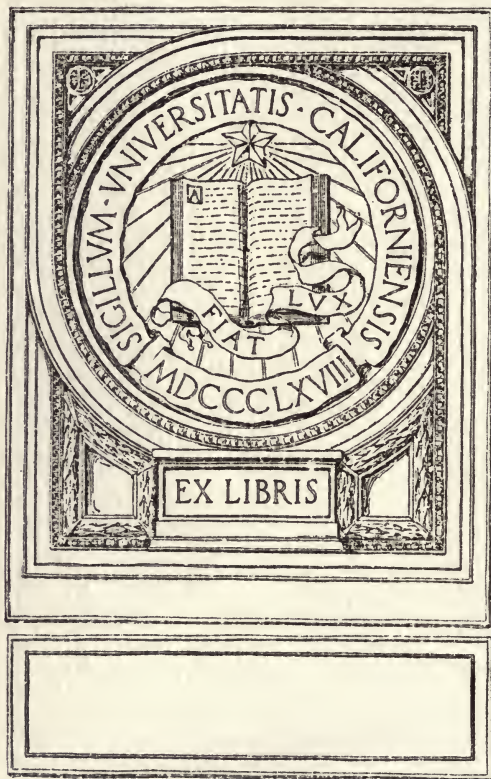


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CONCRETE ROADS

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E 1760

A concrete road between Totnes and Paignton, Devon.

[Frontispiece

CONCRETE ROADS

and Their Construction

BEING A DESCRIPTION OF THE
CONCRETE ROADS IN THE
UNITED KINGDOM, TOGETHER
WITH A SUMMARY OF THE
EXPERIENCE IN THIS FORM
OF CONSTRUCTION GAINED
IN AUSTRALIA, CANADA, NEW
ZEALAND AND THE UNITED
STATES OF AMERICA



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TO JIM
ALBERTA

FOREWORD

ONE of the most pressing problems of the time in connection with public works is that presented by the necessity for improved roads to meet the demands of modern traffic conditions, which have resulted from the enormous development of motor transport during recent years.

The adoption of concrete is a serious attempt to grapple with this problem, which really resolves itself into a search for the ideal road, and so many of our thoroughfares and highways are insistently calling for speedy reconstruction that the present would seem to be an opportune time for approaching the question dispassionately and without prejudice, examining it in the light of recent experience and determining whether the time has not arrived for giving the concrete road a fair trial in this country. True, our acquaintance with modern traffic conditions has been brief, but, brief as it may be, it is sufficient to form a clear indication of our future needs and to serve as a guide for future methods.

Frequent reference has been made in the public Press to the headway made by concrete roads in America, where, owing to the wide adoption of motor transport, the road question has assumed serious proportions for years past. Thousands of miles of concrete road are in use there, and something like 75,000,000 sq. yds. are in contemplation during the present year. It cannot be supposed that a nation so keen at weighing up the possibilities of a business proposition would, after fourteen years' experience, continue to lay these roads on such an extensive scale were they not entirely satisfied as to their efficiency and economy. As might have been expected, there were partial failures, particularly in America, in the early days, but only in this way is progress attained—and the progress has, indeed, been great, both in the United States and in the United Kingdom—and even to-day, greatly as methods have improved, no sane person would venture to say that concrete road practice has reached finality.

The experimental stage is, however, long since past ; we have the advantage of American experience as well as our own to serve as a guide for future practice, and, claiming as we do that the concrete road approaches more nearly to the ideal than any other, we maintain that, as Mr. H. Percy Boulnois, M.Inst.C.E., said in his report to the Roads Improvement Association, it should "be included in the practice of road building, and should be given a better chance in the future, than it has received in the past, to prove or disprove its merits." Should this opportunity not be given, progress here must inevitably be slow. But we believe it will be acknowledged that the records we present of roads laid in the United Kingdom are sufficient to show that this form of construction is quite sound, and that from the point of view of efficiency the concrete road is entirely justified ; while comparative figures have clearly proved that its initial cost is little in excess of, and its ultimate cost is appreciably lower than, that of any other type of road.

In the following pages particulars are given, as far as it has been possible to obtain them, of the various concrete roads that have been laid in this country up to the time of going to press, and the methods adopted in their construction. Every effort has been made to present a complete survey of the work done, and to this is added the latest information obtained from the officials concerned with regard to the condition of each road. It will be seen that these communications are all strongly in favour of the concrete road, and there is thus established a valuable summary of evidence from those best able to form an opinion from the point of view of the road authorities. A chapter has been devoted to roads in other countries, for the account in which of the concrete roads in America we are indebted to the courtesy of Mr. Thomas J. Harris.

For the chapter on mechanical devices as applied to concrete roadmaking we have had the advantage of the services of Dr. A. B. Searle, and our thanks are due to the various engineers and surveyors mentioned who have willingly supplied us with information.

December, 1920.

THE EDITOR.

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CHAPTER I

CONCRETE ROADS IN THE UNITED KINGDOM

A. METROPOLITAN ROADS

Southwark

Mr. Arthur Harrison, M.Inst.C.E., the Borough Engineer of Southwark, has long been convinced of the value of the concrete road, and under his recommendation a stretch of concrete roadway was laid as an experiment in Penton Place in August and September, 1918. The success of this having been assured, the Southwark Borough Council laid down a programme for nine concrete roads, all of which have now been constructed, and so satisfactory have they proved that a more extensive scheme still has been decided upon, to include a total of twenty-five roads and streets by the end of 1920. At the time of going to press twenty-one of these have been completed.

Penton Place. Half of this roadway was laid in concrete as an experiment in August and September, 1918, and the remainder in 1919, being opened to traffic on December 19. Its length is 370 yds., and the area 2,680 super. yds. The traffic is described as being part heavy and part medium.

Amelia Street. *Length*—320 yds.; *area*—1,940 super.yds.; *opened to traffic*—July 14, 1919; *nature of traffic*—part heavy, part medium.

Steedman Street. *Length*—193 yds.; *area*—1,630 super. yds.; *opened to traffic*—August 16, 1919; *nature of traffic*—heavy coal traffic in winter.

Warner Street. *Length*—220 yds.; *area*—2,459 super.yds.; *opened to traffic*—October 1, 1919; *nature of traffic*—heavy.

Standard Street. *Length*—186 yds.; *area*—1,141 super. yds.; *opened to traffic*—October 21, 1919; *nature of traffic*—part heavy, part medium.

CONCRETE ROADS

Brockham Street. *Length—85 yds. ; area—710 super. yds. ; opened to traffic—November 6, 1919 ; nature of traffic—light.*

Content Street. *Length—93 yds. ; area—538 super. yds. ; opened to traffic—January 10, 1920 ; nature of traffic—light.*

Wadding Street. *Length—163 yds. ; area—1,013 super. yds. ; opened to traffic—January 10, 1920 ; nature of traffic—medium.*

Queen's Row. *Length—182 yds. ; area—1,440 super. yds. ; opened to traffic—February 12, 1920 ; nature of traffic—light.*

Westmoreland Road. *Length—217 yds. ; area—1,920 super. yds. ; opened to traffic—March 26, 1920 ; nature of traffic—medium.*

Trafalgar Street. *Length—340 yds. ; area—3,000 super. yds. ; opened to traffic—April 3, 1920 ; nature of traffic—medium.*

Thurlow Street. *Length—533 yds. ; area—3,700 super. yds. ; opened to traffic—June 3, 1920 ; nature of traffic—medium.*

South Street. *Length—177 yds. ; area—1,479 super. yds. ; opened to traffic—June 26, 1920 ; nature of traffic—medium.*

Wooler Street. *Length—80 yds. ; area—573 super. yds. ; opened to traffic—July 10, 1920 ; nature of traffic—light.*

Avenue Road. *Length—80 yds. ; area—614 super. yds. ; opened to traffic—July 24, 1920 ; nature of traffic—fairly heavy.*

Heiron Street. *Length—217 yds. ; area—1,637 super. yds. ; opened to traffic—August 7, 1920 ; nature of traffic—medium.*

Deverill Street. *Length—275 yds. ; area—1,890 super. yds. ; opened to traffic—November, 1920 ; nature of traffic—medium.*

Lawson Street. *Length—35 yds. ; area—280 super. yds. ; opened to traffic—November, 1920 ; nature of traffic—medium.*

Lorimore Street. *Length—350 yds. ; area—3,010 super. yds. ; opened to traffic—November, 1920 ; nature of traffic—medium.*

Ralph Street. *Length—112 yds. ; area—733 super. yds. ; opened to traffic—November, 1920 ; nature of traffic—medium.*

Theobald Street. *Length—200 yds. ; area—1,206 super. yds. ; opened to traffic—November, 1920 ; nature of traffic—medium.*

The other roads to be laid in this borough by the end of 1920 are Alsace Street, Alvey Street, Hill Street, and Mina Road, and 5,000 additional yards are to be laid in Westmoreland Road.

The general method adopted is the same for all, although Mr. Harrison states that each street laid taught them something new, and that, therefore, the whole scheme so far has been one of continual progress, each road being an improvement in various small details upon the one previously laid.

Construction.—The original roadway was of granite macadam,



FIG. 1.—Concrete road in Brockham Street, Southwark. The end of a day's work. Note the planks by means of which the vertical edge is formed.



FIG. 2.—Concrete road in Steedman Street, Southwark. This thoroughfare has been open to traffic since August, 1919. Although the photograph was taken soon after a heavy shower of rain, it will be noticed that, with the exception of a few damp patches, the road is already dry.

and this was excavated to a depth of 9 in. The foundation, which was found to be fairly solid, received no special preparation, and after being rolled was ready to receive the concrete.

The two-course method was adopted, the lower being 4 in. thick and the wearing coat 2 in., the latter being laid before the former had set, so that the whole might form one monolithic structure. The concrete for the lower consisted of a 6 : 1 mixture, and the material from the old macadam road was used as the aggregate. The upper course was composed of a 3 : 1 mixture, the aggregate in this case also being the material from the original road, crushed, washed and graded from $\frac{1}{4}$ in. down.

By the use of the material from the old roadway a very considerable economy is effected by the elimination of costs for the purchase and transport of new aggregate.

With a view to further economy, the Council, in 1919, purchased a washing and grading machine which has already more than paid for itself. (*See Chapter VI.*)

The reinforcement was placed 2 in. from the bottom, i.e., in the middle of the bottom course. It consists of $\frac{3}{8}$ in. rods simply interlaced, like bedstead laths, and wired at the ends, successive lengths being joined to each other by being hooked together.

The method of laying alternate sections was not adopted, but each day's work was finished off by a clear vertical edge as shown in Fig. 1, against which the next day's work was butted without the intervention of a joint filler of any description. The reinforcement does not extend over these joints, so that each section consists of a slab of reinforced concrete in itself.

The contour was formed by the use of pins, which were removed as the work proceeded.

For finishing the surface, a special tool has been devised, which consists of a metal plate 15 in. square, to which is attached a handle fixed obliquely so that the tool can be operated from the side of the road. The surface was rubbed over with this tool, and parts of the road which were found to be too smooth were roughened with a bass broom.

The joints were tarred first, and after an interval of some weeks the whole road was coated with tar and sand. This gives a surface which is not too smooth and which affords a good grip for horses and wheels.

The traffic was kept off the road for about three weeks.

The roads in question are of varying character. Whilst not

themselves main roads, several of them link up one main road with another, and all, therefore, carry a fair traffic, which on some of them may be described as heavy.

The average cost of the roads so far laid in concrete is 12s. 6d. per super. yard, which, having regard to the low maintenance cost, compares very favourably with macadam, the maintenance cost of which is very high in Southwark. The Borough Engineer is of the opinion that macadam is quite unsuitable for town roads and streets, and has the utmost confidence in concrete, which he believes will in all cases ultimately be cheaper than any other form of road construction.

It is noteworthy that the majority of the men employed for this work were recently demobilized men who had never previously done any work of this kind and were trained by the Engineer's staff.

Fig. 2 shows one of the roads open to traffic.

Latest Report.—In November, 1920, Mr. Harrison stated that in two streets weaknesses appeared, but only over very limited areas, and there was nothing which could be termed a failure. The principal weakness was in Warner Street. This is thought to have been due to want of care in curing. In Steedman Street one weak place developed, the cause of which was believed to be want of consolidation along the "joints" at the beginning of the day's work.

All the other streets opened to traffic on the date named were in excellent condition.

