{4}$ in. ...	Limestone ...	2·9	1/11d.	8·7
12	Limestone (with pre-coated granite chippings).	$\frac{1}{8}$ in down ($\frac{3}{4}$ in.)...	None	7·1	2/0d.	8·7
13	Quartzite and Limestone	$\frac{1}{8}$ in. down ...	As aggregate ...	7·2	1/7d.	(Road heated.)
14	Slag	$\frac{7}{8}$ in.–$\frac{1}{8}$ in. ...	Slag	4·2	1/10d.	12·9
15	Slag	$\frac{3}{4}$ in.–$\frac{3}{8}$ in. ...	Slag	5·4	1/10d.	14·7
16	{Quartzite ... ... {Limestone	$\frac{3}{4}$ in.–$\frac{1}{2}$ in. $\frac{1}{8}$ in.–20 mesh }	None	4·9	1/8d.	—
17	Granite	$\frac{3}{8}$ in.–$\frac{1}{8}$ in. ...	Hydrated lime ...	5·3	1/11d.	—
18	Limestone and Quartzite	$\frac{3}{4}$ in.–$\frac{1}{8}$ in. ...	Slag	4·6	1/7d.	16·5
19	Slag, Quartzite and Limestone.	$\frac{1}{4}$ in. down ...	Powdered Asphalt	6·8	1/9d.	12·3
20	Granite	$\frac{3}{4}$ in.	Cement	2·4	1/11d.	(Road heated; 4·5.)

TABLE 3.

WOKING–CHOBHAM ROAD, B. 383.

Results of Skidding Tests, and Costs.

Section No.	Sideway Force Coefficient.		*Cost of Thin Carpet per square yard.
	January, 1937.	March, 1937.	
1	—	—	2/0½d.
2	—	0·65	1/7½d.
3	0·80	0·67	1/11d.
4	0·73	0·61	2/6d.
5	0·68	0·60	2/3d.
6	0·69	0·57	2/6d.
7	0·83	0·67	2/1d.
8	0·85	0·67	1/11½d.
9	0·83	0·65	1/8d.
10	0·82	0·64	1/11d.
11	0·77	0·69	1/10d.
12	0·77	0·67	1/8d.
13	0·76	0·68	1/11½d.
14	0·80	0·70	1/11½d.
15	0·75	0·70	1/10d.
16	0·76	0·74	1/11½d.

TABLE 4.

EGHAM–SUNNINGDALE ROAD, A. 30.

Results of Skidding Tests, and Costs.

Section No.	Sideway Force Coefficient.		Cost of Thin Carpet per square yard.
	January, 1937.	March, 1937.	
1	0·89	0·75	2/2d.
2	0·86	0·78	2/4d.
3	0·90	0·81	2/4½d.
4	0·86	0·78	1/10½d.
5	0·80	0·73	1/9½d.
6	0·83	0·68	1/10d.
7	0·81	0·73	2/0d.
8	0·83	0·66	2/0½d.
9	0·83	0·72	2/0½d.
10	0·83	0·67	1/10½d.
11	0·82	0·77	1/8½d.
12	0·82	0·75	1/9d.
13	0·83	0·79	1/7½d.
14	0·83	0·80	1/9½d.
15	0·83	0·82	1/10d.
16	0·82	0·78	1/11d.

* Includes 6d. for Sections 6, 7, and 8 and 4d. for the remaining sections for burning off old surface dressings.

CHAPTER VI.

SURFACE DRESSING.

(a) LANARKSHIRE.

Bathgate—Airdrie Road (*A*.89) *near Clarkston.*

Previous references:—*Report for* 1932, *pp*. 45-46.
Report for 1933, *p*. 96.
Report for 1934, *p*. 111.
Report for 1935-6, *pp*. 81-82.

Twelve sections were treated in August, 1932, to compare four types of ¾-in. gauge chippings for surface dressing, namely, whinstone, limestone, steel slag and blast furnace slag, when used in conjunction with two different tars and a tar-bitumen mixture. The carriageway is 30ft. wide and the average daily traffic (1935 census) 3,648 tons (1,200 vehicles).

Little change has taken place in the surface dressings during the past year, but deterioration of the base coat has developed. A number of the sections have been spoilt in appearance by subsidence of the foundation near the channels and by excavations for pipe lines. The experimental life of these sections is regarded as finished and it is not proposed to continue observations. The conclusions given in the last report have been confirmed, viz.:—

1. Five sections have retained a light grey colour:—
   (*a*) Blast furnace slag with tar-bitumen binder.
   (*b*) Limestone with tar-bitumen binder.
   (*c*) Blast furnace slag with tar No. 1.
   (*d*) Blast furnace slag with high viscosity tar.
   (*e*) Steel slag with tar-bitumen binder.

2. The three sections retaining the best appearance are:—
   (*a*) Blast furnace slag with tar No. 1.
   (*b*) Blast furnace slag with tar-bitumen binder.
   (*c*) Limestone with tar-bitumen binder.

Under the conditions of this experiment, the slags, particularly the blast-furnace type, have proved the most durable and have the best appearance. The tar-bitumen mixture has held the chippings best without darkening the surface; marked smoothing and the presence of an excess of binder on the surface is confined almost entirely to the tar sections.

(b) Oxfordshire.

Oxford—Henley Road (*A*.423)

Previous references:—*Report for* 1933, *pp.* 82-84,
Report for 1934, *p.* 108.
Report for 1935-6, *p.* 78.

As this experiment is the only one remaining of four carried out during 1933 it is of interest to recall the circumstances under which they were undertaken. The following quotation is from the Report for 1933, page 79:—

"The surface dressing experiments carried out during 1931 and 1932, and described in previous Reports, showed that tests of this kind involved so many factors which could not be controlled that the Committee decided not to undertake further experiments under normal traffic conditions until the results of work which had been put in hand in the Laboratory were available. It was considered, however, that it would be an advantage to obtain in the meantime information regarding current practice among road engineers in this country, and arrangements were accordingly made through the Department's Divisional Road Engineers for careful observations to be kept of the surface dressing and subsequent behaviour of a number of selected roads which were being dressed by the surveyors concerned in accordance with their normal practice.

"The earlier experiments had suggested that one of the factors of particular importance in surface dressing work was the moisture content of the chippings used, especially in the case of gravel. It was therefore suggested that on certain of the roads included in the above programme the effect of using dried and heated chippings, in addition to chippings taken from the roadside heaps in the usual way, should be investigated, and the surveyors were accordingly invited to dress sections of road, for comparison, with such "roadside" chippings, chippings dried and spread cold, and chippings dried and spread hot, respectively."

In consequence, the County Surveyor dressed twelve sections on the above road, each 220 yds. long, in July, 1933, with the object of comparing the results obtained using:—

(1) Two binders, viz., a No. 1 road tar and a proprietary tar-bitumen mixture.

(2) Two kinds of aggregate, viz., $\frac{3}{4}$ in.-$\frac{3}{8}$ in. Clee Hill granite and $\frac{3}{4}$ in.-$\frac{3}{8}$ in. local gravel.

(3) Chippings which were either
 (*a*) dried and warm,
 (*b*) dried and at atmospheric temperature, or
 (*c*) taken from heaps at the roadside.

The average width of the carriageway is 20 ft. and the average daily traffic (1935 census) 3,610 tons (2,603 vehicles).

The sections have been inspected at intervals since the work was done, the latest inspection being made in April, 1937. The results which have been previously noted have been confirmed by this inspection and are as follows:—

(1) The tar-bitumen binder gave better results than the No. 1 tar.

(2) The granite gave better results than the local gravel.

(3) The "dried and warm" and "dried and at atmospheric temperature" chippings gave rather better results than those taken from roadside heaps, the difference being more marked with the tar-bitumen mixture than with the tar, and more marked with the gravel than the granite.

These tests, taken into consideration with other work done in this connection, show that:—

(1) Dried gravel is likely to give much better results than damp or wet gravel.

(2) Difficulty due to dampness of the stone is more likely to be experienced with materials such as gravel which have to be washed before supply than with stone such as granite which does not need washing.

(3) The use of warm stone is an advantage when work is done in comparatively cold, damp weather and/or when using a high temperature binder. Equally good results are likely to be obtained with gravel at atmospheric temperature (provided it is dry) when the work is carried out on a dry day, especially with a comparatively low temperature binder. (*Note.*—The summer of 1933 was very hot.)

It is noteworthy that all these surface dressed sections have given four years' life (though with varying degrees of success) without needing remedial surface treatment.

(*c*) County of Southampton.

Basingstoke-Winchester Road (A.33).

The surface dressing experiment on the above road was undertaken in August and November on behalf of the Road Tar Research Committee, who desired this full scale work to supplement the research work being carried out for them at the Road Research Laboratory. It was arranged that the experiment should be carried out under the general direction of the Ministry of Transport in collaboration with the County Surveyor of Hampshire, and the research officers were given every facility for making observations and records. The site of the work was immediately north of Lunways Inn, where the road carried an average daily traffic (1935 census) of 5,264 tons (2,690 vehicles). Each section was 80 yds. long.

The objects of the experiment were:—

I. To compare the effects of:—

(*a*) a high-aromatic tar,

(*b*) a low-aromatic tar, and

(*c*) a low-aromatic tar containing calcium soap,

on the set and life of a surface dressing, and to determine the correlation of the results with the drying properties of the respective tars.

II. To determine the effect on the life of a surface dressing of using:—

(*a*) a mixture of two sizes of " cubical " chippings, and

(*b*) flaky chippings,

two different rates of spread of tar being used in each case.

III. To determine whether the life of a surface dressing of Hampshire gravel could be prolonged by preliminary treatment of the gravel with oil.

The Road Tar Research Committee desired that the work should be carried out during the normal surface dressing season and that the experiment on the questions in Group I should be repeated in November, so that the research workers might have quantitative results from practical work on the effect of different weather conditions to compare with their laboratory research.

Details of the sections laid are given in Table I of the Appendix to this Chapter.

After eight months the following interim conclusions have been drawn, by the research officers, from the differences which exist between the different sections.

Object I:—to compare the effects of:—

(*a*) a high-aromatic tar,

(*b*) a low-aromatic tar, and

(*c*) a low-aromatic tar containing calcium soap,

on the set and life of surface dressing and to determine the correlation of the results with the drying properties of the respective tars.

(i) Under the conditions of the experiment no advantage has resulted from the addition of calcium soap to the low-aromatic tar.

(ii) Weather conditions resulted in the early failure of the surface dressing done in November, thus emphasising the difficulty of carrying out surface dressing with hot binders so late in the year. It is consequently impossible to make any comparison regarding the setting properties of tar between the results obtained from the work done in November and those obtained from work done in August.

Object II:—to determine the effect on the life of a surface dressing using:—

(i) a mixture of two sizes of cubical chippings, and

(ii) flaky chippings,

in conjunction with two different rates of spread of tar in each case.

(i) The use of additional small chippings resulted in a small improvement on the section having the normal rate of spread of tar (4·7 sq. yds./gal.) and a very great improvement on the section having less than the normal rate of spread (6·7 sq. yds./gal.). The sections containing the additional small chippings were the best of all, and their surface texture was somewhat closer than that of any of the others.

(ii) The surfaces resulting from the use of flaky chippings are in good condition and non-skid, but not so rough as those on which cubical chippings of the same material are used. When flaky chippings are used the covering capacity per ton of aggregate is greater than that for cubical chippings and less tar is required than for cubical chippings of the same material and same nominal sieve size.

Object III:—to determine whether the life of surface dressing with Hampshire gravel could be prolonged by preliminary treatment of the gravel.

The result obtained with dried, warm Hampshire gravel, and tar spread at 4 sq. yds./gal., was as good as that given by dolerite. Otherwise the results with Hampshire gravel are not so good as those with dolerite. Preparation of the gravel by drying or by treatment with tar oil appears to offer a slight advantage. The rate of spread of tar on the different gravel sections varied from 4 to 6 sq. yds./gal., and it is apparent that with this aggregate the effect of rate of spread of binder predominates over that of any preliminary treatment of the gravel.

General.—The temperature of tar falls very rapidly when it is applied to the road and attains the road temperature within a very few moments of its application. For this reason, in normal work, the viscosity of the tar to be used should be decided, as far as is practicable, by the seasonal temperature.

It may be of interest to add that, in the opinion of the County Surveyor, on all sections which may be considered successful, in that the chippings have been held, there has been rather more facing up in the wheel tracks than is usual or desirable at this stage in the life of a surface dressing.

(*d*) Midlothian.

Edinburgh-Peebles Road (*A*.703) *at Glencorse.*

Previous References:—*Report for* 1933, *pp*. 84-86.
Report for 1934, *pp*. 108-109.
Report for 1935-6, *pp*. 79-80.

The two objects of the experiment were:—

(1) To compare the results obtained in surface dressing with whinstone chippings spread (*a*) hot, (*b*) dry but cool, (*c*) as taken from heaps at the roadside.

(2) To ascertain what advantages resulted from the application of chippings (whinstone) in two successive dressings, the second being of smaller gauge than the first.

Six sections, each 300 yards long, were laid, three being used for each of the two objects of the experiment. The road is 27 ft. wide and the average daily traffic (1935 census) is 1,830 tons (1,294 vehicles). Brief particulars of the work, which was carried out in July, 1933, are given in the following table:—

Section.	Condition.	Size (in.).	Rate of application (sq. yds./ton).	Percentage brushed off after 10 days.
A	Hot			3·7
B	Dried ...	$\frac{3}{4}$–$\frac{1}{2}$	80	6·1
C	Roadside ...			8·6
D	Roadside ...	Lower coat:	65	7·5
E	Roadside ...	$\frac{3}{4}$–$\frac{1}{2}$		13·3
F	Dried ...	Upper coat: $\frac{1}{2}$–$\frac{1}{4}$	400	11·3

The proprietary binder used was heated to 240-250°F. and applied at the rate of 6 sq. yds./gal., except on Section D, for which the rate of application was 5 sq. yds/gal. The chippings on Section A were applied at a temperature of 163°F. A 10-ton roller was used on all the sections.

Immediately after the completion of Sections D and E there was continuous rain for 24 hours, and in the case of Section F completion of the work was followed by 6 hours of rainfall and 36 hours of warm, dry weather.

The dressings on the southern half of Section E and the whole of Section F were burned off in the early spring of 1936 as the surface had become rich, no doubt due to the loss of chippings caused by the rain, and the sections were excluded from further consideration as part of the experiment.

When the sections were inspected early in 1937 their general appearance had changed little during the year. Patches made near the channels last year remain in good condition, but small additional patching has recently been necessary as a result of the severe winter.

With regard to the first part of the experiment, the section on which heated chippings were used is still rich in surface binder, but Sections B and C are in good condition. Owing to the rainfall previously mentioned it is not possible to draw conclusions regarding the second part of the experiment. The appearance of the various surfaces has undergone definite seasonal changes, becoming rather smooth in the summer and quite rough in the winter, although the smoothing up in the summer becomes less pronounced from year to year. As the sections showed no general tendency to fray and were still reasonably non-skid in appearance, it was decided that they should remain under observation.

Recent skidding tests on Sections A, B and C, after four years' wear, show sideway force coefficients of 0·57, 0·58 and 0·55, respectively.

(*e*) County of Southampton.

Bullington Cross-Tufton Road (*A*.34).

Previous References:—*Report for* 1934, *pp.* 105-106.
Report for 1935-6, *pp.* 75-76.

The experiment was undertaken during July, 1934, to compare various surface dressings of Hampshire gravel, a material which had been found to present considerable difficulty in use as compared, for example, with granite. Thirteen sections were dressed, each 320 yards long and 18 ft. wide, on a length of Route A.34 which carried an average daily traffic (1935 census) of 3,275 tons (2,086 vehicles). On six of the sections screened gravel was used, on five others crushed gravel was used, and on the remaining two a mixture of crushed and screened gravel was used. $\frac{5}{8}$ in.-$\frac{3}{8}$ in. material was used on all sections except Section No. 13, on which $\frac{1}{2}$-in. dust was used. The gravel was either untreated, or pre-coated with cement, oil or bitumen emulsion, and was used in conjunction with four proprietary bituminous binders. The characteristics of the binders used were given in the Report for 1934, page 121, Table 3, and details of the sections, including cost, on pp. 119 and 120, Tables 1 and 2. A 10-ton roller was used throughout for consolidation. Brief particulars of the sections are given below:—

Section No.	*Binder.*	*Type of Gravel.*
1	A	50 per cent. screened, 50 per cent. crushed, coated with cement.
2	B	(as above)
3	C	Screened.
4	C	Crushed.
5	D	Screened.
6	D	Crushed.
7	B	Screened and treated with oil.
8	B	Crushed and treated with oil.
9	A	Screened and treated with oil.
10	A	Crushed and treated with oil.
11	A	Screened and treated with bitumen emulsion.
12	A	Crushed and treated with bitumen emulsion.
13	B	$\frac{1}{2}$-in.—dust.