Deptford

New King Street.—This road was laid under the supervision of the late Borough Surveyor, Mr. F. Wilkinson, A.M.I.C.E., and certain features render the construction unique.

The length of the street is about 350 yds., and the average width 16 ft. The traffic passing through this thoroughfare, though it is not a main road, is said to be amongst the heaviest in London, since the street leads to the entrance of the Supply Reserve Department, and owing to the narrowness of the road, which does not admit of any spreading out of the traffic, the whole weight and impact is concentrated within narrow limits. This constitutes a very severe test.

The two special features of this road are :—

1. Double reinforcement, one layer being placed near the top, and the other near the bottom.

2. The dipping down of both concrete and the lower reinforcement under the kerb and up on the inside as shown in Fig. 3 ; the kerbs are of granite.

The lower reinforcement takes the stresses due to the weight of the traffic in the usual way ; the object of the upper reinforcement is to take the stresses due to the horizontal motion of the traffic, the theory being that there is a tendency for the particles of concrete in front of a moving wheel to be pushed forward, with a reverse tendency in the case of the particles behind the wheel. Between those two a tensional stress is set up, and it is to take this stress, and so prevent cracks, that the upper reinforcement is intended. It is also considered that the double reinforcement

METROPOLITAN BOROUGH OF DEPTFORD
Re-inforced Concrete Road

Borough Engineer
F. WILKINSON. AMICE. AMIE.

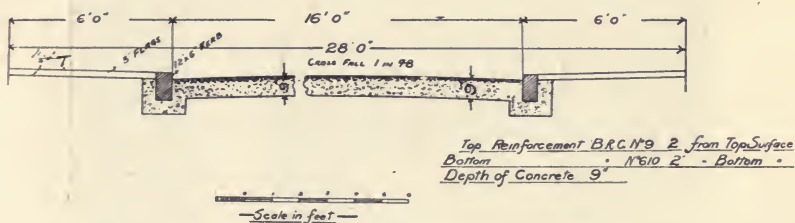


FIG. 3.—Transverse section of the concrete road laid in New King Street, Deptford, showing the kerbs embedded in concrete.

renders expansion joints unnecessary ; these were, therefore, not provided.

Construction.—No special foundation was prepared, as the sub-grade of the original road was found to be sufficiently firm for the purpose.

The road was constructed in two courses, a lower, $6\frac{1}{2}$ in., and an upper, $2\frac{1}{2}$ in. On account of the upper reinforcement it was not possible to lay the surface coat before the concrete of the lower had set ; the former was, therefore, laid 24 hours after the latter, this being the earliest time at which the men could get on to the concrete to place the second or upper reinforcement in position.

The lower reinforcement was first placed in position 2 in. from the bottom. To keep it in place the mesh was stretched over a 2-in. plank, and was supported elsewhere by portions of concrete passed through a mesh. The wet mixture was then deposited to a depth of $6\frac{1}{2}$ in. and left until next day. After an interval of 24 hours the top reinforcement was placed and supported in position $\frac{1}{2}$ in. above the surface of the lower concrete, and the wearing coat put in to a depth of $2\frac{1}{2}$ in.— $\frac{1}{2}$ in. below the reinforce-



FIG. 4.—Concrete road under construction in New King Street, Deptford. The reinforcement for the lower course, stretched over a 2 inch plank to keep it in position, is seen in the foreground.

ment and 2 in. above it. Thus the depth of the concrete for the whole was 9 in.

The surface was finished with a wooden float.

The amount of camber was 1 in 48, to obtain which a screed was used. This, which was very shallow, remained in position until the concrete had set. It was then removed, the trench extended down to the first reinforcement and filled with the same mixture as the wearing coat.

Unwashed Thames ballast graded up to 1 in. was used for the lower course in the proportion of 6 : 1, and Mount Sorrel chippings and sand 3 : 1 for the wearing coat ; the former passing a $\frac{3}{8}$ in. sieve. Fig. 4 shows this road in course of construction.

It was not proposed to surface the road with tar, but to test it, at any rate for some months, as an unsurfaced concrete road. An experiment was, however, being made in material in the following way with a view to ascertaining which treatment produced the best results in point of wearing quality.

The length of the road was, for this experiment, divided into four sections, in each of which a different treatment has been adopted for the wearing coat, thus :—

Section 1. Wearing coat plain 3 : 1 concrete.

Section 2. Same as section 1, but sprinkled with powdered carborundum.

Section 3. Plain 3 : 1 concrete with a different brand of cement.

Section 4. Same as No. 3, but sprinkled with carborundum.

The carborundum was laid to prevent horses from slipping. It was, of course, applied while the concrete was wet, and was not tamped, but allowed to sink in by its own weight.

After the concrete had set sufficiently hard the surface was covered with damp sand to a depth of 2 in. or 3 in., and the traffic was kept off the road for a month.

The cost of this road was 17s. per super. yard, but now that the men have experience in this form of work it is expected that the next concrete road will be laid at a cost of from 10s. to 12s. per yard.

The road has been open to traffic for eighteen months, and with the exception of two or three small surface cracks and a pot-hole at one of the joints, the road is in a good condition.

In a report, dated July, 28, 1920, the Borough Surveyor states that this road was tar-sprayed for the first time on May 10, 1920. "It was treated with a very thin coat of tar and covered with fine sand. The present condition is good."

Latest Report.—The Borough Surveyor, Mr. H. Morley Lawson, in his report in November, 1920, on the present condition of the road, attributes the pot-hole, mentioned above, to careless floating after the surface screed was removed; this conclusion was arrived at from the fact that all the other joints are perfect and show little deterioration. The cost of repairing this pot-hole will be small.

As before stated, the road takes all the heavy traffic going to and from the Supply Reserve Depot, which is ever increasing, and on account of the narrow width of the road the test to which it will be submitted is severe.

CHAPTER II

CONCRETE ROADS IN THE UNITED KINGDOM

B. PROVINCIAL ROADS

Berkshire

Northbrook Street, Newbury.—Northbrook Street is the main business street of Newbury, and, being part of the main road between the Midlands and Southampton, bears a fairly heavy traffic of a general character.

This road, which was laid in the spring of 1920, is 440 yds. long, and the width of the roadway, from kerb to kerb, is 45 ft.; this enabled the reconstruction to be carried out in half widths without undue inconvenience.

Construction.—The particulars of construction are as follows:—

Foundation.—The foundation is that of the original macadam road, and is fairly well consolidated.

Course.—For the concrete road itself the one-course method was adopted, and the thickness of the slab is 8 in.

Aggregate and Proportions.—The materials were mixed by hand in the following way: A measuring box of one-third cu. yd. capacity was employed, and this was filled,

Once with 2-in. Clee Hill granite,

Once with 1-in. to $\frac{1}{2}$ -in. Clee Hill granite, and

Once with sharp sand and flint grit.

This gives 27 cu. ft. of aggregate, to which was added 6 cu. ft. of Portland cement, resulting in a $4\frac{1}{2}$ to 1 mixture.

Reinforcement.—The subsoil here is peat, and it was solely with a view to counteracting its effect upon the road surface that reinforcement was employed. For a like reason the concrete was treated as a slab, and the reinforcement placed $2\frac{1}{2}$ in. from the under side.



FIG. 5.—The concrete road in Northbrook Street, Newbury, before being opened to traffic.



FIG. 6.—The concrete road in Northbrook Street, Newbury, after being opened to traffic.

Joints.—There are no transverse joints, the end of each section being finished with a vertical face, and the concrete of the next section butted up against it.

At the sides the construction presents a feature which appears to be a novelty. Between the longitudinal edge of the road slab which runs underneath the kerb (to which reference will be made later) and the outer edge of the footpath foundation a space of 2 in. was left. This formed a groove or trench 2 in. wide and 8 in. deep, running under the kerb the whole length of the roadway on each side, so that should there be any lateral expansion in the concrete a 2-in. space is provided in which such movement can take place. This is seen in the section, Fig. 7.

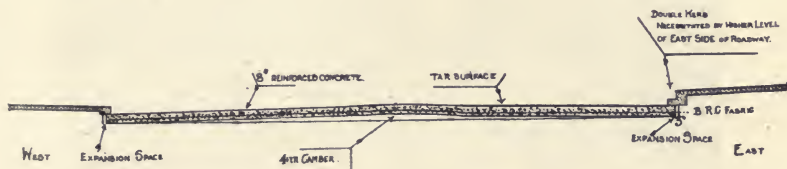


FIG. 7.—Transverse section of the concrete road in Northbrook Street, Newbury. On the right is a double kerb, necessitated by the higher level of that side of the street.

Finish.—The surface was not floated, but tamped with a cambered iron-shod screed, 2 in. by 9 in. The surface obtained is very fine from the point of view of “grip” for horses and motor-vehicles.

Surfacing.—Traffic was kept off each portion for one month, and the road was tarred and gritted the day before being opened to the public.

Camber.—A fall of 1 in 50 is allowed from centre to side, and the flatness of the finished concrete portion, with its consequent freedom from skidding, is very striking when compared with the camber of the original road.

Footpaths.—The footways practically throughout the town are of concrete, laid *in situ* slabs 6 ft. wide with $\frac{1}{2}$ -in. joints formed with wooden strips, which are left in place. Those in the main street have been down for 23 years and are in remarkably good condition. In some cases the aggregate was composed of gravel and in others of granite chips.

Kerbs.—In Northbrook Street the kerbs (of concrete) were laid *in situ* with $\frac{1}{2}$ -in. joints, as in the case of the footways themselves.

As the original footpaths were being retained, an outer form only was required for the kerb. This was placed in position on the road slab and about four or five inches from the edge, so that the outer portion of the kerb rests upon the roadway itself.

Before placing the concrete for the kerb, a strip of tarred paper was laid in the bottom of the trench formed by the edge of the pavement and the outer form. This strip, which may be seen



FIG. 8.—Concrete road in Northbrook Street, Newbury. The kerb is here seen under construction. In the foreground the strip of tarred paper will be observed lying in the bottom of the trench. The form is kept in position by spacers on the inside and blocks of stone on the outside.

in Fig. 8, covered over the 2-in. space which has been mentioned above and which acts as a longitudinal joint to the roadway. The concrete was then placed in position up to the level of the footpath, and finished off with a steel trowel. The appearance of the finished kerb is very neat.

Cost.—The total cost cannot, at the time of going to press, be given exactly, but is expected to work out at approximately £1 2s. 6d. per super. yard. As prices rule to-day this is not high, and in the present instance is regarded as eminently satisfactory.



FIG. 9.—Showing metal reinforcement and the placing of the surface concrete, Roberts Lane, Chester.



FIG. 10.—View of completed road, Roberts Lane, Chester.

Northbrook Street has always been a bad roadway, and for 20 years prior to the war had cost £300 per annum in maintenance. To-day, if retained as a macadam road, it would cost something like £500 per annum.

The concreting of this road will cost somewhere about £5,000, and as the interest on this at, say, 6 per cent., will amount to £300 only, it will be seen at once that the contention of Mr. S. J. Lee Vincent, A.M.I.C.E., the Borough Surveyor, that the laying of a new concrete road is a sound commercial proposition, is borne out by actual figures.

It is anticipated that, when the present road has had time to prove itself, other concrete roads will be laid in the borough.

Latest Report.—In December, 1920, the Borough Surveyor stated that, in order to give a real concrete road a thorough test, all top dressing was omitted with the exception of a thin coat of refined tar and granite chippings. After seven months of heavy traffic, the surface is in a thoroughly satisfactory condition.

Cheshire

Roberts Lane, Saltney, Chester.—One of the first reinforced concrete roads to be constructed in this country was Roberts Lane, Saltney, in the environs of Chester, laid in 1912, under the personal supervision of Mr. Matthews Jones, late City Surveyor. Briefly described, this road, which is 950 ft. long and 20 ft. broad, was excavated to a depth of 8 to 10 in. On top of the clay subsoil 2 in. of cinders were placed to bind it, and on this $2\frac{1}{2}$ to $3\frac{1}{2}$ in. of concrete. Across the road the reinforcement was then laid. Covering this was concrete to a depth of $3\frac{1}{2}$ to $4\frac{1}{2}$ in. The concrete was made of five parts broken granite $\frac{3}{4}$ in. to $\frac{1}{2}$ in. and sharp sand mixed to one of cement. The road was closed for about three weeks, and for part of the time was kept well watered. After being opened for traffic, the road remained for nearly a year without anything being done to it, when it was tar-sprayed and sprinkled with granite chippings, at a cost of $1\frac{1}{2}d.$ per yard. This treatment is carried out once a year, so the cost of maintenance is a very light one.