The road was inspected during fine, cold weather in April, 1935, when it appeared that the gravel treated with oil or with bitumen emulsion had given better results than the untreated or cement-coated gravel. At an inspection during similar weather conditions in April, 1936, all the sections were in good condition with the exception of Nos. 1 and 2, on which a considerable amount of the gravel had been removed from the wheel tracks on both sides of the road. All the sections on which binders B and C had been used, except No. 2, gave good results. The screened gravel gave a better general result than the crushed gravel, the best section appearing to be No. 7, although Section No. 9 and Section No. 13, which was the cheapest, were but little inferior.

A further inspection was made during fine weather in March, 1937. Sections Nos. 1 and 2 were still the least satisfactory; on these the gravel was a mixture of screened and crushed material, coated with cement, and there was rain on the day following laying. It is not possible to say how far the results were attributable to any or all of these three conditions. The oil and emulsion treated sections were still in good condition, those of crushed gravel having improved slightly during the year. With the exception of No. 2, all the sections on which binder B had been used still gave good results, and the sections on which binder A had been used had not deteriorated but, in some cases, had improved. Sections 3, 4, 5 and 6 (binders C and D) were becoming bare of chippings in the wheel tracks, but after three years' wear could not be regarded as having failed. Section No. 7 was still in the best condition, closely followed by Section No. 13, as last year, but Sections Nos. 10, 11 and 12 were in better condition than the remainder.

Pre-treatment of the gravel with oil or with bitumen emulsion has thus secured a marked improvement in the results obtained. The process, however, gives rise to great difficulties at the time of application of the dressing and for this reason it is not likely to become general practice.

None of the sections appears to have reached the end of its useful life but the road is to be surfaced with asphalt during 1937 and the experiment will then have to be terminated.

(*f*) County Borough of Sheffield.

Hathersage Road (*A*.625).

Previous reference:—*Report for* 1935-6, *pp.* 74-75.

Twelve sections on the above road, each 85 yds. long, were surface dressed in July, 1935, with the object of obtaining information as to the relative merits of various types of chippings from the point of view of night driving. The carriageway width varies from 20 to 25 ft. and the average daily tonnage is

5,274 (1935 census) (3,007 vehicles). A proprietary tar-bitumen mixture (tar of 90 secs. viscosity with 10 per cent. of bitumen) was used throughout in conjunction with gravel and various types of chippings, as indicated in the following table:—

Section.	*Chippings.*
A	$\frac{5}{8}$-in. Pink Leicestershire granite.
B	$\frac{5}{8}$-in. Red Doncaster shale.
C	78 per cent. of $\frac{5}{8}$-in. Staffordshire gravel and 22 per cent. of $\frac{5}{8}$-in. red Sheffield shale.
D	$\frac{5}{8}$-in. Staffordshire gravel.
E	$\frac{3}{4}$-in. Doncaster gravel.
F	$\frac{3}{4}$-in.-$\frac{3}{8}$-in. Kirk Ireton gravel.
G	$\frac{5}{8}$-in. local sedimentary stone.
H	$\frac{3}{4}$-in. basalt.
J	$\frac{3}{4}$-in. cement-washed basalt.
K	50 per cent. of $\frac{3}{4}$-in. basalt and 50 per cent. of $\frac{5}{8}$-in. limestone.
L	64 per cent. of $\frac{5}{8}$-in. limestone and 36 per cent. of $\frac{5}{8}$-in. Doncaster shale.
M	73 per cent. of $\frac{5}{8}$-in. Horton stone and 27 per cent. of $\frac{5}{8}$-in. Sheffield shale.

Owing to the widening and realignment of the road most of Section M has been reconstructed and this section has therefore been omitted from the report on the experiment.

In November, 1935, an examination of the reflection characteristics of the sections made by the Lighting Department of the County Borough Council of Sheffield during the day and at night, and under wet and dry conditions, showed that the sections could be divided roughly into two groups, of which the more satisfactory included Sections A-F and Section L. Section K was somewhat difficult to place owing to the uneven distribution of the chippings but could probably be classified as intermediate between the other two classes.

In March, 1937, some smoothing was noticeable in the wheel tracks on most sections and in places a slight excess of binder had appeared on the surface due to the underlying road having been rich in binder. The gravel sections showed signs of further wear and on the sections where shale had been used the softer material in this aggregate had disintegrated, leaving the surfaces very rough.

Three skidding tests were carried out in 1936 and 1937; in July and October, 1936, the surfaces were watered before testing, but in February, 1937, the road was wet with rain. The values of the sideway force coefficients at 30 m.p.h. obtained during these tests are given in the following table:—

Section.	Sideway Force Coefficient at 30 m.p.h.			
	March, 1936.	July, 1936.	October, 1936.	February, 1937.
A	·68	·63	·69	·83
B	·76	·70	·76	·91
C	·63	·63	·67	·78
D	·64	·63	·65	·75
E	·63	·58	·65	·77
F	·65	·69	·70	·75
G	·67	·69	·69	·83
H	·66	·71	·73	·81
J	·65	·64	·68	·79
K	·62	·65	·66	·84
L	·72	·67	·72	·90

All the above figures indicate good resistance to skidding. The surfaces were inspected as regards colour by day and night, the road being dry on each occasion. There were some differences in the results of the two inspections, but Sections A, B, C, D, E and L gave better results than the others, from the point of view of driving, both by day and night. Section F was good by day but not by night. Section K was next in order of merit, Sections G, H and J coming last.

As regards durability, Sections A, B, G, J, L and M were the best, there being little to choose between them. It will be seen that to a considerable extent the materials which are the best as regards colour are less satisfactory as regards durability. Sections A and L are, however, good in both respects and so is section B except, possibly, as regards colour at night when wet.

Comparing this experiment with that in Buckinghamshire undertaken for the same purpose, it will be seen that the gravels used in each case give a good light surface. The sideway force coefficients are generally consistently good, but the cement washing process is not justified as the cement soon wears off, except in the interstices of the stone, where most of its value is lost as regards colour. Observations on these sections will be continued.

(*g*) BUCKINGHAMSHIRE.

London—Oxford Road (*A*.40).

The experiment was undertaken to obtain information as to the relative merits of various types of chippings from the point of view of night driving. Eight sections on Route A.40, each

170 yds. long, were surface dressed in June; the experimental length extends westwards from the boundary of the Borough of Chepping Wycombe, where the carriageway is 20 ft. wide and the average daily traffic (1935 census) 6,629 tons (2,654 vehicles). A proprietary bitumen was used. Particulars of the sections are given in the following table:—

No.	Chippings.	Cost per ton.	Area (sq. yds.).	Total amount used (tons).	Average cover (sq. yd./ton).	Amount swept off 48 hours after road opened to traffic (tons).
		s. d.				
1	Grey Leicestershire Granite.	18 9	1,083	16¼	66·7	2½
2	Pink Leicestershire Granite.	18 2	1,089	16½	66·0	1½
3	Cornish Granite ...	27 8	1,071	14¼	75·3	¾
4	Shropshire Quartzite.	25 5	1,077	18	59·9	2¾
5	Local Gravel ...	8 3	1,071	15½	69·2	3¼
6	Local Gravel, cement coated.	8 3	1,065	16	66·6	2½
7	Grey Leicestershire Granite, cement coated.	18 9	1,089	15¼	71·4	1¼
8	Derbyshire Limestone.	20 6	1,083	13¾	78·8	1¾

The existing surface was asphalt macadam, except on Section No. 8, part of which was asphalt macadam and the remainder tar macadam which had been previously surface dressed. With the exception of the cement coated chippings used on Sections Nos. 6 and 7, all the chippings were dried and heated in a portable stone drier at the site of the work, their temperature at the time of application being 100-150° F. The road was swept clean and the rate of application of the binder, which was kept as constant as possible, averaged approximately 5 sq. yd./gal., at 250-300° F. The rates of application of the chippings are given in the above table and the results of examination of the chippings are given in Table 2 of the Appendix to this Chapter. Rolling was carred out by either an 8- or a 12-ton roller.

The greater part of the experimental length is on a short by-pass. It was therefore possible to divert traffic from it during the work, but on Section No. 1 and on parts of Sections Nos. 2 and 8 there was no alternative route and in addition they were subjected to turning traffic at the ends of the diversion. Further, a part of Section No. 8 was on a gradient of 1 in 22, so that conditions on these sections were more severe than on the other sections.

The work was commenced in the afternoon of 23rd June and completed by mid-day on 27th June. With the exception of a few showers of rain on the morning of 26th June the weather was fine and warm. The daily air temperatures during working hours varied from 58-82° F. and the temperature of the road surface from 64-100° F. just prior to the application of the bitumen. Traffic was allowed on to Sections Nos. 1 and 8 24 hours after the completion of each half-width, but in all other cases the sections were closed to traffic until the morning of 29th June.

In December the road was inspected by members of the Experimental Work on Highways (Technical) Committee, the County Surveyor, and representatives of the Royal Automobile Club and the Automobile Association, in order to assess the relative merits of the eight different sections from the point of view of motorists. Inspections were made during the day and night and under wet and dry conditions. The consensus of opinion was that Sections Nos. 4, 5, and 6 gave the best results; the Shropshire stone (Section No. 4) had the lightest colour, whilst the gravel sections were also pleasing in this respect. Next in order of merit were Sections Nos. 2 and 3, with Sections Nos. 1, 7 and 8 at the lower end of the scale. The cement coated chippings were preferred to the uncoated chippings.

Skidding tests were carried out in December; the results, which are given in Table 3 of the Appendix to this Chapter, show that the values of sideway force coefficient were satisfactory, except for Section No. 8, which had become smooth. The excess of binder on this section was subsequently burned off and the surface was raked and rolled.

The remaining 7 sections are in good condition, but some bare areas have developed in the wheel tracks, particularly on the gravel sections. The uncoated gravel sections have shown more wear than the cement-coated gravel. On Sections Nos. 6 and 7, most of the cement coating has been worn off by traffic, although traces are still visible, especially on Section No. 7, on a strip about 3 ft. wide in the middle of the carriageway.

Arrangements have been made with the Laboratory for tests to be carried out on the road in order to develop a method of measuring quantitatively the light reflecting characteristics of road surfaces.

(*h*) DUNBARTONSHIRE.

Dumbarton-Helensburgh Road (*A*.814).

Previous References:—*Report for* 1934, *pp*. 116-118.
Report for 1935-6, *pp*. 84-85.

During August and September, 1934, arrangements were made to compare four methods of treating smooth asphalt. Four sections east of Cardross, each 220 yards long, were treated respectively with gravel, whinstone and two types of granite, precoated in each case with bitumen and limestone filler; the existing smooth asphalt laid in 1926 was heated, raked and rolled before the chippings were spread. The carriageway is 20 ft. wide, and the average daily traffic (1935 census) 3,750 tons (1,699 vehicles). A further four sections opposite Craigendoran were treated in a similar manner except that in this case the surface was made up with new asphalt where necessary. Extensive patching has been required on all the sections from time to time since they were laid. Unfortunately this repair work was carried out with a number of different types of chippings, with the result that the present surface has a very patchy appearance. A recent inspection shows that both the sections treated with granite No. 1 are in appreciably better condition than any of the others, a conclusion which has been borne out each year. The two whinstone sections are also in good general condition, although the surface is somewhat dark in colour. All the remaining sections have needed a great deal of patching. In general, on the sections made up with new asphalt, patching has been necessary in small areas across the whole width of the road, but on the remaining sections the patching has generally been confined to the wheel-tracks. On all the sections the chippings were still standing appreciably proud of the matrix.

The experiment shows that the methods adopted for improving the resistance to skidding of the smooth asphalt surface have been successful in their main object.

(*i*) West Lothian.

Edinburgh-Glasgow Road (*A*.8).

Previous References:—*Report for* 1934, *pp.* 112-114.
Report for 1935-6, *p.* 83.

In collaboration with the County Surveyor of West Lothian, an experiment was undertaken to investigate various methods of surface treatment of asphalt which had become smooth under traffic. The section of road chosen was near Uphall, where the carriageway had a gradient of 1:34, the width being 30 ft. and the average daily traffic (1935 census) 5,792 tons (2,078 vehicles).

Three sections were treated during September and October, 1934; Sections Nos. 1 (*a*) and 1 (*b*) differed only in the type of bitumen emulsion used, whilst tar was used as binder on Section No. 2. Precoated whinstone chippings were used for dressing all three sections. The work was carried out in the following manner:—

A key coat was provided by spreading and rolling ¼-in. chippings on a spray coat of binder. Traffic was not allowed on the work until after 4 hours had elapsed. A surface coat of ¾-in. chippings was later applied in the same manner, traffic being again excluded for 4 hours.

An inspection in April, 1937, disclosed that little change had taken place during the past year. Section No. 1 (*a*) still retains the best appearance, having a good matt surface on which the wheel tracks are only slightly smoother than the rest. Section No. 1 (*b*) is also in good condition except that in the central 10 ft. the bare areas previously reported have developed; this section, however, was laid in poor weather conditions. Section No. 2 is smooth in the wheel tracks but the central 10-ft. strip remains in its original condition. This section is the most polished of the three and is very similar in appearance throughout the whole of its length. Even the smoothest parts, however, do not appear so polished as the smooth asphalt adjoining the experimental sections.

The treatment on all the sections has produced a surface which is less inclined to slipperiness than the original smooth asphalt. All the sections appear durable, the bitumen emulsion having so far given a better surface than the tar. Skidding tests made during 1936 showed that in all cases satisfactory coefficients had been maintained, without any repairs being required. The experiment has shown the value of the treatment, in providing, at a cost of about 1s. per sq. yd., a good non-skid surface which has remained rough for three years and seems likely to maintain its rugosity even longer.

APPENDIX TO CHAPTER VI.

TABLE 1.

BASINGSTOKE–WINCHESTER ROAD.

Details of Experimental Sections.

Section No.	Specified rate of application (sq. yds./gal.).	Actual rate of application (sq. yds./gal.).	Type of chippings.	Specified rate of spread of chippings (sq. yds./ton).	Average temperature of road. (°C)	Average temperature of tar on road. (°C)	Chippings swept off 2 days after laying. (cu. yd.)
1	5½	4·6	½ in. cubical dolerite	90	25½	34½	¾
2	5½	4·9	½ in. cubical dolerite	90	24	30	¾
3	5½	4·8	½ in. cubical dolerite	90	18½	26	½
4	5½	5·2	½ in. cubical dolerite	90	17	25	½
5	5½	4·7	½ in. cubical dolerite and 4–7 mesh dolerite grit.	90 120	21	27½	¾
6	7½	6·7	½ in. cubical dolerite	90	23	27½	¾
7	7½	6·7	½ in. cubical dolerite and 4–7 mesh dolerite grit.	90 120	23	26½	1
8	5½	5·0	½ in. cubical dolerite	90	27	31	½
9	5½	5·0	½ in. flaky dolerite ...	120	31	29	½
10	7	6·4	½ in. flaky dolerite ...	120	24½	26	¾
11	4½	4·0	½ in. dry Hants. gravel	90	22	27½	1
12	5½	5·1	½ in. cubical dolerite	90	24	31½	½
13	6	5·9	½ in. oiled Hants. gravel wetted with 4% of water.	90	20	29	1¼
14	6	5·4	½ in. dry Hants. gravel	90	31	45	1½
15	5½	5·9	½ in. oiled Hants. gravel.	90	22	34½	1¾
16	5½	5·6	½ in. dry Hants. gravel	90	41	43	1½
17	5½	6·0	½ in. dry Hants. gravel	90	21	30½	1½

NOTE.—A high-aromatic tar was used on all sections excepting Nos. 1 and 2. On Section No. 1 a low-aromatic tar plus 1½% of calcium soap was used and on Section No. 2 a low-aromatic tar was used.

On all sections excepting Nos. 13, 14 and 17, the viscosity of the tar used was 55 seconds. On Sections Nos. 13, 14 and 17, the viscosity of the tar used was 120 seconds.

TABLE 2.

LONDON-OXFORD ROAD.

Results of Examination of Samples of Chippings.

Material.	Grey Leicestershire granite.	Pink Leicestershire granite.	Cornish granite.	Shropshire quartzite.	Local gravel.	Local gravel cement coated.	Grey Leicestershire granite, cement coated.	Derbyshire limestone.
Grading (%) :—								
Passing 18 mesh	—	—	—	—	—	—	—	0·9
Passing 8 mesh retained 18 ,,	0·3	—	0·1	—	—	—	0·6	0·9
,, 1/8 in. ,, 8 ,,	0·5	0·2	0·5	0·2	—	0·3	0·3	2·0
,, 1/4 in. ,, 1/8 in.	21·0	2·1	20·9	0·9	1·0	1·0	20·5	22·1
,, 3/8 in. ,, 1/4 in.	52·0	29·5	41·4	16·4	31·2	27·8	44·0	61·3
,, 1/2 in. ,, 3/8 in.	24·6	64·7	34·6	56·8	65·2	66·6	32·4	12·8
,, 3/4 in. ,, 1/2 in.	1·6	3·5	2·5	25·7	2·4	3·9	2·2	—
,, 1 in. ,, 3/4 in.	—	—	—	—	0·2	0·4	—	—
,, 1 in.	—	—	—	—	—	—	—	—
Covering Power :— (sq. yds./ton)	130	110	120	90	100	100	130	150
Volume Weight :— (lb./cu. ft.)	88	90	89	92	91	91	87	90
Voids (%)	47	45	46	44	42	42	49	45

TABLE 3.