The traffic on this road in 1913 was computed to be about 60 tons per day—not heavy—but undoubtedly this has increased, and will still further do so as the property in and around this district is developed. The original cost, including the excavation, was 3s. 10d. per yard, and the cost of maintaining the surface has already been mentioned,

Latest Report.—When this road was inspected in the May of 1914, the surface was in perfect condition. In the spring of 1915 the tar-spraying, etc., was done, and when seen again in August, 1919, the surface was still in complete order, and there was not the slightest sign of the dressing lifting in any way. On this point it is well worth remembering that when the tar spraying and chippings were first put down, the concrete was thoroughly dry and hard.



FIG. 11.—View of completed road, Whitefriars, Chester.

Whitefriars, Chester.—This road, which is 510 feet long and 15 feet wide, was laid in August, 1914. It was originally a road made with wooden blocks resting on a concrete foundation. The foundation, having been broken up at different times for various repairs, was not in good condition. Two inches of concrete were put in, after which the metal reinforcement was placed across the road, and upon the reinforcement a further 4 in. of concrete was laid. This was a 6 to 1 mixture composed of four parts Welsh granite, graded from $\frac{1}{8}$ to 1 in., two parts fine sharp sand and one part cement. On completion the road was closed for three weeks, kept well watered, and then opened to traffic. Somewhat later it was tar-sprayed and granite chippings were put on. The cost of this road, including excavation, was 6s. 3d. per yard super.

Latest Report.—Speaking at the Roads and Transport Congress, held in London at the end of 1919, Mr. Matthews Jones, the City Surveyor, stated that his Highways Committee had been so satisfied with the results obtained that permission had been given



FIG. 12.—Road in course of construction, Foregate Street, Chester.



FIG. 13.—A portion of completed road, Foregate Street, Chester.

to lay a further reinforced concrete road right through the main thoroughfare of the City of Chester, namely, Foregate Street and Eastgate Street.

Foregate Street and Eastgate Street, Chester.—This street takes all the through traffic from Manchester, Warrington and Liverpool to North Wales, and, speaking roughly, there is not less than 1,500 tons of traffic passing over the roadway each day. Along the centre of these streets is a double line of tramway track which was concreted in at the same time. So far, only a portion of the road has been completed and opened to traffic, but up to now the results have been all that were anticipated. Very careful observations are being made, and in the event of any defect developing it will be possible, from the statistics obtained, to find the cause and so remedy it in the future. The sanction of the Local Government Board was received to do this work, and the Road Board have shown their interest in the experiment by granting the full estimated amount for carrying it out, viz., £5,000. The reconstruction of this road was estimated for early in 1919, at a cost of 11s. 3d. per super. yard, but up to now the cost has been 12s. 9d. per super. yard; this is owing to the increase in the cost of materials and of labour.

If this scheme proves a success, application will be made for permission to deal with eight miles of roads in Chester in a similar manner. Mr. Matthews Jones stated in his paper that if the eight miles of roads are reconstructed with reinforced concrete, the estimated cost will be 13s. per super. yard, making a total of £82,368. If the work were done with granite sett paving on concrete foundation he could not, in Chester, estimate a lower cost than 25s. per super. yard, or a total of £158,400; or, again, if it were done with tar-macadam, including a foundation, 17s. per super. yard, or a total cost of £107,712.

The method adopted for laying this main street was as follows: The concrete was mixed in the proportion of 5 to 1. The granite used was of the following sizes: $1\frac{1}{2}$ in., 1 in., $\frac{3}{4}$ in., and $\frac{1}{2}$ in. These were mixed in equal proportions. The concrete consisted of $3\frac{1}{2}$ of granite, $1\frac{1}{2}$ of clean sharp sand, to 1 of cement. When the concrete surface had been completed—that is, after it had been trammelled to the contour and allowed to set—the surface was tar-sprayed and covered with $\frac{1}{2}$ -in. granite chippings.

Our two illustrations, Figs. 12 and 13, show the road in course of construction, and a portion of same after completion,

Cornwall

Padstow Station.—This road is on the Fish Quay at Padstow, on the London and South-Western Railway, and was laid towards the end of 1914. Its length is 107 ft. and width 20 ft.

Since it was thrown open it has so well stood the test of practical use that there is no sign of wear. In the formation of this road there was first laid 2 in. of cinders, on this 3 in. of concrete, consisting of five parts of broken granite $\frac{3}{4}$ in. and small and sharp sand mixed, to one of cement. Across the roadway on the top of the concrete reinforcement was placed. Covering this was concrete of the same character as previously described to a depth of 3 in., the surface being roughly smoothed over. For three weeks the road was closed to traffic, and for the first nine days the concrete was kept well watered.

The illustrations, Figs. 14 and 15, show the road in course of construction and when finished.

Latest Report, November, 1920.—Mr. A. W. Szlumper, Chief Engineer of the L. & S.-W. Railway, states that the present condition of the roadway is very good, and the cost of maintenance since the road was opened has been *nil*.

Devonshire

The Marine Drive, Exmouth, is one mile in length and has a total width of 65 ft., viz., carriage-way 39 ft. 6 in., footpaths 5 ft. 6 in. and 20 ft. wide respectively.

The carriage-way is concrete 5 in. thick on a sand underbed between concrete kerbs. Felt expansion joints were placed every 24 ft.

The reinforcement is placed 2 in. from the surface.

The concrete was composed of six parts of beach gravel, fine and coarse proportionately, to one part Portland cement.

A trial portion was laid in May, 1915, and after six weeks was tar-sprayed one coat. Traffic was put on three weeks later and restricted to a width of 8 ft. of the carriage-way in order seriously to test the concrete. Considerably more than 1,000 tons passed over this narrow portion between May and November, and there was not the slightest sign of wear.



FIG. 14.—Padstow Station. Fish Quay road under construction.



FIG. 15.—View of finished road, Fish Quay, Padstow.







FIG. 16.—Marine Drive, Exmouth, showing the trial portion, with concrete kerbs made on the site.

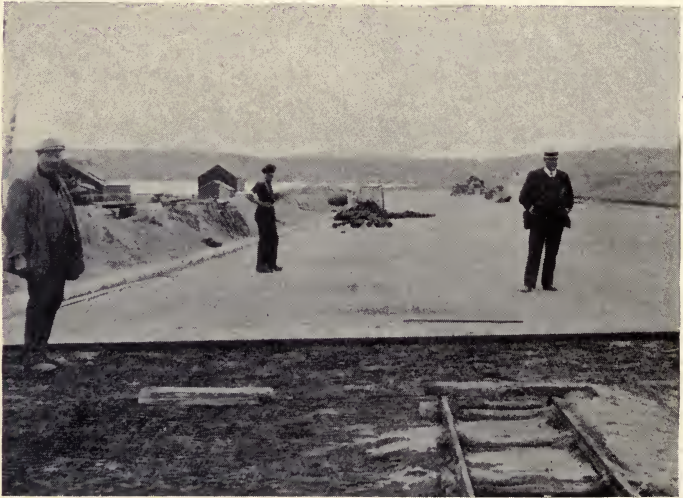


FIG. 17.—Marine Drive, Exmouth, during construction.



FIG. 18.—View of finished road, Marine Drive, Exmouth.



FIG. 19.—A reinforced concrete roadway and footway at Sidmouth.

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The remainder of this road was laid and completed in September, 1916.

The photograph, Fig. 16, shows the trial portion referred to, with concrete kerbs made on the spot.

Half a mile of this Marine Drive is an excellent example of the application of reinforced concrete to engineering ends—the piling of concrete reinforced with plain bars, the slope and parapet also of concrete reinforced with expanded metal and faced with limestone, and, as stated above, the roadway of reinforced concrete.

The engineer for the whole of the road construction and the half mile of reinforced concrete sea defence was Mr. Samuel Hutton, Engineer and Surveyor to the Exmouth Council.

Latest Report.—Mr. Hutton, reporting on the condition of this road in November, 1920, stated that its present condition was very good, and that the cost of maintenance during the whole period since the road was laid has been less than £5, except for tar-spraying, which averages 1*d.* per super. yard per annum.

Although the question of expansion joints in concrete roads is debatable, after three and a quarter years' experience Mr. Hutton is not prepared to advise that they should be dispensed with, since in this particular case the road, which is nearly 40 ft. wide, has a southern aspect and is exposed fully to the sun's rays.

The area so far laid is about 20,000 super. yards, and an extension of another 6,000 yards in the immediate future is in contemplation.

This engineer finds that repairs can be done quite easily, and is of the opinion that concrete roads will be more economical than other types.

Totnes—Paignton.—An experimental section of reinforced concrete road was laid in December, 1919, on the main road between Totnes and Paignton.

The particular stretch was chosen owing to (1) its very damp nature; (2) no proper foundation; (3) narrowness; (4) The fact of there being a convenient road where traffic could be diverted, thus permitting the section to be dealt with being closed.

The road has a length of 100 yds., a width of only 16 ft., with the addition of a 3 ft. wide footpath, and was excavated to a depth of from 6 in. to 2 ft. in order to bring the bed to a gradient of 1 in 42·5.

Before concreting was started all drains were laid, these being placed under the footpath where possible,

The aggregate used was composed of equal proportions of granite broken to sizes $1\frac{1}{2}$ in., 1 in., $\frac{3}{4}$ in. and $\frac{1}{2}$ in. free from dirt and dust ; the sand was washed River Dart sand. Cement was to the British Standard Specification.

Frequent tests for voids were made, as a result of which the proportion of material worked out at about $4\frac{1}{2}$ to 1. The mixture was turned three times dry and three times wet, care being taken that only sufficient water was added to bring the whole to a plastic consistency. The centre of the road for a width of 12 ft. was 6 in. in thickness, the remaining 2 ft. on each side being 10 ins. The reinforcement was placed $2\frac{1}{2}$ in. from the bed.

Very little ramming was done, the material being carefully deposited approximately to required levels and floated with a



FIG. 20.—Road between Totnes and Paignton.

long wooden template run on screeds of wood. No joints were provided for longitudinal expansion.

Over a week's frost was experienced whilst the work was in hand, which necessitated a stoppage, the section completed being covered with a layer of sand over which bags were placed. Care was taken to leave the edge of the work stepped, rough, and doubly reinforced, so as to form a good key when a recommencement was made. No injury was done by the frost, nor is the junction noticeable.

Five weeks after completion the surface was sprayed with refined tar and the road opened to traffic.

A regular motor-bus service, as well as heavy traction engine traffic, passes over the section daily.

Latest Report.—Mr. Andrew Warren, County Surveyor (Southern Division) writing in November, 1920, stated: "The road is as good to-day as when first reopened (January, 1920), and no complaints have been received of its being slippery. The noise when steel-tired vehicles are running over the section is no greater than when macadam was employed."

Essex

Mountnessing.—This road, which was laid in 1915, is one of peculiar interest, inasmuch as the sides of it are composed of reinforced concrete, whilst the centre track, a little over 11 ft., is of water-bound macadam. Mountnessing is on the main road between London and Colchester. The length of the section under notice is about three-quarters of a mile, and the width 22 ft. 4 in.

The subsoil in this locality is clay, but as in early days this road

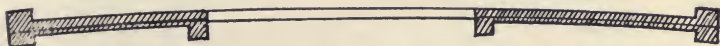


FIG. 21.—Section : Road at Mountnessing, Essex.

from time to time had been dressed with gravel it was on the latter that the work of the new road was started. First of all the road was excavated to a depth of 7 in., except at the side, where the depth was 13 in. to provide for the kerb. A layer of 3 in. of ashes was placed on the loose gravel, then $1\frac{1}{2}$ in. of concrete, on which the metal reinforcement was laid, and on the top of this $3\frac{1}{2}$ in. of concrete. On either side of the road is a concrete kerb reinforced with one steel rod and sunk to a depth of 10 in. This stands 3 in. above the surface of the road, and is 5 in. wide. The kerbing was made and placed as the road progressed. The width of the reinforced concrete on either side of the macadam is 5 ft. 7 in., and supporting the macadam is a concrete abutment running down from the level of the road to a depth of 8 in.

As regards the water-bound macadam, which extended to a depth of 3 in., it is the old material scarified and a thickness of 2 in. of new macadam rolled into it and water-bound.

The whole of the concrete was made up of three parts of crushed ballast, graded so as not to exceed 1 in., one part of washed sand, and one part of cement.



FIG. 22.—Road under construction, Mountnessing, Essex.

It should be observed that the first intention was to use the reinforced concrete as a foundation for other material, but it was afterwards decided that the concrete should be employed for the whole thickness of this portion of the road, and this plan was carried out. Some time after laying, the surface was covered with a thin coating of tarred slag.

Fig. 21 is a diagram of the road, showing in a section from kerb to kerb the position of the concrete, reinforcement, macadam, etc.

This work was planned and arranged with the approval of the Road Board by Mr. Percy J. Sheldon, County Surveyor, and Mr. Alfred Lyddon, late Deputy County Surveyor, Essex.

Latest Report.—Mr. Sheldon, reporting upon the road in November, 1920, states that it is in very good condition, and the cost of maintenance has been practically *nil*. The road carries a very heavy traffic.

Epping New Road—Buckhurst Hill.—This road forms part of a great highway which runs from London, through Woodford, to Newmarket and Cambridge, and the portion which has been laid in concrete is the Epping New Road at Buckhurst Hill. It carries a weight of traffic of some 1,500 tons a day.

The stretch of concrete road originally designed was 500 yds.,

but owing to strikes and other labour difficulties, 235 yds. only have been possible up to the present.

The Epping New Road at this point is 27 ft. wide, and since it is a main road, the traffic could not be diverted; one-half of the width of the road was constructed at a time, the other half remaining open for traffic.

Method.—The two course method was the one adopted at

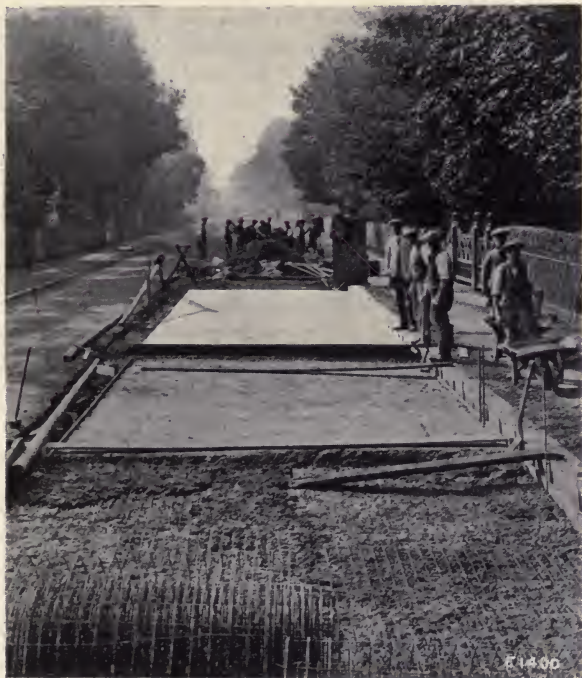


FIG. 23.—The reinforced concrete road under construction at Buckhurst Hill.

Buckhurst Hill, the lower course being $5\frac{1}{2}$ in. in thickness, with a wearing course of 2 in., making a total of $7\frac{1}{2}$ in. At the channel on each side to the width of a foot from the kerb the depth of the concrete is 12 in.

The mixing was done by hand, and the upper course laid immediately after the lower, so that the whole forms one monolithic structure.

For the lower course local ballast was employed in the proportion of 6 : 1, and for the wearing course granite chippings and crushed granite graded from $\frac{1}{2}$ in. down, and mixed in the proportion of 3 : 1.

The original road was macadam, and since the foundation has proved to be thoroughly sound it received no special preparation other than shaping and hand ramming.

The road is reinforced $1\frac{1}{2}$ in. from the bottom.

No transverse joints were provided, the material at the commencement of each day's work being butted against the vertical edge left at the end of the previous section. Next to the kerbs longitudinal joints filled with bituminous material have been provided.

For purposes of surface drainage the road is shaped to a camber of 1 in 50.

The surface was finished by being worked over with a shaped board or straight-edge until the mortar had been brought to the top. When the concrete was thoroughly dry and hard it was tar-sprayed.

After the concreting was completed the road was kept sprinkled with water for several days ; the traffic was kept off for twenty-one days in the warmer weather, and twenty-eight days during the autumn weeks.

The surveyor for the county of Essex, Mr. Percy J. Sheldon, M.Inst.C.E., under whose supervision the work was carried out, reported as follows on the condition of the road.

Latest Report, November, 1920.—The cost of maintenance has been *nil*, and very heavy traffic conditions prevail. The road has been in use about five months.

Mr. Sheldon is convinced that there is no question as to the strength and durability of concrete for roads, and that their success and efficiency are only a question of workmanship.

It is interesting to note that all the bridges that are being renewed in the area administered by the Essex County Council are being constructed in concrete, and there is every reason to anticipate an extensive development of concrete roads within the next few years.

Tilbury Dock Road.—The South Ward of Tilbury immediately adjoining the huge dock of the Port of London Authority lies well below the river level—the surface level being only four

Ordnance datum. The soil being alluvium for a depth of 40 ft. before the ballast is reached, considerable trouble was formerly encountered when erecting buildings or constructing roadways, because of the unequal settlement of foundations.

The success which attended the erection of some cottages by the use of reinforced concrete foundation rafts caused the Council to look to a somewhat similar form of foundation for remedying the difficulties met with in the heavily trafficked portions of their road system; instructions were therefore given their engineer to prepare specifications for a trial length of concrete roadway with suitable reinforcement.

The experimental section was laid down on the main Dock Road during the months of September, October and November, and opened to traffic at Christmas, 1917. It is 130 ft. long, 27 ft. wide, and 7 in. thick.

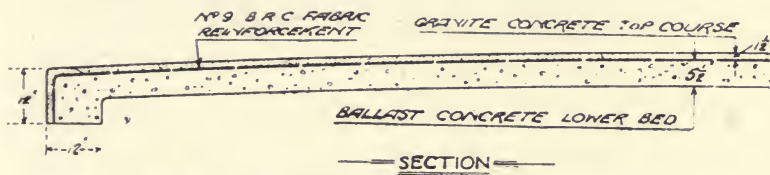


FIG. 24.—Reinforced concrete roadway, Tilbury.

The section is level longitudinally, with a cross-fall of 1 in 50.

It is on the main road leading from London to Tilbury Main Dock, where the Cunard, Atlantic Transport, Orient, Peninsular and other companies' large liners are berthed, and a summary of traffic statistics shows "heavy traffic," there being more than 250 vehicles daily in addition to tractors.

Before the new roadway was laid down, the road paving had consisted of water-bound macadam resting on about 1 ft. of hard core.

The eastern end of the roadway being the turning corner of Arroll's Bridge leading to the Port Authority's property, the heavy lorries in turning caused deep ridges to keep appearing, and much nuisance from dust in dry weather ensued, to the annoyance of inhabitants of adjoining property, with a large accumulation of mud whenever the weather was wet.

The existing surface of the new carriage-way was excavated

to an average depth of 7 in., except the portions adjoining existing kerbs, which were cut out to a depth of 12 in.

At this stage the gas and water companies' men visited the site and satisfied themselves as to the necessity for any repairs to their mains and services before the new work was commenced.

The concrete for the lower bed consisted of three parts of local ballast to the following specification: 1 part of material passing through a 1-in. screen and retained on $\frac{1}{2}$ -in.; 1 part of material passing through a $\frac{3}{4}$ -in. screen and retained on a $\frac{3}{8}$ -in.; 1 part of material passing through a $\frac{1}{4}$ -in. screen and retained on a 22 screen.

To this was added 1 part sand all through $\frac{3}{16}$ in. screen, and 1 part Portland cement, complying with British Standard Specification for slow-setting cement.

The top-course concrete was $1\frac{1}{2}$ in. in thickness, and consisted of one part best granite chippings graded from dust to $\frac{1}{2}$ in. One part sand all through $\frac{3}{16}$ in. screen, and one part Portland cement.

The concrete was mixed by hand to a plastic consistency, and special attention was given to the placing of the top course, which throughout the entire job was carried along simultaneously with the putting in of the lower bed or base.

Transverse expansion joints were made in the concrete every 40 ft., and longitudinal expansion joints in the concrete alongside the kerbs. These were provided for before the concrete was laid by placing $\frac{1}{2}$ -in. by 7-in. wrought boards of convenient lengths and slightly greased with a hard lubricating grease; the boards were withdrawn when the concrete had set sufficiently to allow their being removed without the arrises being destroyed, and the expansion joints were filled flush with the finished surface of the concrete with commercial soft pitch.

As soon as the lower course was finished, and while the material was still plastic, the reinforcement was placed upon it and slightly pressed into it, the sheets of fabric being overlapped 4 in. at the sides. While the reinforcement covered the whole area between the expansion joints, in no case did it extend across them.

As the top-course concrete was laid the surface was immediately struck off by means of a template resting on one kerb, and one longitudinal screed, the template being moved over the surface with a combined longitudinal and transverse motion. Any excess of material accumulating in front of the template was uniformly



FIGS. 25 and 26.—Views showing road in course of construction at Tilbury.



FIG. 27.—Road in course of construction, Tilbury.



FIG. 28.—View of finished road, Tilbury.

distributed over the surface of the new road except when near the expansion joints, when the excess material was removed.

When the concrete had set sufficiently for a man to walk upon its surface without in any way disturbing it, it was fenced in and kept free from all traffic for twenty-one days, and the surface was well watered by means of a watering can for the first ten days and nights.

At each end of the new roadway a double row of 4-in. granite setts on Portland cement concrete, 6 in. in thickness, was laid to effect the junctions with adjoining surfaces.

Although owing to the increase in transport work at the docks the roadway has had to bear a continuously increasing traffic, the road after over a year's wear is as when laid down. The repairs and maintenance have been *nil*, in the summer there is a complete freedom from dust, in the winter an absence of mud, and a very agreeable running surface is provided for vehicular traffic.

The cost of the complete work, including granite, ballast, cement, reinforcement, and granite setts at junctions with adjoining roads, was 10s. 2 $\frac{3}{4}$ d. per sq. yard.

Latest Report.—Mr. S. A. Hill-Willis, reporting on this road in November, 1920, stated that since the road was constructed in 1917 it has been traversed by all types of heavy traffic in and out of the Docks, and he is in every way satisfied with this trial length, so much so that contracts have now been placed by the Tilbury Urban District Council for 6 $\frac{1}{2}$ miles of similar roadway in the place of tar-macadam. A 50-ton Parsons trench excavator recently passed over this road; the rear wheels of the excavator were shod with heavy steel studs, but in spite of the great weight of the machine no injury was caused to the surface.

Hampshire

Southampton Docks.—This road was laid down at Southampton Docks in the summer of 1917. It is 342 ft. long, 25 ft. wide, and 6 in. thick, and has no paths or kerbs. It is level longitudinally, but has a transverse camber of 4 in. (about $\frac{1}{16}$ in. per foot). The greater part is straight, but at one end it has a curve of about 100 yds. radius. It approaches one of the most important quays, where vessels up to 20,000 tons are berthed, and consequently has to sustain a fairly heavy traffic of all kinds. The ground in this neighbourhood was reclaimed from the estuary some years

ago, the filling consisting of broken chalk several feet in thickness and overlying the original river mud. The site of the road had, however, been in use for about twenty years, so that the ground was fairly well consolidated. Before the new concrete was laid down the road paving had consisted of water-bound macadam resting on about 1 ft. of hard core, which again rested on the chalk filling. The latter had settled so much that in places it was necessary to raise the road as much as a foot. This was effected by covering the old macadam with ashes, which were consolidated by watering and rolling with a 10-ton roller, the surface being finished off with a camber ready to receive the concrete. The



FIG. 29.—Reinforced concrete Dock Road, Southampton, for London and South-Western Railway.

new pavement was made with Portland cement, and sea gravel dredged from Langston harbour. As no machine mixer was available it was all turned by hand three times dry and three times wet to ensure good mixing. It was 6 in. thick in all, the lower 4 in. being mixed in the proportion of 1 to 6, and the upper 2 in. in the proportion of 1 to 3. For this upper layer, the gravel was all passed through a $\frac{3}{8}$ -in. square mesh screen so as to avoid the possibility of the road surface being pitted by the splintering

of large pebbles. In the lower layer of the concrete, and 2 in. from its under surface, was placed one thickness of reinforcing fabric.

While carrying out the work it was fortunately possible to divert the traffic on to a temporary road. After rolling the base, the first operation was to lay down the fabric, which was weighted and kept from touching the base by 2-in. pebbles or pieces of brick here and there. On the curved part of the road the fabric was laid parallel to the straight part and sheared off at the sides to suit the curve. Immediately before placing the concrete, which was of a moderately wet consistency, the base was well watered.