LONDON–OXFORD ROAD.

Results of Skidding Tests.

Section No.	Chippings.	Average values of sideway force coefficient recorded on 3rd December, 1936, at					
		5 m.p.h.	10 m.p.h.	15 m.p.h.	20 m.p.h.	25 m.p.h.	30 m.p.h.
1	Grey Leicestershire Granite	0·87	0·85	0·83	0·81	0·79	0·77
	Spot values on bitumen ...	(0·57 at 24·5 m.p.h. and 0·50 at 34 m.p.h.)					
2	Pink Leicestershire Granite	0·80	0·80	0·80	0·80	0·80	0·80
3	Cornish Granite	0·82	0·82	0·82	0·82	0·82	0·82
4	Shropshire Quartzite ...	0·83	0·81	0·80	0·78	0·77	0·75
5	Local Gravel	0·75	0·73	0·70	0·68	0·66	0·65
6	Local Gravel, cement coated	0·64	0·63	0·63	0·63	0·62	0·62
7	Grey Leicestershire Granite, cement coated	0·87	0·82	0·78	0·74	0·70	0·67
8	Derbyshire Limestone ...	0·56	0·56	0·56	0·56	0·56	0·56
	Values registered where bitumen had bled through in centre of section ...			0·27	0·26	0·25	0·24

NOTE.—The road was clean, and thoroughly wetted by means of watering carts.
temperature, 51°F.

CHAPTER VII.

FOOTPATHS IN RURAL AREAS.

(*a*) SURREY.

Kingston By-Pass (*A*.3).

Previous references:—*Report for* 1934, *p.* 127.
Report for 1935-36, *pp.* 89-91.

Eight experimental lengths of footpath, each 220 yds. long and 8 ft. wide, were laid for comparison on the above road. The work was commenced in November, 1934, and completed in March, 1935. The foundation of the existing bituminous clinker footpath, which required reconstruction, was scarified, re-shaped and rolled, the estimated cost being 9d. per sq. yd. The various sections laid were as follows:—

Section No.	*Description.*	*Cost per sq. yd.* *s.*	*d.*
1	Limestone tar macadam, ½-in. wearing course on 1½-in. binder course	3	8
2	¾-in. bituminous sand carpet	2	7
3	¾-in. cold gravel asphalt, using slow-breaking bitumen emulsion	1	5
4	2-in. cold gravel asphalt	2	4
5	2-in. tar-sprayed hoggin	1	9
6	2-in. precast gravel concrete slabs	4	8
7	3-in. reinforced gravel concrete	3	3
8	3-in. cement grouted gravel	5	2

The sections have been inspected periodically; their present condition is as follows:—

Section No. 1.

There are slight inequalities in the surface, but the general condition is good.

Section No. 2.

There are several transverse and longitudinal cracks although the surface generally is in good condition. The last 70 ft. length at the northern end of the section has been patched. For 30 ft. the patches extend for a width of 2 ft. 6 in. and 2 ft. respectively on the sides only, the remaining 40 ft. having been resurfaced over the full width of the path.

Section No. 3.

The general condition is poor, there being many loose places about 6 in. in diameter where the top skin has disappeared.

Sections Nos. 4 and 5.

These sections had deteriorated and become uncomfortable to walk on, and surface dressing was therefore undertaken. The footpaths were hand-rolled, sprayed with tar No. 1 at the rate of 1 gal. per 3·67 sq. yds., and gritted with $\frac{1}{8}$-in. to dust limestone at the rate of 180-190 sq. yds. per ton. The chippings were hand-rolled after spreading.

Section No. 6.

Very good surface. Some of the joints between the slabs are wide and grass is visible. One of the slabs in the middle of the section is cracked across the corner.

Section No. 7.

Very good surface.

Section No. 8.

The surface is rougher than that of Section No. 7. Full width transverse cracks were observed on the two bays and the edges of the cracks are spalling. In two cases slabs have sunk at one end and the adjoining slabs are at different levels, in one case the difference amounting to $\frac{1}{2}$ in.

Sections Nos. 4 and 5 must be regarded as having failed after less than two years' life. The concrete sections have proved the most durable and appear likely to justify their higher cost. Section No. 7 is the best and its initial cost was moderate (3s. 3d. per sq. yd.). The precast concrete slabs did not appear suitable for rural surroundings and are likely to be displaced by grass and weeds growing in the joints.

(*b*) COUNTY BOROUGH OF LEEDS.

Previous reference:—*Report for* 1935-6, *pp.* 91-92.

The following two sites in the County Borough of Leeds were selected for experimental work to compare the initial and maintenance costs of various types of footpath:—

(1) *Swinnow Lane* (*A*.6110).

Seven lengths of footpath were laid in February, 1935, in Swinnow Lane, on the outskirts of Leeds, where pedestrian traffic is considerable as there are several factories in the neighbourhood. The materials were laid to a width of 6 ft. on a uniform foundation of old tar macadam which had been thoroughly consolidated to a minimum depth of 4 in.

(2) *St. Helens Lane (Unclassified).*

Seven further experimental lengths of footpath were laid during the early part of 1935 on a foundation of 4 in. of macadam. Pedestrian traffic at this site is less than in Swinnow Lane, but the footpath has a northerly aspect and is bounded on the south side by high walls, and there are also overhanging trees. In consequence the surface tends to remain damp for long periods.

The following table gives the present position with regard to the sections. A description of the materials used was given in the Report for 1935-6 but for convenience the type of construction and the costs are included in the table. In several cases materials to similar specifications were laid at both sites.

From the table it will be seen that Sections Nos. 5, 6 and 7 at Swinnow Lane have so far given good results at reasonable cost, but in this experiment the concrete sections had too rough a finish to be comfortable for pedestrians.

Description.	Cost (per sq./yd.)	Section No.	Swinnow Lane Results to date.	Section No.	St. Helens Lane (corresponding sections). Results to date.
	s. d.				
2-in. compressed concrete. (No roller used on St. Helens Lane).	1 4	1	Transverse cracks at 12-yd. intervals noted in July, 1935. No subsequent deterioration.	1	Transverse cracks have appeared during the year.
$\frac{3}{4}$-in. bituminous sand carpet ...	$9\frac{3}{4}$	2	Not so smooth as Section 5 (St. Helens Lane) but in sounder condition.	5	Surface beginning to fray at the edges. Otherwise smooth and firm.
2-in. cold asphalt dressed with bitumen emulsion and $\frac{1}{4}$-in. gravel.	1 $10\frac{1}{2}$	3	Parts replaced in early life. Soft and easily displaced	3	Beginning to fray in places but good regular surface.
3-in. compressed concrete, finished with $\frac{3}{4}$-in. chippings.	2 4	4	Very rough surface. Uncomfortable for walking.	4	Slightly rougher than in Swinnow Lane. One-third has been resurfaced with fine tar macadam.
2-in. hoggin mixed with a proprietary binder of vegetable origin, sprayed and chipped.	1 $5\frac{1}{2}$	5	Very good, comfortable for walking.	—	—
$\frac{3}{4}$-in. fine clinker mixed with bitumen emulsion, dressed with emulsion and $\frac{1}{4}$-in. chippings.	1 3	6	do. do.	2	Beginning to fray.
$\frac{3}{4}$-in. tarred limestone.	1 5	7	do. do.	—	—
2-in. sandstone chippings with a binder of vegetable origin.	1 5	—	—	6	Rather soft surface. Fairly good.
2-in. waterbound sandstone chippings.	$6\frac{1}{4}$	—	—	7	do. do.

(*c*) Isle of Ely.

Wilburton-Stretham Road (*A*.1123).

Previous reference:—*Report for* 1935-6, *pp*. 93-95.

Twelve lengths of footpath, each 220 yds. long, were constructed on this road during August, September and October, 1935. The existing grass verge was stripped to a width of 6 to 7 ft. and the subsoil was shaped and levelled; the foundation so formed was treated with creosote at the rate of 3 sq. yds./gal. to prevent the growth of weeds. On this surface a 3-in. layer of gravel was spread and consolidated by hand rolling to provide a uniform foundation for the experimental lengths.

The sections were as follows:—

Section No.	*Description.*	*Cost per sq. yd.* *s.*	*d.*
1	1½-in. unreinforced gravel concrete	2	3½
2	1-in. reinforced gravel concrete	2	7
3	2-in. cement-grouted gravel	2	5½
4	1½-in. cement-grouted clinker	2	8½
5	3-in. cement-grouted gravel	2	11
6	Two-coat tar macadam (top course, limestone, and bottom course, slag)	2	1
7	¼ in.-½ in. of tarred limestone on 1½-in. layer of gravel	1	5½
8	2-in. cold gravel asphalt, surface dressed ...	1	8½
9	2-in. cold gravel asphalt, surface dressed (similar to No. 8 but with a different emulsion)	2	3½
10	2½-in. layer of gravel, surface dressed ...		11½
11	2½-in. clinker, grouted with bitumen emulsion	1	3½
12	2 in. of earth mixed with emulsion and surface dressed	1	6

At the end of March, 1937, the concrete sections were generally in good condition. Slight spalling had occurred at the transverse joints and along the edges of the slabs, which had suffered also by vehicles encroaching on the footway and by subsidence of the foundation along the ditch side of the path. On Sections Nos. 1, 2 and 3 a few of the slabs had cracked across the corners, and two slabs on Sections Nos. 1 and 2 had cracked across their full width. The surface of the cement-grouted sections, particularly No. 3, was rather too rough in parts for walking upon in comfort. Subsidence of the foundation had occurred on Sections Nos. 6 to 11, where the path is close to a ditch. Extensive patching had been undertaken on Section No. 6 and also, to a less extent, on Section No. 7. The more stable parts of these two sections were, however, in good condition. Sections Nos. 8 and 9 were in good condition, although there were a few small areas where the surface was beginning to fray and where weeds were coming through the surface. Gate entrances across the path on these two sections have been relaid with tarred chippings.

As the surface of Section No. 10 had begun to break up it had been necessary to surface dress it in the early summer of 1936. This section had been laid during adverse weather conditions. In addition a sample of the tar used on the section was found to have a viscosity lower than the minimum requirements for a tar No. 1. The section is again showing signs of failure.

Section No. 11, which had shown signs of failure and had therefore been surface dressed in the summer of 1936, and Section No. 12 were both in satisfactory condition; some weeds were, however, coming through the surface. Since all the sections have been in use for only about 18 months it is too early to draw final conclusions. The fact however that the cement-grouted sections had a rough surface which was unpleasant to walk on was in conformity with similar experience elsewhere.

APPENDIX 1.

The following is a list of experiments on which reports have been suspended pending further developments:—

	Reference No.
(*a*) Pratts Hill (Leicestershire)	6
(*b*) Carlton and Jarrom Streets (City of Leicester)	7
(*c*) Leeds-Wetherby Road at Bardsey (West Riding) ...	12
(*d*) Glamorgan:	
(1) Neath-Abergavenny Road at Rhigos	18
(2) Newport-Carmarthen Road at Caegarw	19
(*e*) Exeter-Newton Abbot Road (Devonshire)	25
(*f*) East Lancashire Road (Lancashire)	32
(*g*) North Circular Road (Middlesex)	44
(*h*) Bursledon Bridge (Southampton)	53
(*i*) Silvertown Diversion (West Ham)	75

APPENDIX 2.

Arrangements have been made for the erection at the site of each experiment (as far as practicable) of a board giving brief particulars of the experiment together with the date and a reference number. The following list indicates the particular experiment to which each reference number refers:—

Reference No.		
1.	Middlesex	Experimental Road, Harmondsworth.
2.	Surrey	Chertsey Arterial Road.
3.	Surrey	Hampton Court-Esher Road.
4.	Surrey	Kingston By-pass.
5.	Surrey	Leatherhead By-pass.
6.	Leicestershire	Pratt's Hill.
7.	City of Leicester	Carlton and Jarrom Streets.
8.	Gloucestershire	Gloucester-Newport Road.
9.	Flintshire	Bangor-Chester Road.
10.	Lanarkshire	Bathgate-Airdrie Road.
11.	West Riding of Yorkshire	Great North Road near Aberford.
12.	West Riding of Yorkshire	Leeds-Wetherby Road at Bardsey.
17.	Gloucestershire	Thornbury By-pass.
18.	Glamorgan	Neath-Abergavenny Road at Rhigos.
19.	Glamorgan	Newport-Carmarthen Road at Caegarw.
20.	West Riding of Yorkshire	Wakefield-Goole Road at Rawcliffe.
21.	Cumberland	Carlisle-Newcastle Road.
22.	Oxfordshire	Oxford-Henley Road.
23.	County of Southampton ...	Basingstoke-Winchester Road.
24.	Berwickshire	Earlston-Lauder Road.
25.	Devonshire	Exeter-Newton Abbot Road.
26.	Cheshire	Shotwick-Frodsham Road.
27.	Wiltshire	London-Exeter Road.

Reference No.		
29.	Ayrshire	Glasgow-Kilmarnock Road near Fenwick.
30.	Lancashire	Maghull Diversion.
32.	Lancashire	Liverpool-East Lancashire Road.
33.	Midlothian	Edinburgh-Peebles Road at Glencorse.
36.	Norfolk	Route B. 1145 at Brisley.
38.	Newport (Mon.)	Dock Street By-pass.
42.	City of Gloucester	Ring Road.
43.	Lancashire	Kirkham By-pass.
44.	Middlesex	North Circular Road.
46.	Worcestershire	Worcester-Tewkesbury Road.
48.	County of Southampton ...	Bullington Cross-Tufton Road.
49.	Oxfordshire	Oxford-Henley Road.
50.	Surrey	Kingston By-pass.
52.	County Borough of Leeds	(1) Swinnow Lane. (2) St. Helen's Lane.
53.	County of Southampton ...	Bursledon Bridge.
54.	Radnorshire	Knighton-Penybont Road and Kington-Llangurig Road.
55.	Breconshire	Neath-Abergavenny Road at Clydach.
56.	Dunbartonshire	Dumbarton-Helensburgh Road.
57.	West Lothian	Edinburgh-Glasgow Road.
58.	Kirkcudbrightshire ...	Dumfries-Stranraer Road.
59.	Inverness-shire	Cannich-Beauly-Milton Road at Cannich.
60.	Wigtownshire	Newton-Stewart-Girvan Road at Knockville.
61.	Roxburghshire	Melrose-Galashiels Road.
63.	Isle of Ely	Wilburton-Stretham Road.
64.	County Borough of Sheffield.	Hathersage Road.
65.	Wigtownshire	Dumfries-Stranraer Road.
66.	Ayrshire	Glasgow-Kilmarnock Road.
67.	West Lothian	Edinburgh-Linlithgow Road.
69.	Aberdeen County Council	North Deeside Road.
70.	Buckinghamshire	London-Oxford Road.
73.	Surrey	Egham-Sunningdale Road and Woking-Chobham Road.
74.	Hampshire	Basingstoke-Winchester Road.
75.	West Ham	Silvertown Diversion.

APPENDIX 3.

Concise Review of Current Experiments.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction completed and Average Daily Traffic (1935).	Interim Conclusions.
	CONCRETE.					
1.	To determine :— (i) The economic value of reinforcement in 6 in. and 8 in. slabs. (ii) The effect of laying 8 in. slabs on sub-grades of dry clinker, wet clinker or clinker covered with waterproof paper. (iii) The effect of using concrete of "dry," "wet" or "medium" consistency. (iv) The relative merits of slabs laid in lengths of 30 ft. and 45 ft. (v) The effect of the treatment of a concrete surface with silicate of soda, after curing. (vi) The effect of laying concrete in consecutive or alternative slabs.	20 ft. carriageway. Mix 4 : 2 : 1. All ballast and sand was dried and allowed to cool. The transverse joints are all vertical butt joints filled with bituminous sheeting; these joints are all at 90° to the kerb. There is one longitudinal joint throughout the experimental work; this joint in the case of concrete 8 in. thick is of the tongue and grooved type, whilst for 6 in. work the joints are rebated.	450 yards	Ministry of Transport Colnbrook By-pass, Harmondsworth.	Dec., 1929 16,258 tons	The results do not indicate any marked advantage of singly reinforced as compared with unreinforced concrete. The advantage of using double reinforcement is clearly shown. Other conclusions have also been drawn which cannot be stated briefly but have been set out in previous reports. The road continues to provide a good running surface and in this respect there has been little change during the last three years.
8.	(i) To compare four different aggregates. (ii) To compare two types of jointless concrete. (iii) To test the value of bitumen emulsion for the curing of concrete. (iv) To test the value of silicate of soda for the surface treatment of concrete.	20 ft. carriageway. Length of slab 15 ft. thickness 9 in. Bottom reinforcement of high tensile steel weighing $5\frac{1}{2}$ lbs. per sq. yd. placed with 2 in. bottom cover.	300 yards	Gloucestershire County Council. Gloucester - Newport Road, A.48.	June, 1932 4,224 tons	Frampton gravel, which has been regarded as suitable only for bottom course concrete, has given a satisfactory running surface. Both types of jointless construction have so far proved satisfactory. The section treated with bitumen emulsion became slippery. The use of silicate of soda has so far been of no advantage
17.	To determine what economy could be effected by :— (i) The use of a local gravel for single course concrete, and (ii) reducing the thickness of the concrete below the 9 in. normally used in the County.	30 ft. carriageway. Length of slab 45 ft. Thickness 6 in. and 7 in. Reinforced top and bottom; $5\frac{1}{2}$ lb. of high tensile steel per sq. yd. in each layer. Additional reinforcement at corners of 6 in. work. 3 : $1\frac{1}{2}$: 1 and 4 : 2 : 1 mix with granite aggregate. 6 : 1 mix of Frampton gravel and cement. Sleepers at transverse joints.	450 yards	Gloucestershire County Council. Thornbury By-pass, A.38.	Aug., 1933 9,600 tons	At present there is little difference between the various sections. Frampton gravel, although less durable than granite, is a suitable aggregate for concrete roads.