A length of 12 ft. to 15 ft. only was started every day, so as to be certain of finishing the whole thickness before evening. This ensured the fine concrete on top being incorporated with the coarser concrete below. Each day's work was finished off against temporary timber templates fastened on pegs at the sides and ends, the surface being formed by working a straight-edge longitudinally backwards and forwards on the end templates. By this means a fairly smooth surface was obtained and no rendering or touching up was necessary. To prevent the possibility of the surface being spoilt by rain at night, it was covered for twenty-four hours with a tarpaulin sheet, which was supported so that it did not touch the green concrete. After a length had been completed, the next was omitted for a while, and the alternate length concreted. No attempt was made to form any sort of expansion joint, the concrete being simply shovelled up against the older concrete face. The work occupied five weeks; it was then left for another five weeks—viz., till October 9, 1917, when the traffic was turned on to it. As soon as weather conditions permitted (which was in November, 1917), the whole of the surface was served with a coat of hot tar, and dusted over with coarse sand.

Latest Report.—In November, 1920, Mr. F. E. Wentworth-Sheilds reported that the road has stood the traffic exceedingly well, and although, of course, a slight crack is visible at the joint of each day's work, there is no sign of deterioration here or elsewhere. What little wear there is is very even, so that there are no pot-holes or malformations of a sort likely to become intensified by further traffic. The surface is not slippery, and the road has given general satisfaction, and is still in excellent condition.

Kent

On the Main London-Dover Road.—In the autumn and winter of 1914-1915 a trial length of concrete road 300 yds. in length was laid near Gravesend. During the time of its construction the weather conditions were most unfavourable, and as it was on a section of the highway from which the traffic could not easily be diverted, it became necessary to make one-half of the length of the road at a time. The original specification provided that the concrete should be of a 6 : 1 proportion throughout, that is to say, one part of cement to six of aggregate, including sand—certainly not a rich concrete. That portion of the road laid in this manner was, after its completion, tar dressed, probably before the concrete was properly set. Heavy traffic was put upon it in its early days, and, in consequence, partial disintegration ensued. On the other side, where a bed of $4\frac{1}{2}$ in. of 6 to 1 had been put in with a metal mesh reinforcement above it, the authorities consented to a richer concrete being used for the surface, and this consisted of $1\frac{1}{2}$ in. of 3 to 1.

This road was opened for traffic on March 15, 1915.

Nearly six years have elapsed since its construction, and the section last-mentioned, which has never been tar-sprayed or coated with any bituminous material, is still as good as when it was first used, except for a few slight abrasions where the transverse joints were put in.

The good condition of this part of the road has on more than one occasion been referred to by Mr. H. T. Chapman, the County Surveyor of Kent.

Latest Report.—At the Institute of Municipal and County Engineers in July, 1919, Mr. H. T. Chapman said that the portion which was topped with 3 to 1 concrete was practically as good as when laid, and there were no signs of disintegration or cracks, except at the expansion joints, and we may further add that he is of opinion that the description given above still holds good in 1920.

Monmouthshire

The Main Road from Newport to Cardiff.—The main Newport to Cardiff road is probably one of the most heavily trafficked roads in South Wales. This road, although specially treated, had never been quite satisfactory, the poor subsoil being to some extent



FIG. 30.—A general view of the road.



FIG. 31.—A closer view of the good portion which has proved so satisfactory.

ROAD NEAR GRAVESEND.

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FIG. 32.—A detailed view of one of the joints in the good portion of the road, in order to demonstrate the undesirability of these.



FIG. 33.—A close view of the surface of one of the bays of good concrete, which shows how level this remains after well over 5 years' wear. The half of the road which was laid 6:1 is in the background, and the contrast between the two halves is very noticeable in the photograph.

ROAD NEAR GRAVESEND.

the reason ; so that it was thought that, all things considered, the position would give an excellent test of the possibilities of a reinforced concrete road.

Owing to the absolute necessity of keeping the road open to traffic, the length was treated in two portions. The width of the road between kerb lines was from 24 ft. to 26 ft., and as the width of the reinforcement was 7 ft., a 14 ft. width for the length of 300 ft. was dealt with first, thus leaving the remaining width open to the traffic.

The following specification was adopted :—

“ The thickness generally to be 6 in., laid in one course, with the reinforcement placed about 2 in. above the bottom of the concrete. The concrete to consist of one and a half of 2-in. local limestone, one and a half of 1-in. stone, one and a half of coarse sand to one part of cement. Transverse joints not to be provided, but a longitudinal joint to be formed along the whole length between the two portions of the road as laid. A strip of thin tarred felting to be placed against the finished portion as the work of laying the remaining portion proceeded ; thus the two lengths would be absolutely independent of each other. Where the concrete butts the kerb a clay joint of about $\frac{3}{4}$ in. to be made on both sides. At the end of the day's work an additional strip of reinforcement 3 ft. wide to be built into the last portion of the day's work about 2 in. below the top of the concrete, leaving 18 in. of the 3-ft. width projecting, in order to help the bond with the next day's work. When completed the road to be allowed to harden for at least three weeks before opening to traffic, the surface being treated with tar and grit at the end of this period.”

After the work of scarifying and removing the old macadam surface had been carried out to the required depth, the foundation, which was not any too good, was well rolled by a 12-ton roller and made up in a few sunken places with hard, dry filling.

Laying of Concrete.—The work of laying the concrete was carried out exactly as specified, but it was found difficult to do this economically owing to the somewhat confined space caused through the necessity of keeping the one part of the road free for traffic.

Before spreading the concrete the foundation was saturated

with water in order that none should be drawn away from the concrete when placed into position, and while being spread the concrete was tamped down by shovel and rammer.

The surface was obtained by means of a shaped floater or template 2 in. thick, 6 in. wide, and of a length sufficient to reach across the portion laid. This was operated by two men, one at each end, who gripped the handles provided for the purpose, and tamped along the fresh surface until the ends of the floater rested upon boards placed at the sides at the required level.

No other treatment was given to the surface, and the results obtained are considered to be very satisfactory.

As regards the mixing of the concrete, great care was taken that the proportions as specified were adhered to with each batch. A gauge-box $\frac{1}{2}$ cu. yd. capacity, with strips placed at half depth, allowed the easy gauging of the $1\frac{1}{2}$ of large stone, $1\frac{1}{2}$ of 1-in. stone, $1\frac{1}{2}$ of sand, and the one part of cement; the whole was mixed by hand, and only sufficient water added to make the mass into just a plastic state.

Each portion of the road when completed was allowed to stand at least three weeks before being opened to traffic, and during that time the surface was covered with fine sand to a depth of 1-in., and continually kept damp with water. Immediately before opening to traffic the surface was brushed clean and allowed to dry thoroughly before being covered with tar brushed in by hand and gritted.

Previous to this, the concrete surface was carefully inspected, and gave the appearance of being in excellent condition.

Weight of Traffic.—As with all new constructions, it is the practical test which counts. This road has now been open for over 12 months, and has during that time, especially owing to the railway strike, carried excessive traffic. Two days after the opening of the first portion laid, a very heavy traction engine with three loaded trailer wagons, the whole weighing at least fifty tons, passed over it; also, six days after, a huge piece of machinery which had to pass through the town during the night, owing to its size, the weight upon one axle being close upon twenty tons, was drawn over the new length of concrete road. Coupled with this, the continuous heavy and fully loaded motor-lorry traffic which used this road during the railway strike, it being the main trunk road into South Wales, has undoubtedly proved that this concrete road is well able to

carry any traffic which is likely to be brought upon it. Up to the present, the surface has the same appearance as when first opened.

Cost.—As regards the cost, this has been rather high.

The cost of labour and also the amount of material used are given, as it may be some guide to those contemplating this mode of construction.

Cost of removing existing macadam roadway and preparing for concrete. Length, 300 ft.; average width, 24 ft., equals 800 sq. yds.; average depth, 6 in. :—

	£	s.	d.
Labour	56	10	9
Horse hire	35	8	5
Roller (scarifying and rolling)	8	15	0
Watching and lighting	13	10	0
Supervision (say)	5	0	0
<hr/>			
Total	£119	4	2

This works out at 3s. per super. yard for preparing only.

There were 206 loads of useful material removed from the road and 300 ft. run of 12-in. by 5-in. stone channelling—for which a credit of £71 10s. is placed to the job.

Cost of reinforced concrete work :—

	£	s.	d.
Horse hire	47	8	0
Labour	154	2	3
Watching, lighting and fuel	34	5	0
2-in. stone (73 tons 10 cwt. 3 qr. at 12s.)	44	2	4
1-in. stone (69 tons 2 cwt. 2 qr. at 12s. 3d.)	41	9	6
Gravel and sand (86 tons 5 cwt. 1 qr. at 12s.)	51	15	2
Cement (42 tons 14 cwt. 1 qr. at 74s. 9d.)	159	11	0
Use of timber for staging, etc.	25	3	6
B.R.C. fabric	108	8	9
Incidentals	1	16	0
Tar	2	2	4
Supervision (say)	5	0	0
<hr/>			
Total	£675	3	10

For the 800 sq. yds. 6 in. thick laid this gives a cost per super. yard of nearly 16s. 11d.

Taking the inclusive cost of the whole work and giving credit for the salvaged materials:—

	£	s.	d.
Cost of preparation	119	4	2
Cost of concrete work	675	3	10
	<hr/>		
	794	8	0
Credit material	71	10	0
	<hr/>		
Net total	£722	18	0

or per super. yard, nearly 18s. 1d.

This is a high figure, but irrespective of what has been said above, there is no doubt that with better working facilities and more extensive work the cost would be considerably reduced.



FIG. 34.—The main road, Newport to Cardiff.

Latest Report.—This road was laid under the supervision of Mr. Ivor F. Shellard, A.M.Inst.C.E., and Mr. H. Tremelling, M.Inst.C.E. The present Borough Engineer reported in November, 1920, that “the road is still standing in good condition, the only cause for anxiety being the longitudinal joint in the centre of the road, which is being worn down rather badly.”



FIGS. 35 and 36.—Brecon and Abergavenny Road, in course of construction and partially completed.

Brecon and Abergavenny Main Road.—Work was commenced on this road at a point near the Brecon boundary in September, 1919, under the supervision of Mr. S. A. Bennett, A.M.I.C.E., the County Surveyor, one-half width being laid at a time. After about 100 yds. had been laid this portion was fenced off for twenty-eight days, after which the traffic was turned on to it while the other half of the road was being constructed.

No longitudinal joint was made in the concrete, but a double layer of the reinforcing fabric about 18 ins. wide was laid at the centre of the road where the two halves met. Expansion joints were provided, but instead of being placed at right angles to the direction of the road, these were laid diagonally at intervals, and were filled with bituminous material.

The concrete, which is 6 in. in thickness, was laid in one course and consisted of crushed furnace slag, graded from 2 in. to $\frac{1}{2}$ in., sharp freshwater sand, and Portland cement, in the proportion of $4\frac{1}{2}$ slag, $1\frac{1}{2}$ sand and 1 cement.

Before being opened to traffic the surface was tarred and spread with a $\frac{1}{2}$ -in. coating of granite chippings.

On account of the water-logged subsoil, diagonal cross drains were laid in the road, with 4-in. pipes, open jointed, the trenches being filled in with 6-in. broken slag. These cross drains are connected to a 6-in. longitudinal drain under the footpath, the drainage water being discharged into watercourses.

The width of the roadway is 20 ft., and the length so far completed is about 800 yards.

The nature of the traffic over the road is both heavy and continuous, and consists of heavy steam tractors with trailers, commercial motor lorries, and a frequent omnibus service, in addition to the ordinary local traffic. Prior to the concrete being laid, the road was constructed with most of the known proprietary materials, but on account of the soft nature of the subsoil it became almost impassable on account of corrugations and depressions.

Latest Report.—The County Surveyor, reporting on the condition of the road in November, 1920, says: "So far the concrete road has been a complete success, having withstood the traffic, and showing no signs of disintegration or of any cracks."

Northumberland

Longhoughton Road.—In May, 1920, the first reinforced concrete road in Northumberland was commenced by the Alnwick Rural District Council under the supervision of their Highway Surveyor, Mr. Nicholas Bean. The road, which begins at the Longhoughton railway station, is about a quarter of a mile in length and 24 ft. in width. With a gradient of 1 in 18 this hill has always been a source of trouble to the authorities, since, being the main outlet of the Northumberland whinstone quarries, it has to bear very heavy traffic, consisting mainly of steam wagons carrying loads of five tons of stone between the quarries and the railway, and has always had a tendency to "creep."