42.	To compare three aggregates for the top course of concrete slabs. To ascertain the thickness to which the top course should be laid (in the case of Cornish grit). To compare the "Bridge" method of tamping with the normal method. To compare various types of expansion jointing material.	40 ft. carriageway. In general, length of slab 40 or 42 ft. Thickness 8 in. Two-course work. No reinforcement. Bottom course in each case 6 : 1 mix of Frampton gravel and cement. The top course a $4\frac{1}{2}$: 1 mix with aggregates of limestone, Cornish grit, granite or mixtures of these.	275 yards	City of Gloucester Ring Road, A.40	Sept., 1934 4,445 tons	The Cornish grit has not given such a hard-wearing surface as the other aggregates. There is at present no indication that a greater thickness than 1 in. is necessary for the top course if care is taken to ensure thorough union of the two courses. The bridge method of tamping produced satisfactory concrete but on this short test length had no marked advantage over the normal method. At present it is not possible to differentiate between the various types of expansion jointing material.
20.	To investigate the most suitable dimensions of concrete road slabs and to compare three types of joints.	30 ft. carriageway. Varying length of slab, the maximum length being 60 ft. 10 in. thick. The work is divided into sections having either no longitudinal joint, a central longitudinal joint or two longitudinal joints. The types of joint used were a sleeper joint, a dowelled joint and an interlocking joint.	2,176 yards	West Riding County Council. Wakefield - Goole Road, at Rawcliffe, A.161.	April, 1935 7,356 tons	At present satisfactory results have been obtained with slabs of all the dimensions studied. Little difference has been observed between the behaviour of the different joints.
38.	To determine to what extent the success of unreinforced concrete containing large aggregate and laid in small bays has been due to the large stone used, to the adoption of short bays or to local conditions.	30 ft. carriageway. 9 in. thick, single-course. Limestone aggregate and 4 : 2 : 1 mix. 30 ft. bays with 2 in. aggregate. 12 ft. bays with in. aggregate. 12 ft. bays with $\frac{3}{4}$ in. aggregate.	270 yards	Newport County Borough Council. Dock Street By-pass, A.48.	Sept., 1934 12,444 tons	There is as yet no appreciable difference between the three sections constructed, all of which remain in very good condition.
5 (a)	To compare the relative merits of various dimensions of slabs.	30 ft. carriageway. 30 ft., 45 ft., 60 ft., 75 ft., and 120 ft. slabs. 8 in. thick in cutting, 10 in. thick on embankment. One and two longitudinal joints. Dowel bar joints.	980 yards	Surrey County Council Leatherhead By-pass, A.24. Section No. 1,	Aug., 1932 3,809 tons	The results do not yet indicate the relative merits of various dimensions of slabs. Extensive cracking has occurred. The cracks are roughly of two types, namely, short transverse cracks less than 2 ft. in length commencing at the longitudinal joint, and transverse cracks of considerably greater length. If the transverse joints are staggered, dowel bars should be omitted from the longitudinal joint where the ends of the slabs overlap.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction completed and Average Daily Traffic (1935).	Interim Conclusions.
5 (*b*)	To compare three types of jointless concrete designed to localise shrinkage effects.	30 ft. carriageway. 120 ft. slabs. 6 in., 7 in., and 8 in. thicknesses for each type.	920 yards	Surrey County Council Leatherhead By-pass, A.24. Section 2A,	Feb., 1933 3,809 tons	Extensive cracking has occurred on all three types of construction and they all compare unfavourably with 8 in. unreinforced slabs of normal type.
5 (*c*)	To determine the extent to which the cost of increasing the richness of the concrete might be offset by reducing the thickness of the slab.	30 ft. carriageway. Slabs 30 ft. by 18 ft. with no longitudinal joint. Thickness 6 in., 7 in., and 8 in. Proportions 4 : 2 : 1, 3½ : 1¾ : 1 and 3 : 1½ : 1.	324 yards	Surrey County Council Leatherhead By-pass, A.24 Section 2B.	Sept., 1933 3,809 tons	The weakest concrete, namely 6 in. thick, 4 : 2 : 1 mix, has so far carried the traffic satisfactorily without cracking; it should be noted, however, that the foundation is solid chalk.
26.	To determine the most efficient position for reinforcement; slabs without reinforcement were included for comparison.	30 ft. carriageway. Lengths of slabs 60 ft. 8 in., 9 in., and 10 in. thick. The reinforcement was mild steel with total weight of approximately 14 lb. per sq. yd., placed with 2 in. minimum cover at :— (1) Top and bottom. (2) Top only. (3) Mid-depth. (4) Bottom only.	900 yards	Cheshire County Council. Shotwick - Frodsham Road, A.5117.	Oct., 1933 2,738 tons	It is not yet possible to draw conclusions regarding the merits of the various sections. In two cases cracking has occurred as a result of settlement over a pond and a ditch.
30.	To determine what economy might be effected by using two-course, instead of single-course work, with (*a*) leaner concrete; and (*b*) cheaper aggregate in the bottom than in the top course. Also to determine how far reinforcement may be used to compensate for a reduction of thickness of the concrete.	30 ft. carriageway. 45 ft. slabs. Thickness 8 in., 10 in., or 12 in. Mix 5 : 3 : 1, 4 : 2 : 1 or 3 : 1½ : 1. Reinforcement, where used, consisted of mild steel rods, the weight of each layer being 7½ lb./sq. yd.	2,100 yards	Lancashire County Council. Maghull Diversion, A.59.	Oct., 1934 9,643 tons	The concrete carriageway is in excellent condition on all the sections. Although there are variations in the thickness and quality of the concrete, there is little difference to be observed in the condition of the longitudinal and transverse joints. The longitudinal joints are close and perfect but there is very slight fraying of the transverse joints.
7 (*a*)	To compare granite with gravel aggregate in single-course concrete road construction.	18 ft. carriageway. Length of slab 34 ft. to 45 ft. 6 in. 8 in. thick. Bottom reinforcement of high tensile steel weighing 4½ lb./sq. yd. placed with 2 in. bottom cover.	123 yards	City of Leicester ... Carlton Street (Unclassified).	Aug., 1932	There is no marked difference between the sections, which are both in good condition. If cellular rubber is used as jointing material it should be sealed to prevent entry of water.

7 (b)	To compare single-course gravel concrete with two-course work having gravel aggregate in the lower course and granite aggregate in the upper course.	Width 18 ft. to 26 ft. Length of slab 20 ft., thickness 8 in. Bottom reinforcement weighing $5\frac{1}{2}$ lb./sq. yd. placed with 2 in. bottom cover.	107 yards	City of Leicester ... Jarrom Street (Unclassified).	Sept., 1932	The single-course concrete has so far proved adequate for the traffic conditions. Both sections are in good condition.
2.	To compare six types of transverse joint. Each type was subdivided into two classes, viz. at 90° to centre line of the road and inclined at an angle of 75° or 80°.	40 ft. carriageway. 20 ft. slabs, 9 in. thick. 4 : 2 : 1 mix by volume. A single longitudinal joint. Reinforced top and bottom each with 6·2 lb. of steel per sq. yd. placed with 2 in. cover. Alternate bay construction.	480 yards	Surrey County Council. Chertsey Arterial Road, Old Deer Park, Richmond, A.316.	July, 1930 11,516 tons	The whole section is in good condition and there is at present no marked difference between the various types of joint.
3.	(i) To compare a number of different types of transverse joint. (ii) To compare three lengths designed to localise shrinkage effects.	30 ft. carriageway. 20 ft., 30 ft. and 120 ft. slabs. 9 in. and 10 in. thick. Mix approximately 4 : 2 : 1 by volume. A single longitudinal joint. (i) Reinforced top and bottom, with 6·7 lb. of steel per sq. yd. placed with $1\frac{1}{2}$ in. cover in each layer. (ii) Special construction.	1,617 yards	Surrey County Council. Hampton Court-Esher Road, A.309.	Section No. 1, June, 1931. Section No. 2, Mar., 1932. 8,833 tons.	All the joints are in good condition and have required very little maintenance.
18 & 19.	To determine the behaviour of similar concrete laid on two roads exposed to widely different climatic conditions.	30 ft. carriageway. 45 ft. slabs. 7 in. thick. $3\frac{1}{2}$: $1\frac{3}{4}$: 1 mix. Reinforced top and bottom, with 7 lb. of mild steel per sq. yd. in each layer. Four bays at each site had additional corner reinforcement.	210 yards	Glamorgan County Council. Neath - Abergavenny Road at Rhigos, A.465, and Newport - Carmarthen Road at Caegarw, A.48.	Nov., 1933 3,377 tons 8,100 tons	The work at Rhigos is exposed to more severe climatic conditions than that at Caegarw, but the latter has required more maintenance at the joints. This may be due to the facts that at Caegarw the traffic is nearly double that at Rhigos, part of the section is on embankment, and labourers unaccustomed to concreting were trained on the northern half of this section and subsequently carried out the work at Rhigos.
6.	To study the tendency of slabs to creep downhill.	30 ft. carriageway. 50 ft. slabs. 9 in. thick. Bottom reinforcement with 6 lb. of steel per sq. yd. placed with 2 in. bottom cover.	267 yards	Leicestershire County Council. Leicester-Loughborough Road at Pratt's Hill, A.6.	Mar., 1933 8,987 tons	Slight creep has occurred. The coefficient of expansion of the granite concrete on this road does not exceed ·0000055 per deg. F.; at Harmondsworth, ballast aggregate concrete gave ·0000074 per deg. F.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction completed and Average Daily Traffic (1935).	Interim Conclusions.
	CEMENT-BOUND MACADAM.					
27.	To investigate the merits of the sandwich system of construction.	20 ft. carriageway. 30 ft. bays. 5 in. thick.	220 yards	Wiltshire County Council. London-Exeter Road, A.30.	Aug., 1933 2,910 tons	There was an increase of fine surface crazing during the year, and a number of new cracks. The cracks are more prevalent where the transverse joints are opposite one another. The riding qualities and appearance remain unaltered.
36	To compare the compressed concrete, sandwich and penetration systems.	20 ft. carriageway. 45 ft. bays. 4 in. thick.	209 yards	Norfolk County Council. Brisley, B.1145 ...	Sept. 1934 357 tons	Extensive cracking, spalling and crazing occurred on all three sections. The compressed concrete was the best, followed by the sandwich and cement penetration systems.
59.	To compare the cement penetration and sandwich systems. Three mixes of sand and cement, namely $2\frac{1}{2}:1$, $1\frac{1}{2}:1$ and $1:1$ were used on the penetration section.	16 ft. carriageway. 45 ft. bays. 4 in. thick.	3 sections 220 yards. 1 section 330 yards.	Inverness County Council. Beauly-Cannich-Milton Road, A.831.	Nov., 1934 223 tons	The presence of laitance on all sections emphasizes the importance of removing surplus mortar at time of construction. There was no cracking, but some inequalities at a few of the transverse joints. All sections had satisfactory riding qualities.
60.	To compare the sandwich and cement penetration systems with the County Surveyor's normal bitumen grouted macadam.	18 ft. carriageway. 45 ft. slabs. 4 in. thick.	240 and 210 yards.	Wigtown County Council. Newton Stewart-Girvan Road, A.714.	Oct., 1934 580 tons	All sections are still in good condition. It is not yet possible to draw conclusions.
54.	To compare the sandwich and compressed concrete systems with the County Surveyor's normal tar macadam.	20 ft. carriageway. 30 ft. bays. 4 in. thick.	220 yards	Radnor County Council. Knighton - Penybont Road, A.488, and Kington - Llangurig Road, A.44.	Nov., 1934 App. 1,300 tons.	A.44. *Sandwich system.* There was considerable spalling and cracking, although riding qualities remained good. A. 488. *Compressed concrete.* No increase of spalling; cracks had appeared at the change of cross section. In both cases the adjacent tar macadam sections had been affected by rain and frost and had to be surface dressed.
55.	To compare the sandwich system with the County Surveyor's normal tar macadam.	20 ft. carriageway. 45 ft. bays. 4 in. thick.	255 yards	Breconshire County Council. Brynmawr - Abergavenny Road, A.[illegible]6	Sept., 1935 2,216 tons	Both surfaces were in good condition.

	TAR AND BITUMINOUS SURFACING.					
4.	To compare the life, cost of maintenance and non-skid properties of well-known types of tar and bituminous surfacings.	2 in., 3 in., 4 in. thick. Single and two coat work. Hot and cold asphalts and tar macadam.	11 sections, each 220 yards.	Surrey County Council. Kingston By-pass, A.3.	Sept., 1930 17,245 tons	A full report on this experiment is in course of preparation.
43.	To compare the life, cost of maintenance and non-skid properties of well-known types of tar and bituminous surfacings.	2 in., 2½ in., 3 in. and 3½ in. thick. Hot and cold asphalt, tar and bituminous macadam.	10 sections, each 300 yards.	Lancashire County Council. Kirkham By-pass, A. 583.	Nov., 1934 14,490 tons	Cannot conveniently be summarised; see pages 38–40.
7.	To determine the effect of varying :— (a) The grading of aggregate, (b) The type of binder in tar macadam.	Granites 1-in. down with binder 73 per cent. tar and 27 per cent. bitumen. Granite, ⅝ in. down with binder. (i) 73 per cent. tar. 27 per cent. bitumen. (ii) 90 per cent. tar. 10 per cent. powdered asphalt. Thickness 2 in.	3 sections, average each 425 yards.	Leicester City Council Jarrom Street (Unclassified).	Sept., 1930	Sections with ⅝-in. aggregate were better than that with 1-in. aggregate, and the tar-asphalt binder gave slightly better results than the tar-bitumen binder.
9.	To compare local aggregates for tar macadam.	3-coat tar macadam, total thickness 4 in. Granite, slag, limestone, gravel (abandoned) all with No. 2 tar.	3 sections, average each 750 yards.	Flintshire County Council. Bangor-Chester Road, A.55.	Aug., 1932 5,168 tons	The granite section was generally the best throughout. The limestone section had a new top coat laid after 6 months' wear. All three sections were surface dressed with ¾-in. granite in July, 1934.
10.	To compare three different binders in conjunction with three local aggregates.	Coke-oven tar. Proprietary tar. 75/25 mixture of tar and bitumen. Whinstone (2 types). Steel slag.	8 sections, approximately 220 yards each.	Lanarkshire County Council. Bathgate-Airdrie Road, A.89.	Dec., 1930 1,625 tons	Coke-oven tar with steel slag has given the best results. Proprietary tar with whinstone No. 2 is next best, although with slag it appears the least durable. Of the remaining sections those with tar-bitumen mixtures are the most satisfactory.
11.	To compare five aggregates for bituminous macadam.	Granite, limestone, slag, whinstone and a local sedimentary rock.	5 sections, each 220 yards.	West Riding County Council. A.1 at Aberford ...	Oct., 1932 5,560 tons	The order of merit to date is granite, sedimentary rock, whinstone, limestone, slag.
21.	To investigate the suitability of local gravel for grouted work.	2¼ in.–¾ in. local river gravel with 6 different binders.	6 sections, each 208 yards.	Cumberland County Council. Carlisle - Newcastle Road, A.69.	Feb., 1934 2,011 tons	The aggregate is suitable for grouted macadam.
24.	To investigate the possibility of reducing the cost of construction and maintenance of tar macadam by using crusher-run aggregate and by reducing the thickness.	Thickness. — Average Initial Cost/sq. yd. s. d. 2 in. — 1 5 2½ in. — 1 8 3 in. — 2 3 1¾ in. — 1 6 Four different binders.	16 sections, each 220 yards.	Berwickshire County Council. Earlston - Lauder Road, A.68.	Oct., 1933 1,316 tons	The sections 1¾ in. thick so far appear the most economical.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction completed and Average Daily Traffic (1935).	Interim Conclusions.
25.	To investigate the possibility of reducing the cost of bituminous macadam by decreasing the proportion of binder and thickness of carpet.	Thickness. Cost/sq. yd. s. d. 2 in. 1 11½ 2½ in. 2 1½ 3 in. 2 9	5 sections, each 220 yards.	Devon County Council Exeter-Newton Abbot Road, A.380.	Aug., 1933 4,268 tons	All the sections were surface dressed in 1935, although the 2 in. sections were still in good condition. Their length of life cannot yet be determined.
29.	To investigate the possibility of reducing cost by using crusher-run aggregate instead of graded aggregate for bituminous macadam.	(a) Crusher-run, and (b) Graded material= 60 per cent., 2¼ in. gauge. 40 per cent., 1¼ in. gauge. Each with No. 2 tar, proprietary tar, and 4 proprietary bitumens.	12 sections, each 220 yards.	Ayrshire County Council. Glasgow - Kilmarnock Road, A.77, near Fenwick.	Feb., 1934 7,540 tons	The sections varied in cost per sq. yd. from about 1s. 4d. to 1s. 11d., the average for graded material being 1s. 9d., and for crusher-run material 1s. 8d. All sections have a non-skid surface, tending to be lean rather than rich in binder.
58.	To compare three gradings of local whinstone in 2 in. bituminous macadam.	3 Gradings of aggregate. 2 Proprietary bitumens.	3 sections, each sub-divided into two of 250 yards.	Kirkcudbrightshire County Council. Dumfries - Stranraer Road, A.75.	Nov., 1934 1,820 tons	All sections are in very good condition, although they were laid when the average air temperature was only 45°F.
66.	To compare methods of providing an inherently non-skid surfacing.	Graded bituminous macadam associated in various ways with hot and cold asphalt.	4 sections, each 440 yards.	Ayrshire County Council. Glasgow - Kilmarnock Road, A.77.	May, 1935 7,540 tons	All sections afford a satisfactory non-skid surface. The section with large aggregate rolled into a bed of hot asphalt appears best.
69.	To compare suitability of ten local stones as regards cost and durability.	20 ft. carriageway. 2-in. single-coat bituminous macadam.	10 sections, each 220 yards.	Aberdeen County Council. North Deeside Road, A.93.	July-Sept., 1936 1,691 tons	There is as yet no appreciable difference between the sections, which have a pleasing light coloured surface. On some sections fraying has occurred with evidence of crushing under the roller.
12.	To compare three types of foundation for bituminous macadam surfacing.	9 in. concrete (6 : 1). 9 in. Pitching (cement grouted). 9 in. Hand pitched limestone.	6 sections, each approximately 120 yards.	West Riding County Council. Leeds-Wetherby Road, A.58 at Bardsey.	Nov., 1932 4,972 tons	One section with concrete foundation shows signs of weakness. All the other sections are satisfactory.
44.	To provide test lengths for use in connection with the development of mechanical tests.	3½ in. two-coat asphalts and tar macadam.	4 sections, each 267 yards.	Middlesex County Council. North Circular Road, A.406.	June, 1934 32,147 tons	Under consideration by an *ad hoc* sub-committee.
32.	To provide test lengths for use in connection with the development of mechanical tests.	Rock asphalt. Rolled asphalt. Mastic asphalt. Tar macadam.	4 sections, each 100 yards.	Lancashire County Council. Liverpool - East Lancashire Road, A.580.	Nov., 1933 16,099 tons	Under consideration by an *ad hoc* sub-committee.

	Thin Surfacing Coats.					
46.	To determine the relative durability, resistance to skidding, and cost of thin surfacing coats.	(1) Asphalts mixed at high temperatures. (360°–370°F.) (2) Finely graded asphalt mixed at temperatures at or below 300°F.—maximum size of aggregate ½ in. (3) As for (2) except maximum size of aggregate 1½ in. to ⅝ in. All proprietary materials. Thicknesses ½ in., ¾ in. or 1 in. Aggregates—slag, granite, limestone, quartzite, basalt, or mixture of these aggregates.	13 sections, each 220 yards.	Worcestershire County Council. Worcester - Tewkesbury Road, A.38.	Oct., 1934 7,738 tons	One section (of fine texture) failed after 8–9 months and was replaced. The manufacturers attributed the failure to defective bitumen. Another section required patching during 1935, and is rather uneven.
49.	To determine the relative durability, resistance to skidding, and cost of thin surfacing coats.	Proprietary materials comprising thicknesses varying from ½ in. to 1 in. Aggregates—slag, granite, limestone, quartzite, sand or mixtures of above. Bituminous binders in all cases, except one.	20 sections, each 220 yards.	Oxfordshire County Council. Oxford-Henley Road, A.423.	Nov., 1934 4,522 tons	The sections which have remained most satisfactory in respect of durability, non-slipperiness and general appearance are Nos. 2, 4, 5, 9 and 11.
61.	To compare the relative durability and resistance to skidding of a number of thin surfacing coats laid on new bituminous macadam.	Bituminous thin surfacings. Thickness ½ in., ¾ in., or 1 in. Aggregates—slag, whinstone and sand. Maximum size of aggregate ⅜ in. to ⅝ in.	8 sections, each 220 yards.	Roxburgh County Council. Melrose - Galashiels Road, A.6091.	Sept., 1934 2,100 tons	Although slight deterioration has occurred, all sections are in good condition and afford good resistence to skidding.
65.	To compare a section of thin carpet with the County Surveyor's normal method of surface dressing.	*Thin Carpet.* ⅜ in.–½ in. whinstone mixed with a proprietary bitumen, consolidated to a thickness of ¾ in. *Surface Dressing.* Application of a liquid bitumen followed by ¾ in. whinstone chippings.	2 sections, each 440 yards.	Wigtownshire County Council. Dumfries - Stranraer Road, A.75.	July, 1935 905 tons	On both sections some deterioration has occurred, but it is too early to estimate which section will ultimately prove the more economical.
67.	To compare the merits of thin surfacing coats prepared from the same aggregate, but with different binders.	Whinstone aggregate with different gradings for ¾ in. and 1 in. thicknesses of surfacing. 3 binders:—Coke-oven tar and 2 proprietary materials.	6 sections, each 220 yards.	West Lothian County Council. Edinburgh - Linlithgow Road, A.9.	Sept., 1935 5,280 tons	One of the proprietary binders was not suitable for use with the whinstone. All sections gave good sideway force coefficients. It is too early to compare the sections as regards ultimate cost.
73.	To investigate the effect of varying the factors involved, with design of thin surfacing.	30 ft. carriageway. Leicestershire granite, 5 parts ½ in. down, 1 part ⅛ in. down with 5 per cent. limestone filler. 20 ft. carriageway. ⅛ in.–$\frac{3}{16}$ in. Thames Valley gravel with 5 per cent. limestone filler.	16 sections, each approximately 150 yards. 16 sections, each approximately 150 yards.	Surrey County Council. Egham - Sunningdale Road, A.30. Chobham - Woking Road, B.383.	Oct., 1936 14,130 tons Sept., 1936 3,619 tons	A.30. The sections are in good condition with exception of one or two minor defects. B.383. Many sections have begun to deteriorate, in some cases repairs being necessary.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction Completed and Average Daily Traffic (1935).	Interim Conclusions.
	SURFACE DRESSING.					
10.	To compare 4 types of chippings in conjunction with 3 different binders.	$\frac{3}{4}$ in. steel slag. $\frac{3}{4}$ in. blast-furnace slag. $\frac{3}{4}$ in. whinstone. $\frac{3}{4}$ in. limestone. Each with :— (i) high viscosity tar. (ii) 75/25 tar-bitumen mixture. (iii) No. 1 tar.	12 sections, each 220 yards.	Lanarkshire County Council. Bathgate-Airdrie Road, A.89.	Aug., 1932 1,625 tons	The slags, particularly the blast-furnace type, proved the most durable and had the best appearance. The tar-bitumen mixture held the chippings best without darkening the surface.
22.	To determine whether it is advantageous to use chippings: (a) Hot. (b) Dry but cool. (c) As taken from heaps at the roadside.	$\frac{3}{4}$–$\frac{3}{8}$ in. granite. $\frac{3}{4}$ in.–$\frac{3}{8}$ in. gravel. (a) Dry and hot. (b) Dry and cool. (c) Roadside. Each with :— (i) No. 1 tar. (ii) Tar-bitumen mixture.	12 sections, each 220 yards.	Oxfordshire County Council. Oxford-Henley Road, A.423.	July, 1933 3,610 tons	Generally "treated" chippings were better than the "roadside" chippings (particularly with gravel). Granite gave better results than gravel, and the tar-bitumen mixture was more satisfactory than the No. 1 tar.
74.	1. To compare the effects of :— (a) A high-aromatic tar. (b) A low-aromatic tar. (c) A low-aromatic tar containing calcium soap. 2. To determine the effect of the life of a surface dressing using :— (a) A mixture of two sizes of cubical chippings. (b) Flaky chippings. 3. Prolongation of the life of Hampshire dressing by treatment with tar oil.	20 ft. carriageway. Three lengths of road 2, 1 and $\frac{3}{4}$ miles, giving a total of 19 sections.	Varying from 200 yards to 580 yards with one section 1,147 yards.	County of Southampton. Basingstoke - Winchester Road, A.33.	Nov., 1933 5,264 tons	1. (i) No advantage in using calcium soap. (ii) The dressing carried out in November failed owing to weather conditions. 2. (i) The use of additional small chippings with less than normal rate of spread of tar gave good results. (ii) Flaky chippings have greater covering capacity and need less tar than cubical chippings. They provide a good non-skid surface. 3. Treatment with tar oil renders the gravel equal to dolerite in certain respects.
33.	(1) To determine whether it is advantageous to use chippings: (a) Hot. (b) Dry but cool. (c) As taken from heaps at the roadside.	(1) $\frac{3}{4}$ in.–$\frac{1}{2}$ in. whinstone. (a) Dry and hot. (b) Dry and cool. (c) Roadside. (2) 1st dressing $\frac{3}{4}$ in.–$\frac{1}{2}$ in. gauge. 2nd dressing $\frac{1}{2}$ in.–$\frac{1}{4}$ in. gauge.	3 sections (single coat) each 300 yards. 3 sections (two-coat) each approximately 300 yards.	Midlothian County Council. Edinburgh - Peebles Road at Glencorse, A.703.	July, 1933 1,830 tons	(1) The hot chippings gave a surface slightly too rich in binder. There is little difference between the section laid with dry, cool chippings and that with roadside chippings. All 3 sections still have a non-skid surface.

	(2) To investigate the merits of two-coat work.	(*d*) Tar, 5 sq. yd./gal., with roadside chippings. (*e*) Tar, 6 sq. yd./gal., with roadside chippings. (*f*) Tar, 6 sq. yd./gal., with dry chippings.				(2) The second part of the experiment was adversely affected by weather conditions. 1½ sections appear similar to the single-coat work, the remainder became smooth and were burned off.
48.	To compare various methods of surface dressing with Hampshire gravel.	Gravel ⅝ in.–⅞ in. (except on Section No. 13, where ½ in.-dust was used) (*a*) screened, and (*b*) crushed were used (i) uncoated, (ii) primed with oil, (iii) treated with bitumen emulsion. A 30/50 mixture of crushed and screened gravel was coated with cement. The above were used in conjunction with 4 different binders.	13 sections, each 320 yards.	Southampton County Council. Bullington Cross-Tufton Road, A.34.	July, 1934 3,275 tons	Treatment with oil or emulsion gave improved results, but difficulties during the actual dressing indicate that the process is not likely to become general practice.
64.	To compare the merits of a number of light-coloured chippings for surface dressing.	Granite, shale, basalt, sedimentary rock, gravel (3 types), limestone, and mixtures. Tar binder. One section (basalt) was finished with a cement wash.	12 sections, each 85 yards.	Sheffield County Borough Council. Hathersage Road, A.625.	July, 1935 5,274 tons	All the sections are non-skid. The gravels gave a consistently light-coloured surface. There is no advantage in applying a cement wash, as it wears off rapidly.
70.	To assess the relative merits of various types of chippings from the point of view of night driving.	20 ft. carriageway. With the exception of cement-coated chippings used on two of the sections all chippings were dried and heated on the site. Temperature at application, 100°–180°F. Rate of application of chippings, from 59·9 to 78·8 sq. yd./ton, and of binder, 5 gal./sq. yd.	8 sections, 170 yards.	Buckinghamshire County Council. London-Oxford Road, A.40.	June, 1936 6,629 tons	Quartzite and local gravel gave better results than granite and limestone. Cement-coated chippings were preferred to uncoated chippings.
56.	To investigate the surface treatment of smooth asphalt :— (*a*) On an existing road. (*b*) On a newly made-up road.	¾ in. granite (2 types). ¾ in. gravel, ¾ in. whinstone. (Precoated in all cases.) Road heater employed. (1) Chippings applied direct to road. (2) Fine asphalt interposed between chippings and old surface.	8 sections, each 220 yards.	Dunbartonshire County Council. Dumbarton - Helensburgh Road, A.84. (Two sites.)	Sept., 1934 3,750 tons	All sections were very uneven and disappointing at first. Defects were made good and the road now has a patchy appearance but is non-skid. The methods adopted have been satisfactory in their main object.
57.	To investigate the surface treatment of smooth asphalt.	½ in. whinstone chippings for key coat. ¾ in. chippings for surface coat with tar, bitumen, and 2 bitumen emulsions.	3 sections ...	West Lothian County Council. Glasgow - Edinburgh Road, A.8.	Oct., 1934 1,600 tons	The treatment has provided a good non-skid surface which has remained satisfactory for three years and appears likely to maintain its rugosity even longer. The bitumen emulsion gave a better surface than the tar.

Ref. No.	Object of Experiment.	Main Features of Construction.	Length of Section.	Highway Authority and Site of Experiment.	Date Construction completed.	Interim Conclusions.
	FOOTPATHS IN RURAL AREAS.					
50.	To compare the merits of various methods of footpath construction.	*Section No.* 1. 2 in. two-coat tar macadam. 2. $\frac{3}{4}$ in. bituminous sand carpet. 3. $\frac{3}{4}$ in. cold gravel asphalt. 4. 2 in. cold asphalt. 5. 2 in. tar-sprayed hoggin. 6. 2 in. pre-cast concrete slabs. 7. 3 in. reinforced concrete. 8. 3 in. cement grouted gravel.	8 sections, each 220 yards.	Surrey County Council. Kingston By-pass, A. 3.	Feb., 1935	Sections Nos. 4 and 5 have failed. The concrete sections appear likely to justify their high cost by greater durability than all other sections. The appearance of concrete is more in keeping with rural surroundings than pre-cast slab paving and its initial cost is appreciably less.
52.	To compare the merits of various methods of footpath construction.	*Swinnow Lane.* 1. 2 in. compressed concrete. 2. $\frac{3}{4}$ in. bituminous sand carpet. 3. 2 in. cold asphalt, dressed with bitumen emulsion and $\frac{1}{4}$ in. gravel. 4. 3 in. compressed concrete finished with $\frac{3}{8}$ in. chippings. 5. 2 in. hoggin bound with binder of vegetable origin. 6. $\frac{3}{4}$ in. fine clinker mixed with bitumen emulsion dressed with emulsion and $\frac{1}{4}$ in. quartzite. 7. $\frac{3}{4}$ in. tarred limestone.	14 sections, from 190 feet to 500 feet.	Leeds County Borough Council. (1) Swinnow Lane, and (2) St. Helen's Lane	Feb., 1935	*Swinnow Lane.* The cold asphalt failed and has been replaced. The 2 in. compressed concrete has cracked at approximately 12 yard intervals. On the 3 in. compressed concrete a number of chippings are loose and this section is uncomfortable for pedestrians. The other 4 sections are in good condition. Section No. 2 had the cheapest material which cost $9\frac{3}{4}$d. per sq. yd. for the surfacing.
		St. Helen's Lane. Sections Nos. 1-5 are similar to Sections Nos. 1, 6, 3, 4, and 2 at Swinnow Lane. 6. 2 in. sandstone chippings bound with binder of vegetable origin. 7. Water-bound sandstone chippings.			Mar., 1935	*St. Helens' Lane.* The sections are generally good, but the 3 in. compressed concrete is in very similar condition to the corresponding section at Swinnow Lane. On this road no trouble was experienced in laying the cold asphalt.
63.	To compare the merits of various methods of footpath construction.	1. $1\frac{1}{2}$ in. concrete cast in situ. 2. 1 in. reinforced concrete cast in situ. 3. 2 in. cement-grouted gravel. 4. $1\frac{1}{2}$ in. cement-grouted clinker. 5. 3 in. cement-grouted gravel. 6. 3 in. two-course tar macadam. 7. $1\frac{1}{2}$ in. gravel with $\frac{3}{8}$ in. tarred toppings.	12 sections, each 22 yards.	Isle of Ely County Council. Wilburton-Stretham Road, A.1072.	Oct., 1935	The concrete sections and Sections Nos. 8, 9 and 12 were generally in good condition; parts of the cement-bound sections were uncomfortably rough. Foundation weakness has necessitated patching on Sections Nos. 6 and 7. Sections Nos. 10 and 11 have had to be surface dressed.