The concrete, which is 9 in. thick, was laid on a bottom of whinstone setts and consists of $2\frac{1}{2}$ parts of Northumberland whinstone chippings graded from $1\frac{1}{2}$ in. to $\frac{1}{2}$ in., and $1\frac{1}{2}$ parts of $\frac{3}{8}$ -in. chippings and coarse whinstone grit, to 1 part of Portland cement. This aggregate is an ideal one for road work, being of a very hard, dense nature.

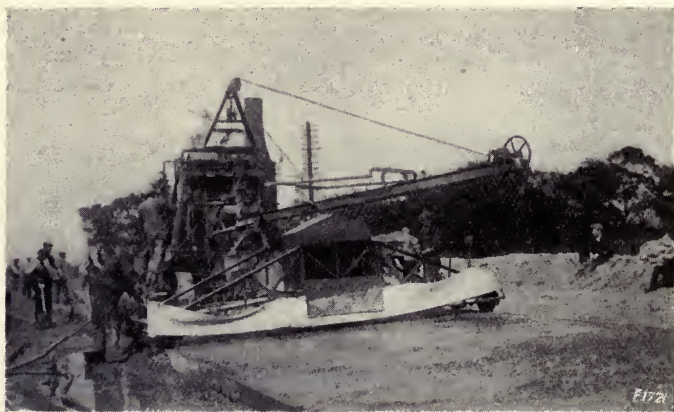


FIG. 37.—Longhoughton Road, Northumberland, showing road-making machine at work.

The Main North Road.—The first section of this road to be laid in reinforced concrete is situated between Wideopen, about five miles north of Newcastle, and Seaton Burn, a length of about one mile. The road is practically level, the only gradient being 1 in 30.



FIG. 38.—Lower Bristol Road, Bath.



FIG. 39.—Bridge Street, Taunton, laid June, 1920. Surveyor, Mr. D. Edwards. Length, 500 yds.; width, 13 ft. 6 in. Traffic very heavy.

The concrete, which was laid on the top of the existing road, was mixed in the proportion of $3\frac{1}{2}$ parts of crushed whinstone $1\frac{1}{2}$ in. to $\frac{1}{2}$ in., and $1\frac{1}{2}$ parts $\frac{3}{8}$ in., mixed with coarse whinstone grit, to 1 part Portland cement.

The thickness of the concrete is 6 in., the reinforcement being placed about 2 in. from the under side.

The cross-fall is about 1 in. to the channel, and the surface is finished with tar paint and chippings.

As it was impossible entirely to close this main road, the concreting was done in half-widths, each section being opened to traffic five weeks after completion. At the time of going to press one-half of the road has been finished and is said to be standing exceedingly well. It is the intention of the County Council, who have acquired some of the most up-to-date road-making plant, to lay about six miles of concrete road, and for this preparations are being made. The work is being carried out under the direction of the County Surveyor, Mr. J. A. Bean, C.E., F.G.S.

Somerset

Lower Bristol Road, Bath.—In the first instance a length of 350 yds. of this road is being constructed in concrete, but upon completion of this section a further length will probably be laid.

The centre of the road is occupied by a tramway track, and on either side of the road, which runs practically east and west, are high buildings which exclude sunshine, with the result that the road is hardly ever free from moisture.

The former road construction was hardwood paving, which had become in a deplorable condition, and, in view of the particularly heavy traffic to which the road is subjected, it was felt by Mr. D. Edwards, A.M.I.C.E., the City Engineer and Surveyor, that the only solution was a concrete surface.

As the traffic could not be diverted and the width of the road in its narrowest part is 29 ft., the work was carried out in half widths.

The foundation is that of the original concrete, and so is well consolidated.

The thickness of the new road is 6 in., and the reinforcement was laid 2 in. above the bottom.

The aggregate consisted of Pennant stone, $1\frac{1}{2}$ in. down to $1\frac{1}{4}$ in.; limestone, $1\frac{1}{2}$ in. down to $1\frac{1}{4}$ in.; fine stone chippings and

sand; and the proportions adopted were 1 part Portland cement, 1 part chippings, 1 part sand, and three parts stone. The amount of water used was from $1\frac{3}{4}$ to 2 gallons for every 6 cubic ft. of the materials taken separately, or, in other words, $1\frac{3}{4}$ to 2 gallons for every cubic foot of dry cement.

A portion of the road was laid with Pennant stone and a portion with limestone, with a view to comparison of results.

A batch mixer is used, and while being spread the concrete is tamped with shovel and rammer and finished off with a floater about 1 in. thick and 7 ft. long.

The finished work was covered with sand, which was watered daily. The road was not opened to traffic until one month after completion.

The surface was not treated in any way and thus this is a concrete road pure and simple.

Scotland

Canmore Street, Dunfermline.—Canmore Street is one of the few "level" streets found in the south side of a city where hills and steep gradients predominate. Connecting, as it does, with the centre of the town at its west end and with New Row at its east end—the latter being the principal route to the lower railway station, and very steep in that portion which lies between Canmore Street and High Street—it has to carry a very heavy traffic. During the summer of 1916 a motor-bus service was inaugurated between the city and the dockyard at Rosyth, with its starting point at the west end of Canmore Street. The roadway, which has an average width of 15 ft. 6 in. between the kerbs, was originally constructed of whinstone setts 7 in. deep, laid without a concrete foundation, and soon gave way under the bus traffic, so much so that within a very few months it became dangerous. The then Burgh Engineer, Mr. P. C. Smith, submitted two schemes to the Town Council: one to lift the setts, lay a concrete foundation, and relay the setts, grouting the same with pitch; and the other to discard the setts and lay the roadway with 6 in. of concrete reinforced with steel wire and surface sprayed with tar and chipped. The latter was adopted.

The old setts having been removed and the surface brought to the proper contour and level, 2 in. of concrete was laid down and on this was spread the reinforcement. Two widths were required to cover the roadway, and an overlap, averaging 8 in.,



FIG. 40.—Road during construction, Canmore Street, Dunfermline.



FIG. 41.—View of finished road, Canmore Street, Dunfermline.

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was allowed; on top of this another 2 in. of concrete of the same proportions as the bottom layer was placed, and above this was laid the finishing coat, 2 in. thick. The work was so carried on that no layer was set before the other was superimposed upon it.

The two bottom layers consisted of three parts $1\frac{1}{2}$ -in. machine-broken whinstone metal, two parts sharp sand, and one part cement, while the finishing coat was of two parts $\frac{1}{2}$ to 1-in. whin-



FIG. 42.—Road prior to reconstruction, Canmore Street, Dunfermline.

stone metal chips, two parts granite $\frac{1}{4}$ -in. to dust, and one part cement.

The surface contour was maintained by the putting in of pegs every 4 ft. along the kerb line and at the crown of the roadway; on these were laid 1-in. laths from kerb to kerb, these being taken up as the work proceeded.

When the surface was about three-quarters set it was gone over lightly with a bass broom, thus securing a "key" for the tar spray; it was thereafter covered over with fine sand which was kept moist for seven days and removed at the end of fourteen days.

On the work being completed, the surface—with the exception

of 12 in. at the sides, which was finished smooth—was tar-sprayed and chipped with $\frac{3}{8}$ to $\frac{1}{4}$ -in. whinstone chips. No expansion joints were put in transversely, but along both kerbs were laid $\frac{1}{2}$ -in. white pine boards the depth of the concrete. It was intended to remove these and fill the cavity with pitch, but wet weather interfered and the wood was left in.

The cost of the work, which included the removal of the old setts, excavation, filling trenches for gas, water, etc., with 6 to 1 concrete, the concrete in the roadway, the fabric and the wood slips along kerbs, was 10s. 4d. per super. yard, and the tar-spraying 1 $\frac{3}{4}$ d. per super. yard.

Latest Report.—When the road was last inspected by the Burgh Engineer in September, 1919, it was found by him to be in as good a condition as on the day it was laid. He further reports that the only maintenance necessary between October, 1916, and the date of his leaving Dunfermline in 1919, was an annual tar-spraying and chipping, which was carried out at an expense of less than £5 per annum.

During the first year the road had to carry a heavy motor-bus traffic, which was suspended in 1917. But apart from this the road continued to bear a very heavy general traffic, including that of traction engines, with no apparent detriment to the surface. Mr. Smith states that from the experience gained in Canmore Street, Dunfermline, he is quite prepared, should occasion arise, to recommend the adoption of a similar construction for roads of a like nature. He is satisfied that where the surface is kept well covered with a coating of tar and chips, such a road will last for many years and will repay the time and cost expended upon it by a greatly reduced cost in annual maintenance.

The above report is borne out by the present Burgh Engineer, Mr. R. Muir Morton, who, writing in November, 1920, stated that "the condition of the road to-day is very satisfactory, and, beyond requiring a new coat of tar, which it will receive in the spring, no fault can be found with the surface of the road. The work as it now stands is satisfactory and it is not anticipated that any extraordinary expense will have to be incurred thereon for a very considerable time."

Edinburgh

Blackwood Crescent.—That concrete roads are not the novelty which is often supposed is shown by the fact that the concrete



FIGS. 43 and 44.—Views showing the road at Glengormly, Belfast, during construction.

carriage-way of Blackwood Crescent, Edinburgh, 441 feet long and 33 feet wide, was laid in July, 1873.

The construction was a 4-inch base of 2-inch broken stone, rolled, and a 5-inch coat of $1\frac{1}{2}$ -inch whinstone grouted with $1\frac{1}{2}$ parts of fine riddled sea gravel and 1 part Portland cement, well beaten down. No reinforcement was used, and the road has never been surfaced with any other material.

The city road surveyor, Mr. James Sims, reporting on this road on November 16, 1920, states that the surface is still in fair condition and, what is very remarkable, the total cost of maintenance has been but £40 since the road was laid over forty-seven years ago.

Gillespie Crescent, Edinburgh, was laid about the same period and by a somewhat similar method.

Ireland

Glengormly, Belfast, Antrim.—In August, 1915, a short length of reinforced concrete road (48 yds.) was laid in the Belfast Rural District about four miles outside the boundary of the borough of Belfast. This was one of three experimental lengths on a portion of the Antrim main road where maintenance has always proved to be difficult and expensive on account of the boggy nature of the subsoil.

The width of the carriage-way is 30 ft., and there is a footpath 6 ft. wide on the north-east side of the road, as well as a grass verge of about the same width on the south west side.

The specification adopted for the work was the one used for the Kent experimental length, with the exception that the concrete, instead of having a uniform thickness of 6 in., was made $7\frac{1}{2}$ in. thick at the middle of the road, reducing to 6 in. at the sides. The road was laid in half widths, and each half width in 10-yd. lengths.

After the foundation bed had been prepared a 2-in. layer of concrete was laid, and on this the reinforcement was placed longitudinally, with 4-in. overlap where the separate sheets joined. On account of the sheets overlapping, the reinforcement did not come quite to the edge of the 30-ft. width of the concrete, but the width outside the reinforcement was given an extra thickness of 3 in. underneath, being 9 in. thick for a width of 12 in. The

upper layer of concrete was laid immediately upon the fabric and carefully tamped to bring it to the specified thickness, when the surface was finished off by men who used contour boards, which ensured that the surface had the proper form and cross-fall. The concrete surface was then covered with a 2-in. layer of damp sand until the concrete had thoroughly set, and an interval of fifteen days was allowed to elapse before traffic was permitted on the new surface. The other half of the road was dealt with in the same way, and when the full width of the concrete had set and was thoroughly dry, the surface was tar-sprayed.

A traffic census on the Antrim Road near the Sandy Knowes cross-roads, where this length was laid, gave a total of 416 tons per day.

Latest Report, November, 1920.—Mr. D. Megaw, A.M.Inst.C.E., the County Surveyor, states that the length is at present in very fair order and there has been very little expenditure on it since it was laid, except the cost of tar-spraying each year : the road is subject to heavy traffic.

CHAPTER III

CONCRETE ROADS IN INDUSTRIAL WORKS AND MILITARY CAMPS

The Port of London Authority.—The system of reinforced concrete roads introduced and developed by the Port of London Authority presents many features of interest.

The road slabs are 9 in. to 10 in. thick, including a top wearing crust of 2 in.