		Section No. 8. Gravel with bitumen emulsion surface dressed. 9. Gravel with bitumen emulsion, surface dressed. 10. 2 in. gravel, surface tarred. 11. 2½ in. clinker, grouted with bitumen emulsion and chipped. 12. Earth premixed with bitumen emulsion, surface dressed.				
	OTHER EXPERIMENTAL WORK.					
53.	To investigate certain points affecting the design of a concrete arch bridge:— (i) Settlement of falsework during concreting. (ii) Internal temperature of the concrete during setting and hardening. (iii) Shrinkage along the axis of an arch rib. (iv) Deflection and spread of arch on removal of falsework. (v) Displacement of piers during and after concreting.	Reinforced concrete bridge of 3 arches. Centre span 62 feet. End spans 55 feet.	—	Southampton County Council. Bursledon Bridge, A:27.	Feb., 1935	A full description of the apparatus and methods of measurement will be given in a later report.
75.	To compare the resistance of various types of kerbs to the abrasive action of iron-tyred wheels.	(1) Aberdeen granite. (2) Cornish granite. (3) Guernsey granite. (4) Leicestershire granite. (5) Mysore granite. (6) Norwegian granite. (7) Northumberland whinstone.	2 test lengths, each incorporating each type of kerb. Length of each type of kerb, approximately 20 yards.	County Borough of West Ham. Silvertown Diversion	Oct., 1934	It is too early to make useful comparisons of the various types of kerb used.

APPENDIX 4

WAKEFIELD—GOOLE ROAD

Variations of Sideway Force Coefficients

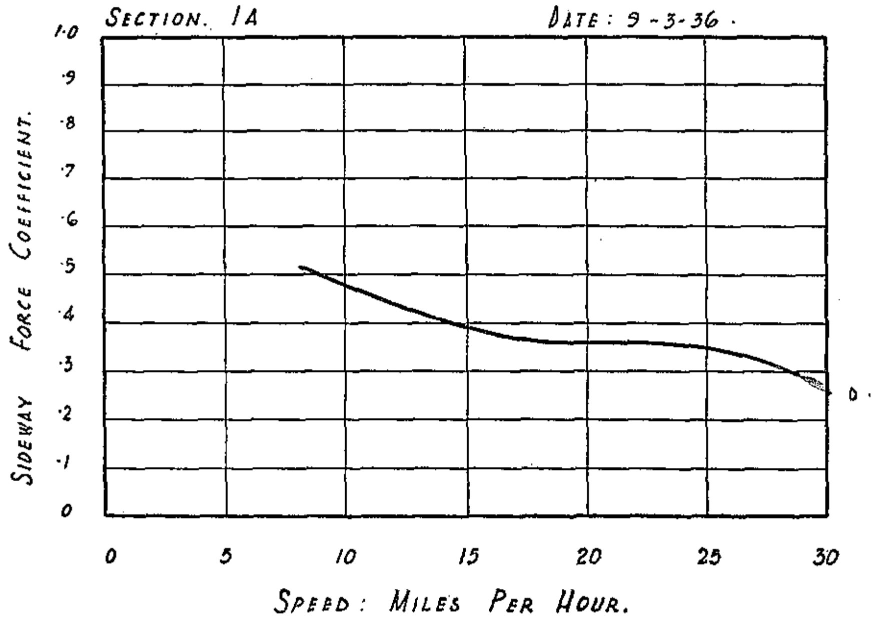


FIG. 1.

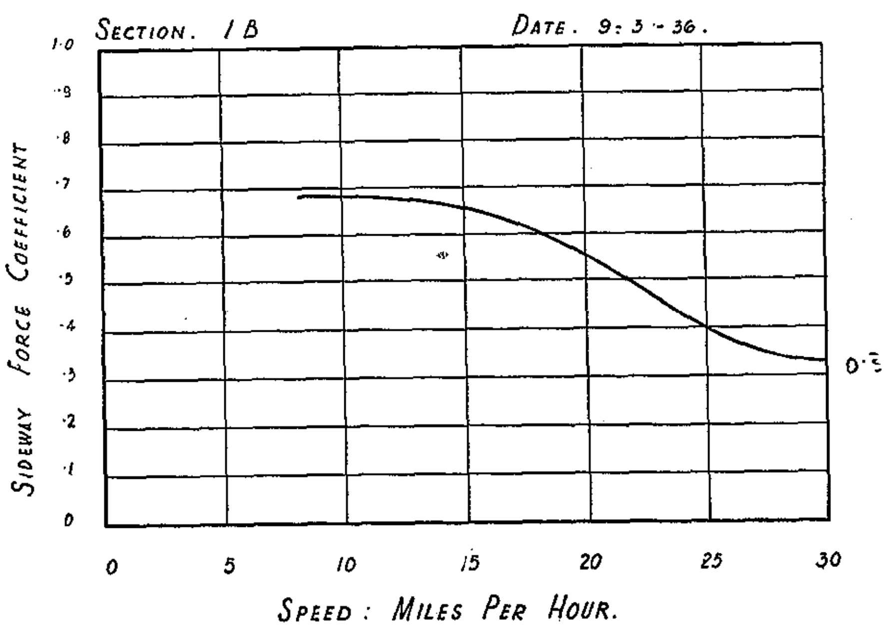
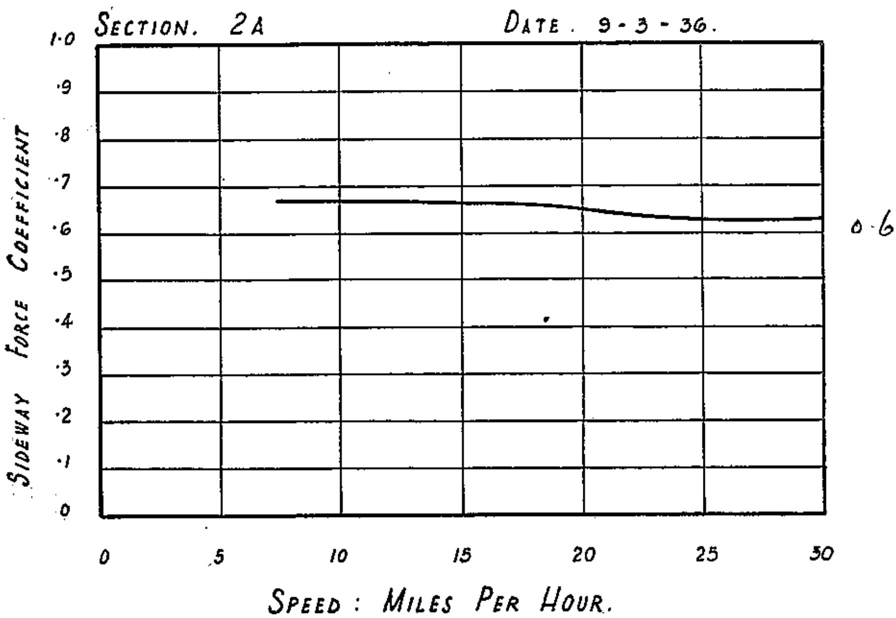
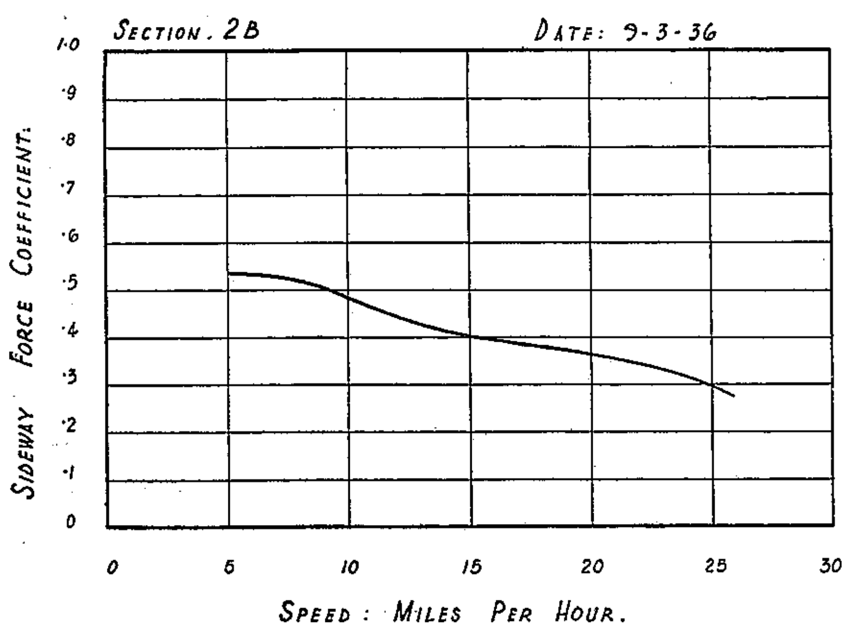


FIG. 2.



Section. 2A
Date. 9-3-36.
Sideway Force Coefficient
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
Speed: Miles Per Hour.
0·6

Fig. 3.



Section. 2B
Date: 9-3-36
Sideway Force Coefficient.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
Speed: Miles Per Hour.

Fig. 4.

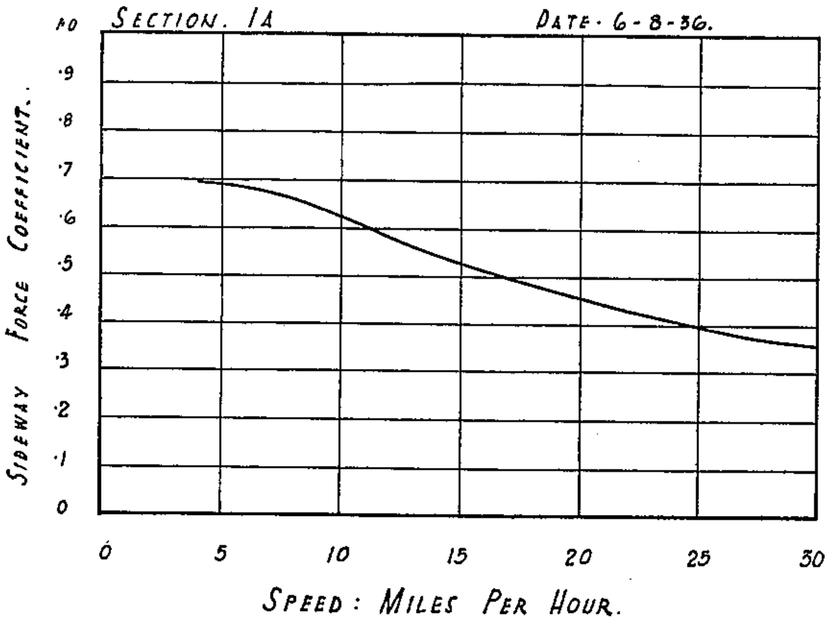

SECTION. 1A
DATE. 6-8-36.
SIDEWAY FORCE COEFFICIENT.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 5.

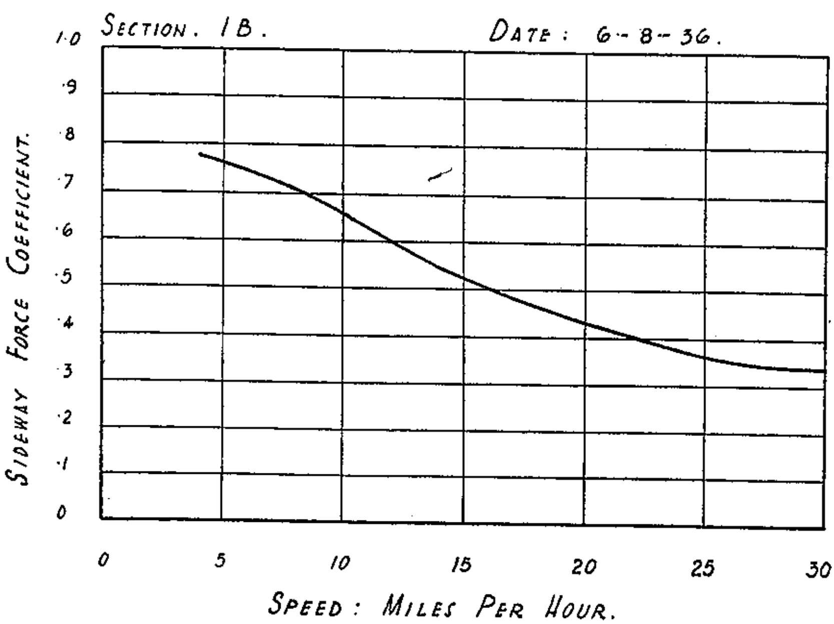

SECTION. 1B.
DATE: 6-8-36.
SIDEWAY FORCE COEFFICIENT.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 6.

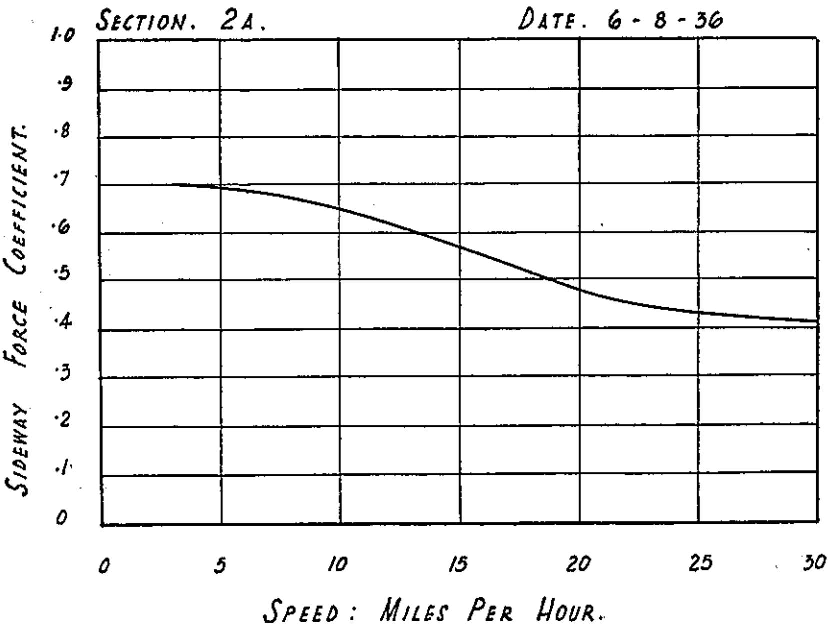

SECTION. 2A.
DATE. 6 - 8 - 36
SIDEWAY FORCE COEFFICIENT.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 7.

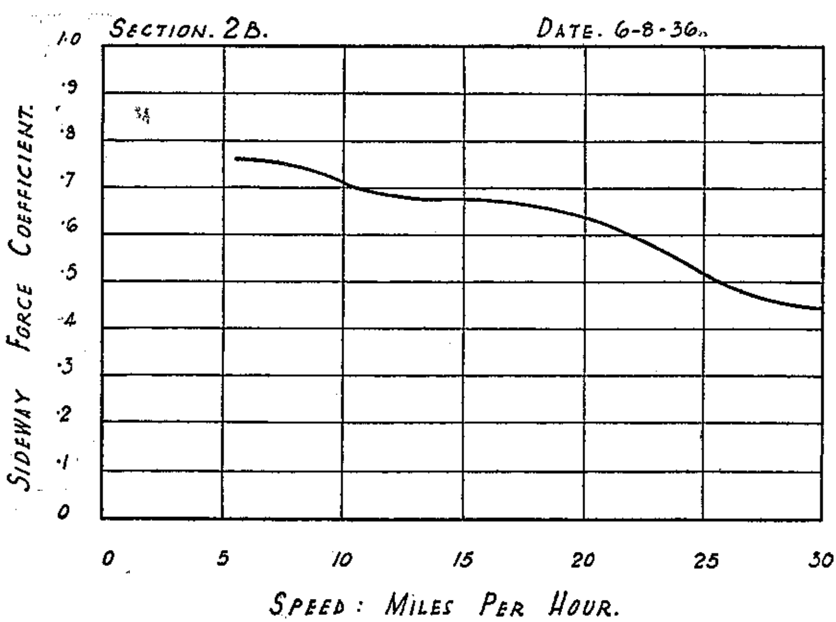
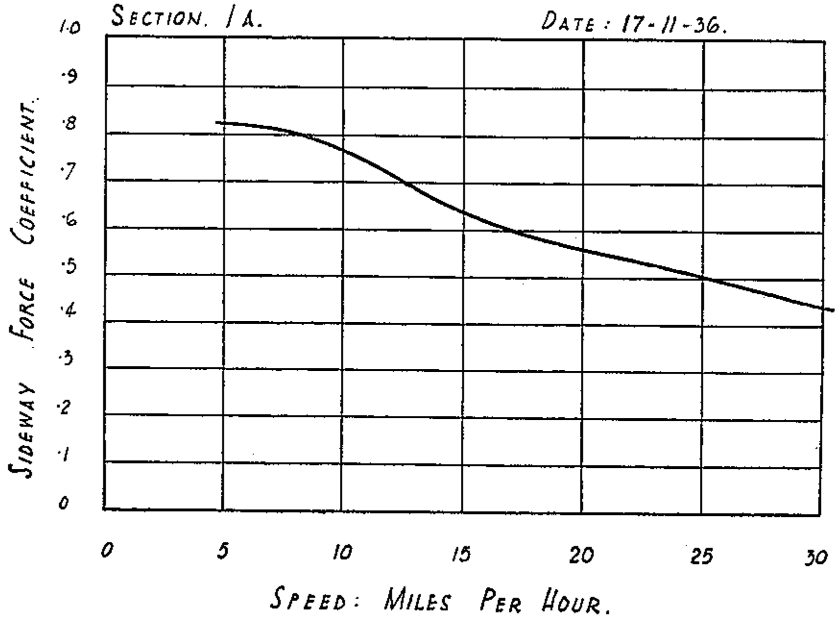
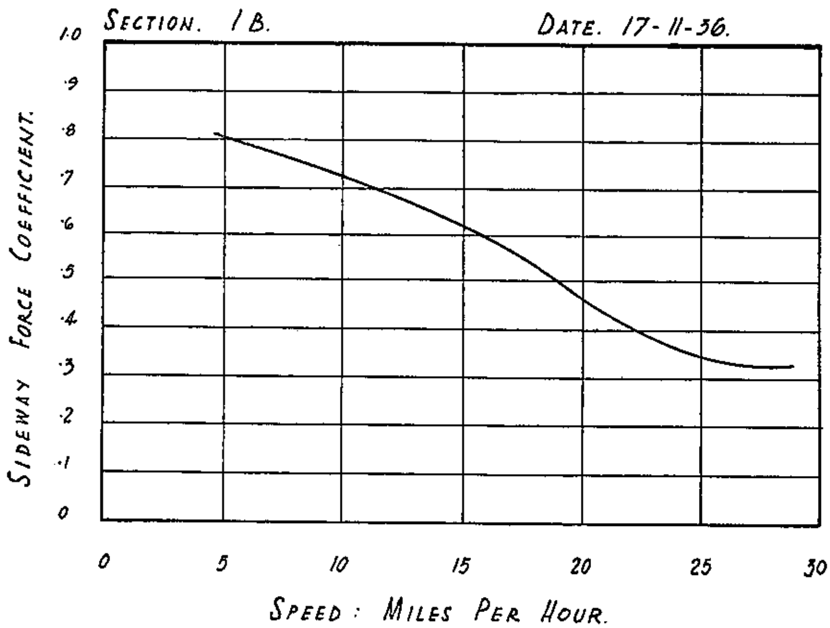

SECTION. 2B.
DATE. 6-8-36.
SIDEWAY FORCE COEFFICIENT.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 8.



SECTION. 1A.
DATE: 17-11-36.
SIDEWAY FORCE COEFFICIENT.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 9.



SECTION. 1B.
DATE. 17-11-36.
SIDEWAY FORCE COEFFICIENT.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 10.

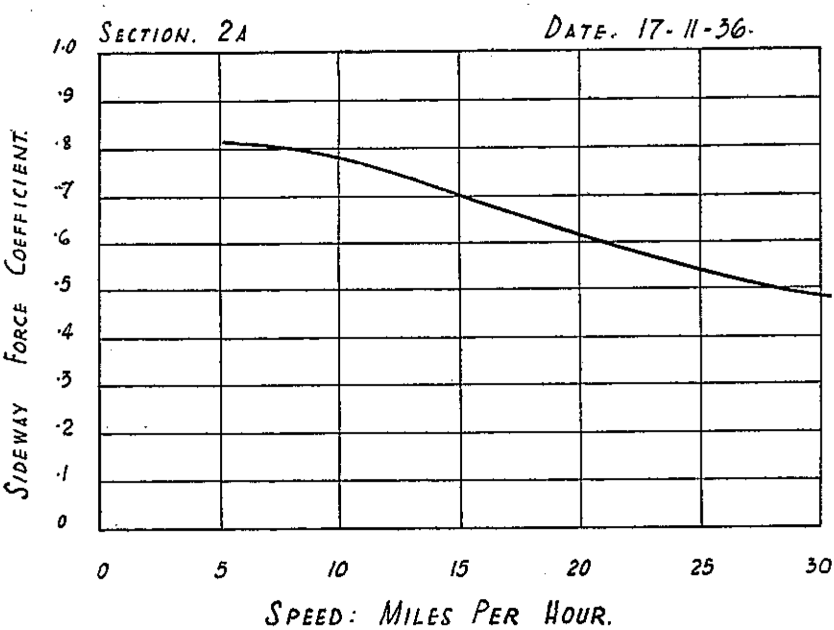

Section. 2A
Date. 17-11-36.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
Sideway Force Coefficient.
0
5
10
15
20
25
30
Speed: Miles Per Hour.

Fig. 11.

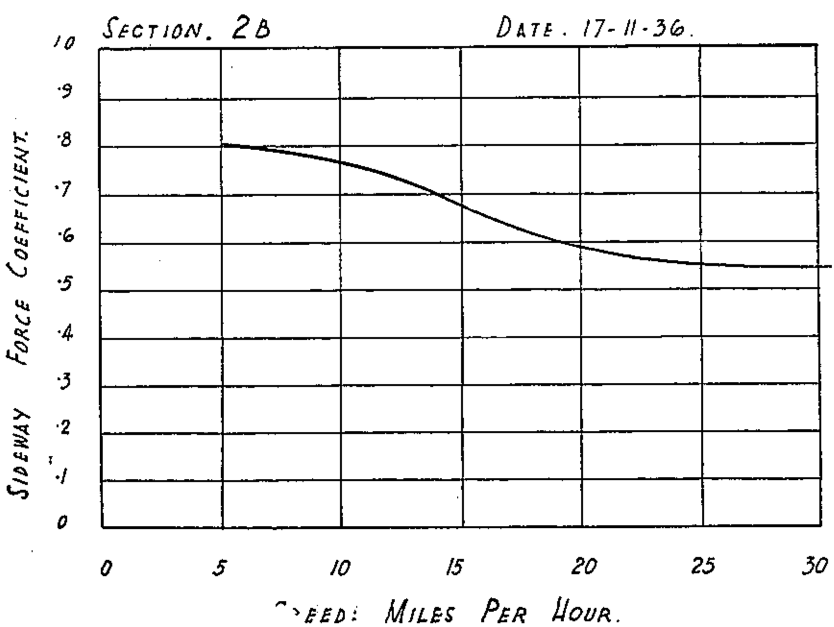

Section. 2B
Date. 17-11-36.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
Sideway Force Coefficient.
0
5
10
15
20
25
30
Miles Per Hour.

Fig. 2.

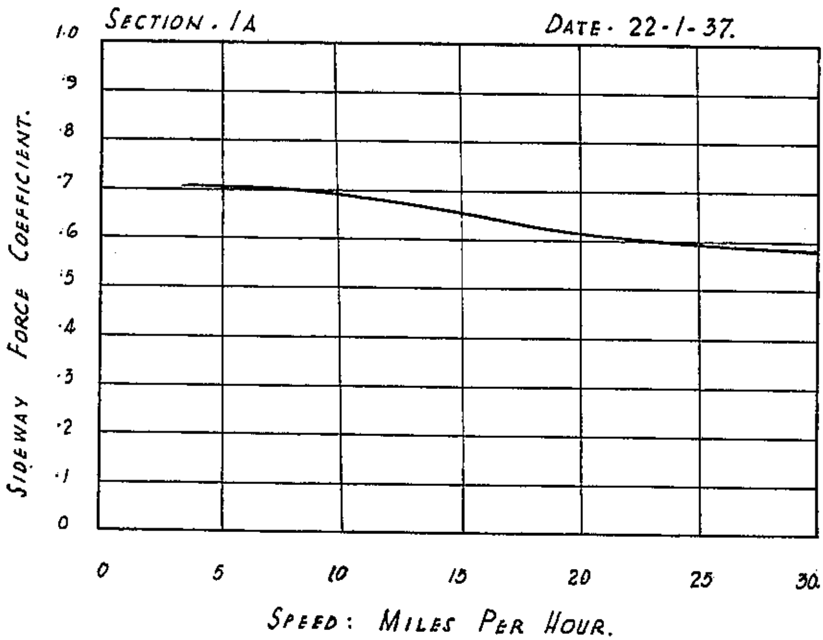

SECTION. 1A
DATE. 22-1-37.
SIDEWAY FORCE COEFFICIENT.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30.
SPEED: MILES PER HOUR.

FIG. 13.

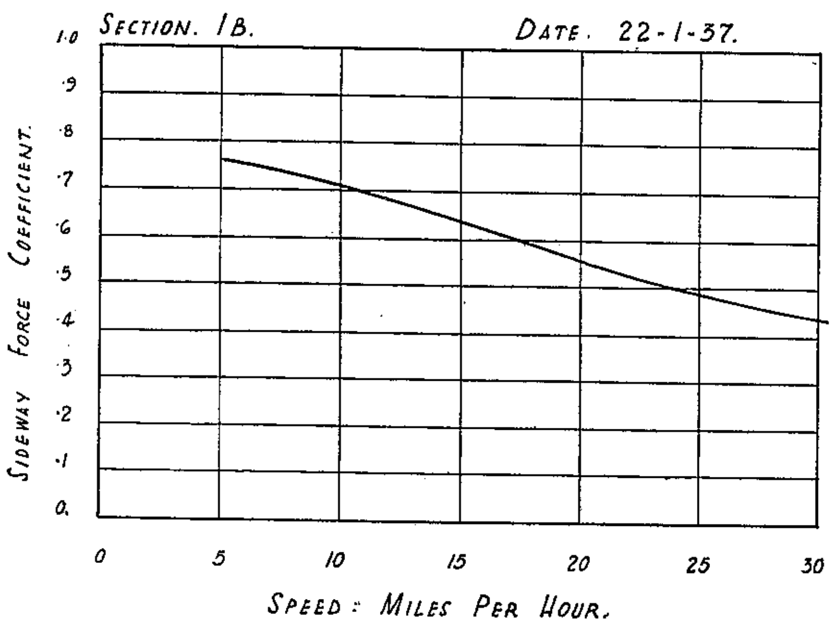

SECTION. 1B.
DATE. 22-1-37.
SIDEWAY FORCE COEFFICIENT.
1.0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0.
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 14.

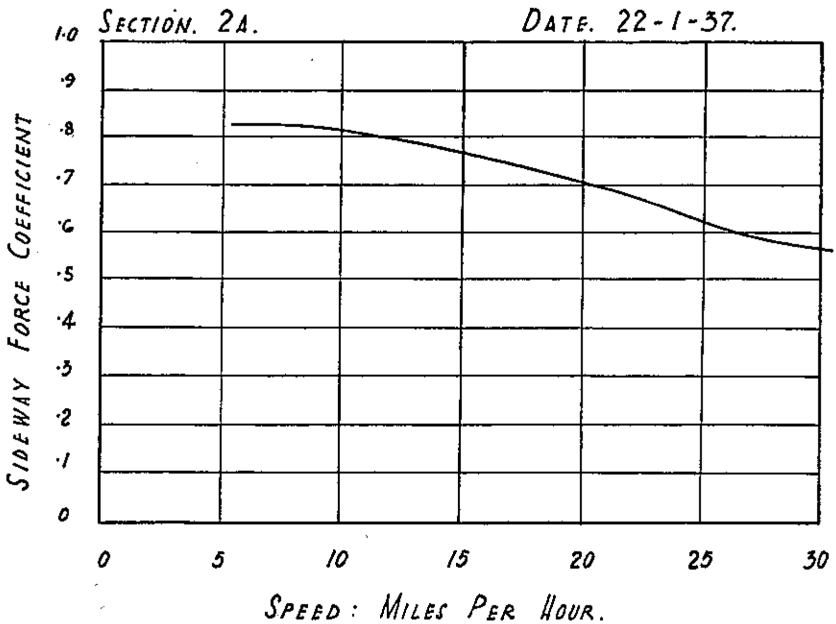

SECTION. 2A.
DATE. 22-1-37.
SIDEWAY FORCE COEFFICIENT
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 15.

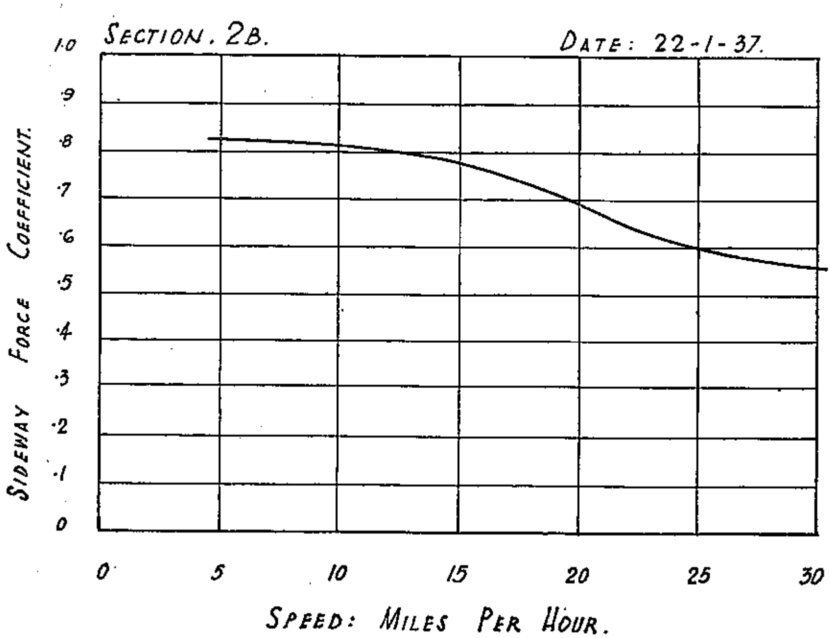

SECTION. 2B.
DATE: 22-1-37.
SIDEWAY FORCE COEFFICIENT.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0
0
5
10
15
20
25
30
SPEED: MILES PER HOUR.

FIG. 16.

OXFORD—HENLEY ROAD

Variations of Sideway Force Coefficients

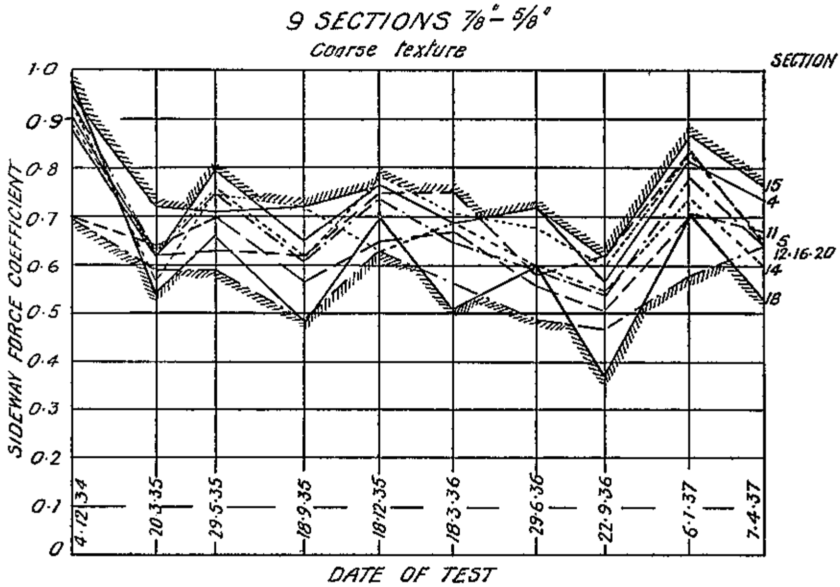


FIG. A

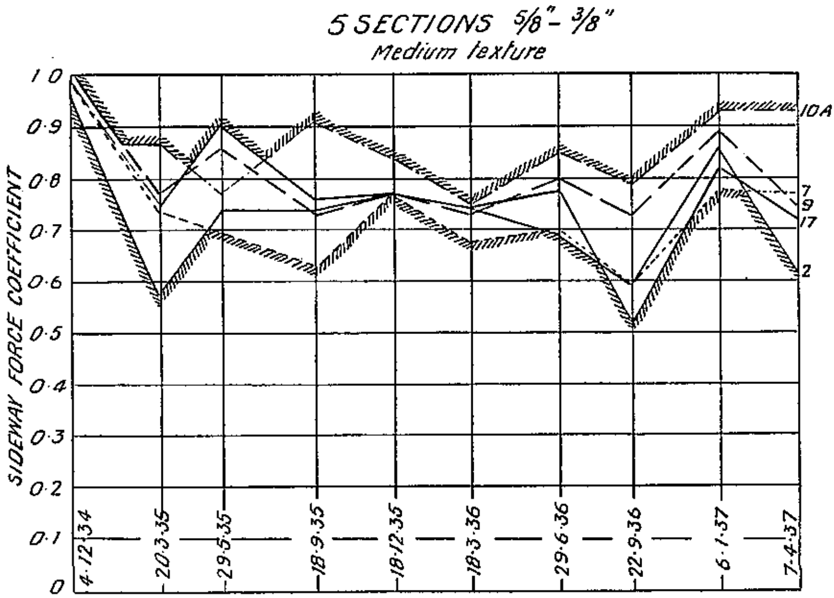


FIG. B.