The method of reinforcement, designed and patented by Mr. J. H. Walker, Assoc.M.Inst.C.E., of the Port Authority, was the outcome of the difficulty foreseen in laying a satisfactory concrete road upon the particularly soft ground of which the land in the vicinity of the docks is composed. The reinforcement provides for top and bottom layers of reinforcing bars combined and interlocked with zigzag diagonal tension members in such a manner as to form a rigid mattress to which any additional bars may be attached as required (see illustration).

The steel is delivered direct to the site from the rolling mills in coils of $\frac{3}{16}$ in. diameter wire and straight lengths of $\frac{1}{4}$ in. or $\frac{5}{16}$ in. bars. The men quickly and economically bend and assemble the bars on rough benches, which latter are moved forward as the road progresses.

Very careful consideration was given to the question of reinforcement. The reasons for adopting such a type of double reinforcement, with its accompanying great advantage of providing steel diagonal members to counteract the shear or diagonal tension stresses, were as follows:—

- (a) Economy.
- (b) To provide two layers of reinforcement to meet the flexure and contra-flexure stresses in the slab imposed by the heavy rolling traffic.
- (c) To eliminate the necessity for providing objectionable expansion joints and to prevent the concrete from devel-

oping contraction cracks due to variations in temperature and amount of moisture in the concrete. The surface of the roadway being exposed to great variations in diurnal weather conditions necessitates steel reinforce-

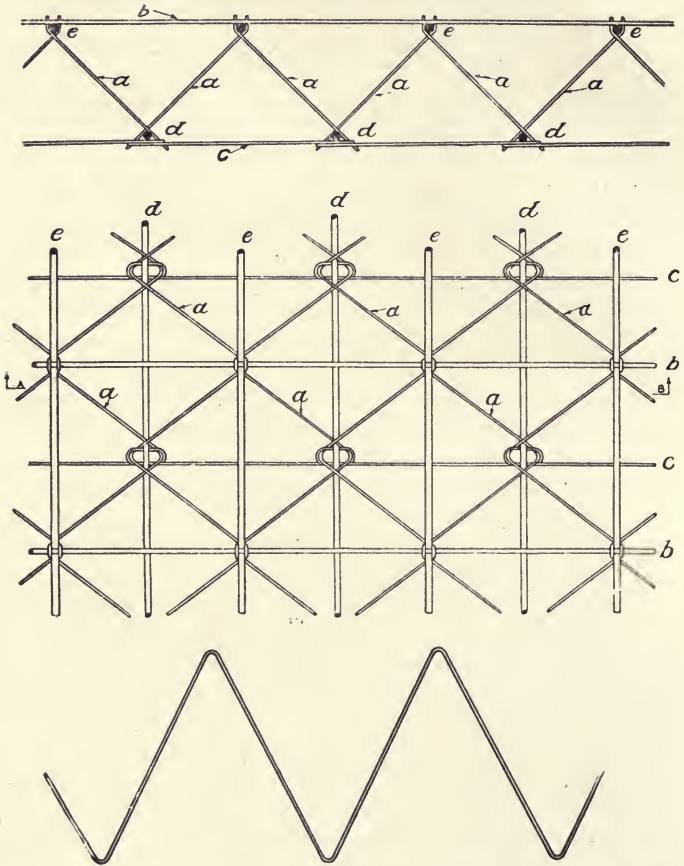


FIG. 45.—Pyramidal interlocked reinforcement for roads, rafts, floors, etc., as used for Port of London Authority roads.

ment near the surface of the concrete, whilst, due to seasonal changes, a bottom layer of steel is also required. The pyramidal diagonal bars being anchored in the bottom layer of concrete also perform a very important



FIG. 46.—Reinforced concrete road in course of construction, showing reinforcement and the road-laying machine covered with canvas.



FIG. 47.—Finished view of road for the Port of London Authority at the Royal Victoria Docks.



FIG. 48.—Reinforced concrete road at the works of Messrs. Joseph Baker, Sons & Perkins, Willesden Junction.



FIG. 49.—Reinforced concrete road at the works of Messrs. Joseph Baker, Sons & Perkins, showing the truck lines.

function in providing for any possible contraction of the concrete by spreading this contraction over innumerable and practically invisible hair cracks.

- (d) To provide a simple, cheap and practicable way of readily assembling the steel, and to ensure that the reinforcement, when laid, shall be in its correct position in the concrete, and also to provide a framework to which any additional bars can be readily attached when required over trenches or other exceptionally weak places.

This system of constructing concrete roads was installed in the Royal Victoria Docks in the winter of 1917-18, and has fulfilled all expectations.

The proportions of the concrete, the methods of mixing, and construction of the road may shortly be described as follows :—

The lower 7 in. consists of 6 of Thames ballast to 1 of Portland cement, the top or wearing crust of $2\frac{1}{2}$ of $\frac{3}{4}$ -in. broken shingle, and $1\frac{1}{2}$ of sand to 1 of Portland cement.

The construction of the road was as follows: After the road bed had been excavated and graded, the reinforcement was laid thereon, the bottom 2 in. of concrete was placed in position, and the reinforcement lifted through it, by hooked bars, so that it rested on the concrete. The remaining 5 in. of the bottom 7-in. coat was then deposited. The top 2-in. coat was afterwards placed in position, tamped and screeded by a specially constructed screed worked by two men, which brought the surface to the actual level and contour required.

A special feature in the making of these roads was the machine for fixing, laying and screeding the concrete, which is briefly described in Chapter VI, page 165.

Messrs. J. Baker, Sons & Perkins, Willesden Junction.—A concrete road was laid down at the works of Messrs. Joseph Baker, Sons & Perkins, engineers, Willesden Junction, under the superintendence of Mr. S. W. Moscrip, the engineer.

Having studied the concrete roads of America and of this country, and examined the question in all its bearings, Mr. Moscrip was satisfied that a concrete road was calculated to meet more satisfactorily than any other the demands made upon it by the heavy traffic which a road of this description has to carry; the company therefore decided to give this method of construction a trial.

The foundation consisted of a mixture of clinker and ballast, well rolled and consolidated. The kerbing, which was laid first, is 1 ft. in depth, and is battered on both sides, being 6 in. wide at the top and 9 in. at the bottom. The concrete for the road itself is 6 in. in thickness, and was laid in two courses, a lower course of 4 in., consisting of a mixture of one part Portland cement and five parts coarse material, and an upper layer of 2 in., consisting of one part Portland cement, one part sand, and two parts pea shingle, graded up to $\frac{3}{4}$ in. diameter. The reinforcement consists of steel mesh. Adopting the principle to which, where reinforcement is used, recent experiments seem to point as being sound, no expansion joints were provided. The concrete was laid in alternate bays, and the material in the intervening spaces was laid close up to the concrete already in position. The surface was worked over by a trammel, shaped to the camber of the road, and was afterwards finished with a wooden float. When the concrete was sufficiently hard, the road was covered to a depth of about 2 in. with ashes, which were kept constantly moist, and allowed to remain for three or four weeks.

The road so far constructed is about 200 yds. in length and 24 ft. wide, and the result is satisfactory in every way. The surface is even, but not smooth, and presents a "dead" face which affords an excellent grip for horses and motor vehicles, and enables each to work up to its maximum power; and although some two or three hundred tons of traffic pass over the road daily, there is in it neither crack nor flaw. Indeed, so satisfied is the engineer with the result of this experiment, that the company has in contemplation the construction of concrete roadways throughout the whole of its yards.

Latest Report.—Mr. S. Moscrip, the company's engineer, writing in November, 1920, states: "The road has been in use now just over three years and has cost nothing for maintenance or repairs. When the concrete was thoroughly dry we gave it a good coat of tar and sand and this has not worn off yet. Heavy loads up to 13 tons have been over the road in motor, steam and horse wagons.

"Messrs. Joseph Baker, Sons & Perkins are thoroughly satisfied with this kind of road construction and will certainly use it in future extensions of their works."

Empire Paper Mills, Greenhithe, Kent.—This road forms the approach to the Empire Paper Mills, Limited, at Greenhithe, and was

laid in the spring of 1918. The length which has been concreted is about 800 ft., and the width of the road is 18 ft. between the kerbs. Concrete kerbing, 6 in. thick, was first moulded *in situ*, the mixture used being 3 of sand to 1 of cement. No reinforcement was used for this kerbing, but to allow for expansion joints were formed with deal strips $\frac{1}{4}$ in. thick, spaced every 12 ft. The concrete of the road was 6 in. in thickness, and consisted of a bottom 4 in. of 6 : 1 mixture, and a finishing surface 2 in. thick of 3 : 1. It was reinforced throughout with metal mesh, placed as nearly as possible 3 in. above the bottom—i.e., in the centre of the concrete. In order to reduce the number of joints (which are a source of weakness in concrete roads), each day's work was done continuously in one bay, and sufficient space was left between one day's work and the next to allow of the intervening bay being put in afterwards when those on each side were set. One thickness of tarred paper was placed against the ends of the completed bays before the intervening bay was filled in. The reinforcement was placed so that it stopped 2 in. from the end of each bay, and also 2 in. from the kerbing on each side, in order to ensure that it was protected by concrete from any risk of corrosion.

The number of vehicles passing over the road is not very great, but they are of all classes, including large motor lorries and steel-shod steam wagons. The illustration Fig. 50 shows this road after completion.

The whole road is on a gradient from one end to the other, but the gradient varies throughout its length. A cross-fall to both kerbs of 1 in 50 was provided.

Latest Reports, November, 1920.—According to a report from the chief engineer of the above Company, Mr. D. T. MacIvor, and a later report by an independent observer, the road has been in use two years and is in as good condition as when first opened.

The method adopted for constructing this road, viz., by alternate bays, has quite justified itself, and has demonstrated that it is both unnecessary and undesirable to provide "expansion" joints in a reinforced concrete road.

It is understood that the Empire Paper Mills Company is highly pleased with this road, as, prior to its construction, great trouble and expense had been experienced in keeping up the macadam roadway, whereas the concrete road has cost nothing for upkeep, and is not affected by the state of the weather.

A Factory at Southampton.—Fig. 51 shows a concrete road laid down at an important factory at Southampton. The road runs the whole length of the main buildings, some 2,500 ft. in all.

During the construction of the factory, which was a Government rolling mills, a hard core roadway had been formed approximately on the same lines as the new concrete road, for which a good foundation had thus been prepared. Preparatory to starting work on the concrete road, the top of the hard core was picked over, screened, levelled and rolled. Concrete kerbs which had previously been cast in moulds were then laid on a concrete bed on either side of the new road, and served as forms for the concrete.

The roadway itself is 10 ft. wide between the kerbs, with double width passing-place, and consists of 6 : 1 cement concrete 10 in. thick, laid direct on the hard core referred to. No reinforcement of any kind was used, but the concrete was deposited in alternate sections 10 ft. 8 in. in length and the full width of the road. Upon this was laid a surface coat, 2 in. in thickness, consisting of granolithic paving. When these sections had set, the intervening portions were laid in a similar manner.

The traffic is of the heaviest and consists of motor wagons up to 10 and 12 tons in weight with broad flanged metal wheels.

The Portsea Island Gas Works, Portsmouth.—The Portsea Island Gas Light Company early in 1919 decided to lay a reinforced concrete roadway in Green Lane, a public thoroughfare for the maintenance of which the Company is responsible. The road, which carries a fair amount of heavy traffic, including tractors, steam wagons and motor lorries, was originally of water-bound macadam but this had been repaired and patched many times, and its condition was very bad; a trial length in reinforced concrete was therefore recommended. The eastern half of the road, extending from the Gas Works entrance to the railway crossing, was put down in concrete, the remaining half, over which the same amount of traffic passes; being laid in water-bound macadam in order to obtain comparative results. The concrete portion measures 725 ft. in length and 22 ft. in width between the kerbs.

Manholes were provided where necessary at the crown of the road, and gulleys were placed on both sides bedded in Portland cement concrete foundations.

Work was commenced on the site in June, 1919, and as it was



FIG. 50.—Concrete road, Empire Paper Mills, Greenhithe.



FIG. 51.—A concrete road at a factory in Southampton.



fortunately possible to divert the traffic, the whole of the road was scarified to a depth sufficient to form a new bed, all surplus material being screened and the recovered metal carted away for use on the second half of the road. A good solid foundation was ensured by filling in, watering and ramming any soft places in the bed, the latter being finally finished off to the required camber.