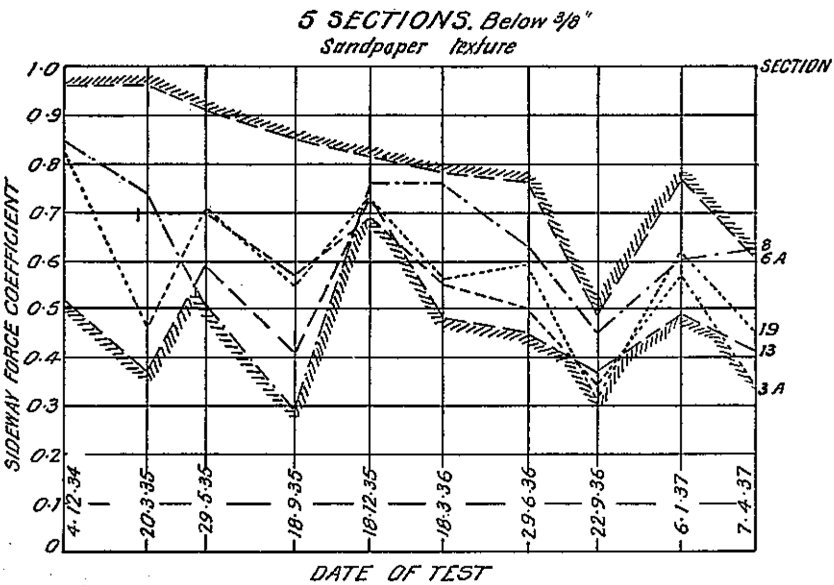

5 SECTIONS. Below 3/8"
Sandpaper texture
SECTION
SIDEWAY FORCE COEFFICIENT
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
4·12·34
20·3·35
29·5·35
18·9·35
18·12·35
18·3·36
29·6·36
22·9·36
6·1·37
7·4·37
8
6 A
19
13
3 A
DATE OF TEST

FIG. C.

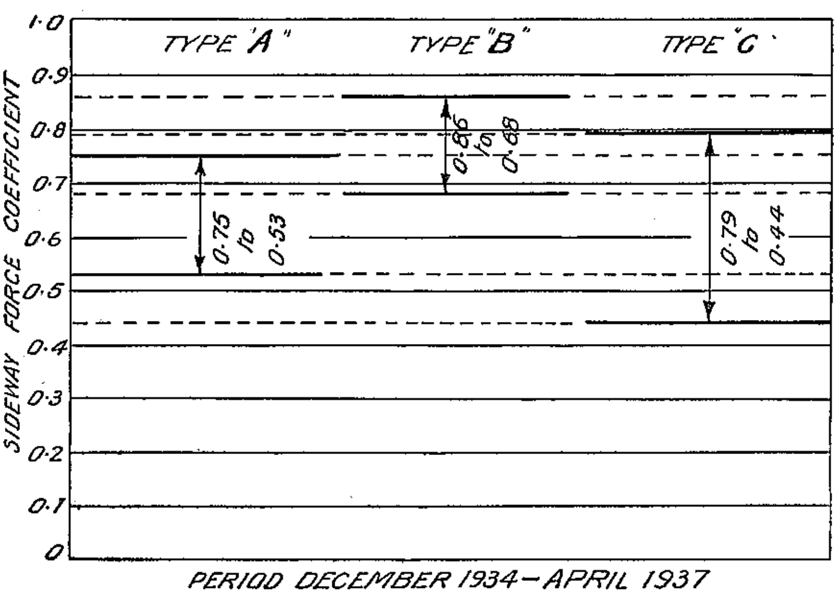

TYPE "A"
TYPE "B"
TYPE "C"
SIDEWAY FORCE COEFFICIENT
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
0·75 to 0·53
0·86 to 0·68
0·79 to 0·44
PERIOD DECEMBER 1934—APRIL 1937

FIG. G.

WORCESTER—TEWKESBURY ROAD

Variations of Sideway Force Coefficients

7 SECTIONS 7/8"-5/8"
Coarse texture

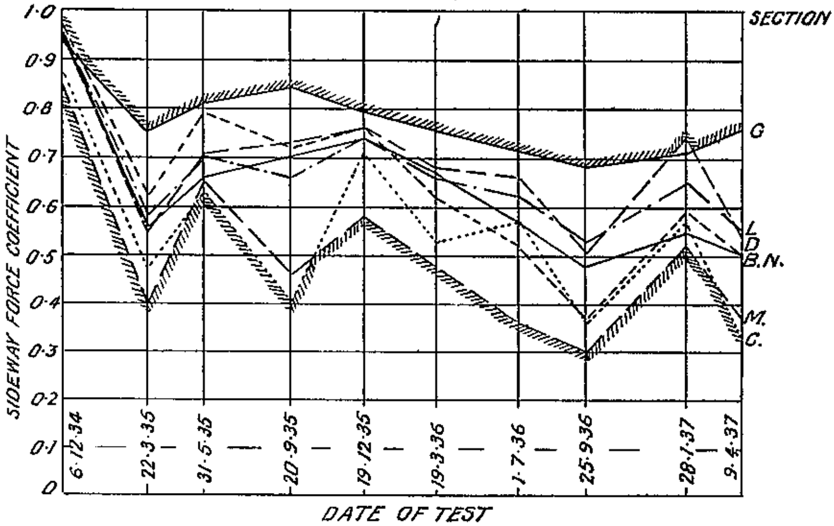


FIG. D.

3 SECTIONS 5/8"-3/8"
Medium texture

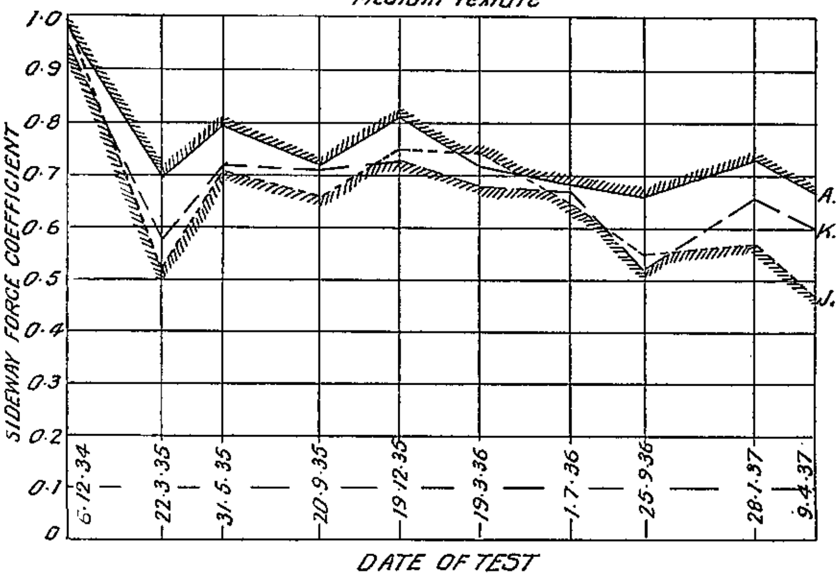


FIG. E.

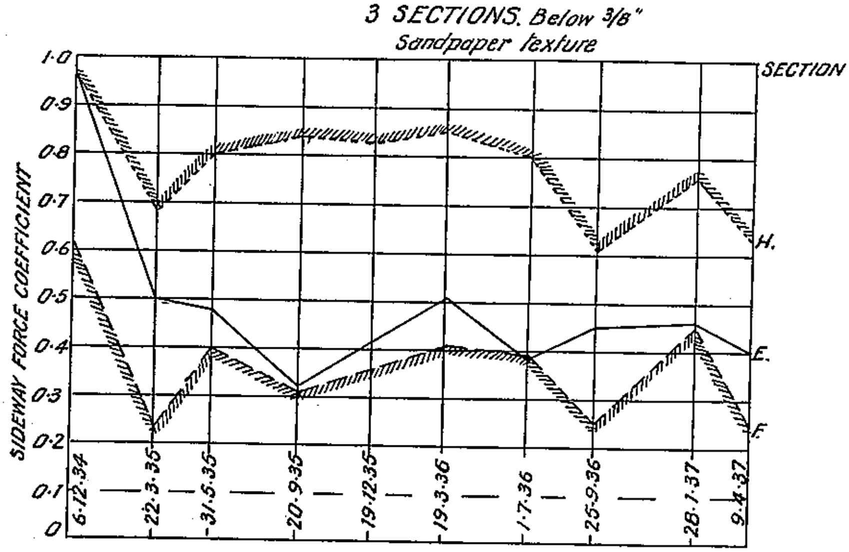
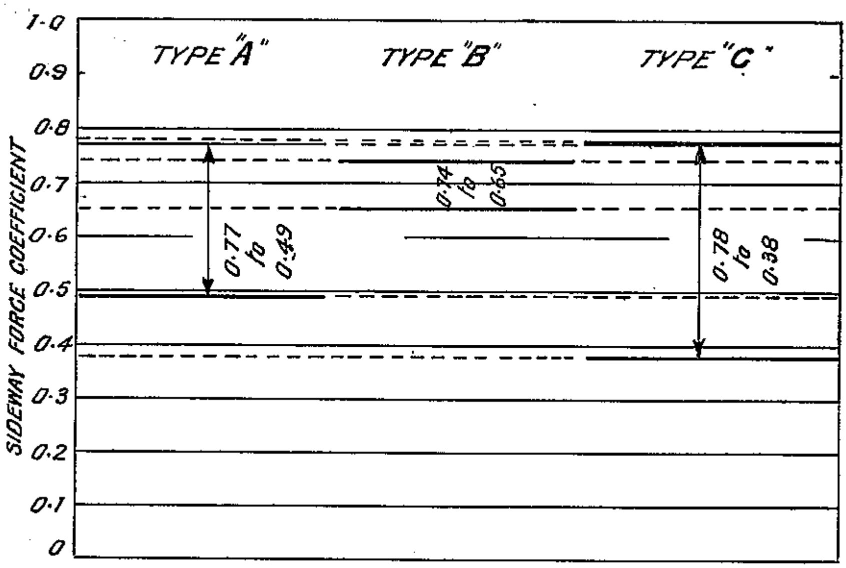


FIG. F



PERIOD DECEMBER 1934—APRIL 1937

FIG. H

(43900—40) Wt. 805—226 1750 & 50 12/37 P. St. G. 373

- *SUBSOIL AND FOUNDATION. (S.F.) (L).
- CONCRETE ROADS. (C.R.)
  - Materials. (M)
    - 1. Cements.
      - (a) Types.
        - (i) Ordinary P.C.
        - (ii) Rapid hardening P.C.
        - (iii) Aluminous cement.
      - (b) Ratio of cement to aggregates. (E)
    - 2. Aggregates.
      - (a) Nature as affecting :—
        - (i) Durability. (E)
        - (ii) Tendency to crack. (E)
        - (iii) Resistance to skidding. (E)
        - (iv) Formation of ice. (E)
      - (b) Grading and proportioning. (L)
  - Design (D)
    - 1. Dimensions of slabs.
      - (a) Length, including continuous construction. (E)
      - (b) Breadth. (P)
      - (c) Thickness.
        - (i) Uniform. (P)
        - (ii) Varying. (E)
    - 2. Reinforcement.
      - (a) Quantity. (E)
      - (b) Distribution. (E)
      - (c) Prestressed. (L)
      - (d) Types. (L)
    - 3. Single v. two course work.
      - (a) Cheaper aggregate and/or leaner mix in bottom course. (P)
      - (b) Large aggregate in top course. (E)
    - 4. Provision for expansion.
      - (a) Joints.
        - (i) Butt. (P)
        - (ii) Sleeper. (P)
        - (iii) Tongued or dowelled. (P)
      - (b) Jointing materials. (P)
  - Subsoil. (S)
    - 1.
      - (a) Testing. (L)
      - (b) Drainage. (L)
      - (c) Treatment to ensure stability. (L)
      - (d) Water-proofing. (L)
  - 1. Methods of control as regards :—
    - (a) Water-cement ratio. (E)
    - (b) Grading of coarse and fine aggregates. (E)
    - (c) Position of reinforcement. (E)
  - 2. Methods of mixing.
    - (a) Large central plants. (E)
    - (b) In transit. (E)
    - (c) Small site plants. (E)
  - 3. Methods of consolidation and finishing.
    - (a) Mechanical tamping. (E)
    - (b) Vibrating. (E)
    - (c) Surface finish as affecting formation of ice. (E)

* Where appropriate to particular forms of construction, subsoils are dealt with under the other headings of this table.

43900

APPENDIX 5.

Experimental Work on Roads.

- Construction (C)
  - 4. Methods of curing.
    - (a) Damp earth. (E)
    - (b) Damp matting. (E)
    - (c) Waterproof paper. (E)
    - (d) Silicate of soda. (E)
    - (e) Bitumen emulsion. (E)
  - 5. Surface colour and markings. (E)
  - 6. Maintenance and Repairs.
    - (a) Reinstatement of trenches. (E)
    - (b) Reconditioning foundation for wood paving and asphalt. (E)
    - (c) Treatment of joints and cracks. (E)
    - (d) Removal of ice and snow. (L)
    - (e) Crack formation and development. (L)
- CEMENT BOUND ROADS. (C.B.)
  - (a) Sandwich. (E)
  - (b) Penetration. (E)
  - (c) Compressed. (E)
- TAR AND BITUMINOUS SURFACES. (T.B.)
  - Materials. (M)
    - 1. Aggregates.
      - (a) Nature, grading and colour for different types of construction. (E)
      - (b) Surface texture for different traffic conditions. (E)
    - 2. Binders.
      - (a) Nature and properties determining the suitability of binders for road work. (L)
      - (b) Suitability of binders for various aggregates. (E)
      - (c) Effect of binder on colour of surface. (E)
      - (d) Nature and amount of filler. (L)
  - Design. (D)
    - (a) Single course v. two course, necessity for binder coats, and appropriate thickness for specified conditions. (E)
    - (b) Necessity or otherwise for chippings, precoated or uncoated, in surface. (E)
  - Subsoil. (S)
    - (a) Testing. (L)
    - (b) Drainage. (L)
    - (c) Treatment to ensure stability. (L)
    - (d) Waterproofing. (L)
  - Construction. (C)
    - (a) Use of road heaters. (E)
    - (b) Mechanical methods of placing, spreading and consolidating. (E)
  - Mechanical Tests (T) (L)
- THIN SURFACING COATS. (T.S.)
  - (a) Comparative suitabilities of different aggregates and binders. (E)
  - (b) Effect of varying the proportion of binder to aggregate. (E)
  - (c) Relative merits of different textures. (E)
  - (d) Effect of size, grading and surface area of aggregate on design. (L)

SURFACE DRESSING. (S.D.)

- (*a*) Properties of binders. (L)
- (*b*) Rate of spread of binder.
- (*c*) Shape of chippings. (L)
- (*d*) Use of South of England gravel. (P)
- (*e*) Colour of chippings. (P)
- (*f*) Size of chippings. (E)
- (*g*) Mixed chippings *v.* uniform chippings. (as to nature and gauge). (E)
- (*h*) Precoated *v.* uncoated chippings. (E)
- (*k*) Special methods, e.g., for surfaces which are rich in binder or particularly hard and smooth. (E)
- (*l*) Treatment of wood blocks. (E)
- (*m*) Treatment of stone setts. (E)

OTHER MATERIALS. (O.M.)

- (*a*) Wood.
- (*b*) Rubber.
- (*c*) Iron.

FOOTPATHS. (F.)

- Comparison of different materials and methods in rural areas. (P)

TRAFFIC MARKINGS. (T.M.)

1. Type.
   - (*a*) Intermittent. (E)
   - (*b*) Continuous. (E)
2. Materials.
   - (*a*) For temporary markings. (E)
   - (*b*) For permanent markings.
     - (i) Studs. (E)
     - (ii) Blocks. (E)

BRIDGES. (B)

- (*a*) Construction and temperature stresses in reinforced concrete arches. (P)
- (*b*) Measurement of strength of bridges. (E)
- (*c*) Strength of bridge deck slabs. (L)

REFERENCE.

L. Laboratory investigation needed before experiments are undertaken on the open road.

P. Initiation of new experiments on the open road postponed pending further information from experiments already in progress.

E. Experiments to be undertaken on the open road; this does not necessarily imply that associated laboratory work is not in progress.

S.O. Code No. 55-180-0-37