On the bed was laid the reinforcement—a metal mesh—a lap of 4 in. being arranged at the junction of each width, and a lap of 12 in. where one length ended and another began.

The aggregate employed was shingle dredged from Langston Harbour, in the vicinity of the Works. This was mixed with Portland cement in the proportion of 6 : 1 for the lower course of 4 in., and 3 : 1 for the wearing coat, the shingle for the latter all passing a $\frac{3}{8}$ in. screen.

On depositing the concrete the reinforcing fabric was lifted and well shaken, and the concrete rammed to a depth of 2 in. below the reinforcement, the position of which was thus uniformly 2 in. from the under surface of the slab. Great care was taken that the upper 2 in. of fine concrete should be laid before the lower layer had set, and the work was finished off each evening at a straight edge placed transversely across the road. At the end of each day's work a strip of reinforcing fabric some 3 ft. wide was so laid across the road as to bond the two days' work together, half the width being left projecting.

The formation of the correct camber was effected by the use of two parallel screeds, placed one on each side of the road, and a template faced with hoop-iron, which was dragged backwards and forwards along the screeds after the laying of the concrete in each section. This gave a very good surface.

Good progress was made by the above method, the average rate of completion being about 30 ft. run per working day.

As the concrete was laid and the surface finished the work was protected from the sun by means of corrugated iron supported on poles. This temporary roof was moved daily to follow the work, and was replaced by a layer of wet sand, which was kept well wetted for three to four weeks after laying. Fig. 53 shows the sub-grade in the foreground, the roll of reinforcing fabric, the template and the corrugated iron protection.

When the concrete had thoroughly matured, the sand was removed, and finally a coat of hot dehydrated tar applied, the whole being dusted over with coarse sand.

The road was opened for traffic six weeks after laying the last batch of concrete, or twelve weeks after commencing the work. The result has been considered very satisfactory, and up to the present has been an entire success. A photograph of the completed road is shown in Fig. 55.

In cost the concrete compares very favourably with the macadam road, and a very large saving in maintenance charges is anticipated.

Benefiting by their experience with this trial length of road, the company has since put down other concrete roads of greater length inside the Works. The method of laying these roads and their general construction are very similar to those of the trial length, but one or two modifications have been introduced.

In the first place the new roads are formed with concrete kerbs instead of stone, which forms the kerbing in the trial length.

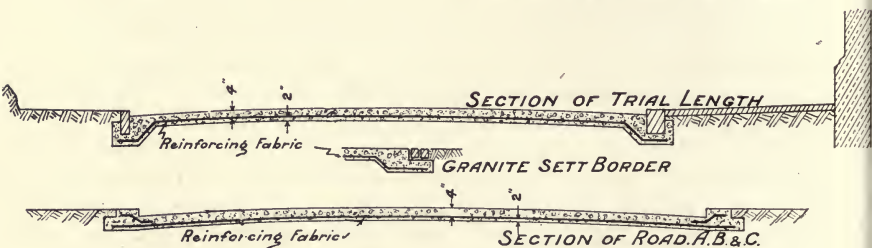


FIG. 52.—Section through roads and border, Portsea Island Gas Works.

The layer of reinforcing fabric will project under the kerb and for a distance of 6 in. beyond its outer edge, where the concrete is formed into a step. This, it is thought, will reduce the stress on the kerb, and, as an additional safeguard, a further strip of reinforcing fabric 1 ft. 6 in. long has been laid through the body of the kerb, as shown in Fig. 52.

The question of camber has required some attention. Many concrete roads are laid with very little camber, 1 in 50 being often specified for this purpose. Doubtless this will allow water to run off provided the road can be kept reasonably clean, but a gas-works yard is usually so muddy as to render the road leading therefrom very needful of attention in this respect. A greater camber was, therefore, given to the trial road—some 4 in. on the total width of 22 ft., or 1 in 33, and this camber has been adhered to in the new roads.

The work was carried out to the specification and drawings of



FIGS. 53 and 54.—Method of laying concrete in Green Lane, Portsea Island, Portsmouth.



FIG. 55.—View of completed trial road at Portsea Gas Works.

Mr. T. Carmichael, the Gas Company's engineer and manager, and, we understand, has resulted in remarkably fine thoroughfares.

Chisledon.—An interesting development of the use of concrete for roads during the War was the making of a number of camp roads, and the illustration, Fig. 59, shows a camp road at Chisledon, about five miles from Swindon, where some concrete roads were constructed during the War. Altogether there are about two miles of these roads. The surface formation of the roads is reinforced concrete, 6 in. thick. The roads comprise different sections, one being 700 ft. long and 20 ft. wide. It was originally intended that the concrete should be covered with asphalt or similar material, but eventually it was decided to leave the concrete surface as it was. Another road was 15 ft. in width. The concrete mix was $5\frac{1}{2}$ to 1. The reinforcement was in the form of electrically welded steel wire placed about 2 in. from the under side of the concrete.

Loch Doon.—This road, which was laid in July, 1917, is about 700 yds. long and 16 ft. wide. It leads down to the loch from a road which runs parallel to the side of the lake but some distance from it. The latter road is of macadam, and in some cases had been filled in several feet in thickness, but was still subsiding,

and it was for this reason that it was decided to try reinforced concrete for the road down to the lake. The ground is boggy, but was drained by a system of field drains and ditches. The road was laid directly on top of the grass, which was fairly level, and any small hollows were filled up with stones, but there was no pitching and no rolling. It was understood at the time that the road was entirely experimental, and nobody expected it to carry the heavy traffic without showing some defects, although it was hoped that it would be better than the macadam road. The result has exceeded all expectations, as the road has carried all the traffic in connection with dismantling the camp at the Loch Doon Aerial Gunnery School and does not show the slightest defect. The surface is coated with tar spray and granite chips. The concrete, which is reinforced, is 7 in. to 9 in. thick.

London, Brighton and South Coast Railway Goods Yard, East Croydon.

—These roads, two in number, have been laid in the sidings which are used mainly for the discharge of coal, with the result that the traffic is of a very heavy order and comprises vehicles of all descriptions up to heavy steam wagons.

The base of the new road was prepared by scouring off to the required depth the top surface of the old road and consolidating to shape with a 10-ton roller.

Before concreting, test blocks were made and were broken at 7 and 28 days, the results being found to be satisfactory.

The thickness of the concrete is 6 inches, and the proportions adopted were 1 : 2 : 4, the larger aggregate being beach shingle obtained from Newhaven Harbour.

The reinforcing mesh was laid 2 inches from the under surface of the slab.

After the concrete had been laid, the surface screeded and the material allowed to set, the road was covered with sand which was kept wet for, approximately, three weeks, at the end of which period the sand was removed, and the surface allowed thoroughly to dry. It was then covered with a thin layer of tar and fine granite chippings.

Fig. 57 shows the sub-grade prepared to receive the concrete, and Fig. 58 is a view of the finished road.

The work was carried out under the superintendence of Mr. J. Petrie, O.B.E., the district engineer.

The first of these roads was opened on 24th June, 1920, and the second on 29th September, 1920.



FIG. 56.—Concrete road, Loch Doon Camp.



FIGS. 57 and 58.—Goods yard, East Croydon.



FIG. 59.—Concrete road at Chisledon Camp.



FIG. 60.—A road at Swindon Works for the Great Western Railway Company (laid partly in 1916 and partly in 1919).



1000 of
California



FIG. 61.—Road at Messrs. Harland & Wolff's Shipyards, Belfast. Laid during 1919–20. Length laid up to November, 1920, about 2,000 ft.; width varying from 18 ft. to 30 ft. Traffic: heavy shipyard traffic.



FIG. 62.—Hamilton Road, Belfast—laid for the Belfast Harbour Commissioners. Engineer, Mr. F. S. Gilbert, M.Inst.C.E.



FIGS. 63 and 64.—Road at Purfleet, at the works of Messrs. Jurgens Ltd. Engineer, Mr. E. H. Simons. Laid in April, 1920. Length, 840 ft. ; width, 18 ft. Traffic : heavy factory traffic,

TO THE
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FIG. 65.—Road for Messrs. Lewis & Tylor, Ltd., Cardiff, laid May, 1920. Length, 164 ft.; width, 16 ft. Traffic: Motor lorries.



FIG. 66.—Colliery road for the Powell Duffryn Steam Coal Co., Ltd., Tredegar. Engineer, Mr. W. J. Jones. Laid in April, 1920. Length, 240 yds. by 13 ft. 6 ins. wide. Traffic: Very heavy motor lorries. Present condition leaves nothing to be desired.

CHAPTER IV

CONCRETE ROADS IN OTHER COUNTRIES

New Zealand

PASSING now to the use of concrete for roads outside the United Kingdom, the experience gained in New Zealand calls for attention, and the following information is based on a paper read by Mr. Walter E. Bush, M.Inst.C.E., City Engineer, Auckland, before the Roads and Transport Congress held in London in November, 1919.

He stated his "belief in the future of concrete paving for climates like that obtaining in Auckland, especially as motor traction would tend more and more to replace horse traction in the future, and in respect to a number of streets he gave alternative estimates for paving such streets in compressed asphalt, wood block, stone setts and concrete. It was not, however, until the latter end of 1915 that the City Council authorized him to put down the first cement concrete pavement in the city, although cement concrete foundations had been put under all paved streets.

"The measure of success met with in the first street has led to its increasing use, and practically all streets that have since been permanently paved have been carried out in cement concrete.

"By March, 1919, some 35,000 yds. in all had been completed, 14,000 yds. were in hand, and an additional 135,000 yds. had been authorized."

The following are some short particulars regarding three of the streets laid in Auckland, according to information furnished by Mr. Bush in his paper at the above-mentioned Congress :—

Little Queen Street.—This street is 423 ft. in length, and lying almost due north and south, thus exposing it to the sun's rays for the middle part of the day, which means that in summer-time the surface temperature is often as high as 120° F., and may sometimes exceed that. Its mean elevation is 9 ft. above sea level, and it

serves the back or cart entrances of a number of warehouses and works to and from which the traffic is of the heaviest description, both two and three-horse lorries and also motor-trucks being used, carrying the largest loads that the very flat grades on the water front make possible, and it is also subjected to much turning and twisting traffic from the fact that many of the warehouses have cart docks, and practically all unloading is done by backing the lorries and trucks either into such cart docks or against the kerb.

The street was prepared for paving by scarifying the water-bound macadam, excavating to the required depth and preparing and rolling the sub-grade to the required camber to receive a uniform thickness of 8 in. of pavement, with a fall from the crown to the channel of approximately 1 in 36.

Two-coat work was adopted, the lower six inches of 7 to 1 concrete and the upper two inches of 3 to 1. The 7 to 1 concrete consisted of five parts of clean beach shingle having a fair proportion of sand, two parts of broken basalt between 1 in. and $2\frac{1}{2}$ in. gauge, and one part of Portland cement, while the 3 to 1 concrete consisted of 2.25 parts of beach shingle, 0.75 parts of $\frac{3}{8}$ in. gauge basalt chippings and one part of cement. The top 2 in. was laid immediately after the lower 6 in. had been roughly brought to its proper shape, and while it was quite green, in order to ensure that the whole 8 in. was practically homogeneous.

The surface was brought to a proper camber by a straight timber template shod with steel, operated transversely to the longitudinal axis of the street, from the centre to the channel, on screeds of angle iron fixed to bars in the ground, after which it was steel trowelled till it presented a wet, even surface; after setting had commenced it was lightly broomed to remove glazing of any portion of the surface, and when setting had taken place the concrete was covered with bags and kept wet for eight or nine days.

It being midsummer, only three weeks were allowed before the road was opened to traffic, and after nine months it was treated with Californian asphalt, brushed on hot and dressed with screened beach shingle.

Prior to the application of the asphalt dressing the surface showed slight signs of wear in one or two places where the shingle had not been so good as in the remaining portions, a fact which emphasizes the necessity of using only the best qualities of aggre-

gate available in this class of pavement. This road was completed in February, 1916.

Durham Street.—This was done with one-coat work 7 in. thick of 5 to 1 concrete, the traffic conditions not being so severe as in the preceding road, and it was left untreated and has stood quite satisfactorily since its completion in October, 1916.

Park Road forms a portion of Auckland's busiest traffic outlet, and lies immediately eastward of the important reinforced concrete viaduct known as Grafton Bridge, which is surfaced with compressed Neuchatel asphalt. The road was completed in July, 1917.

It carries mixed traffic, most of which is fast travelling, and includes heavy petrol motor-wagons and chars-à-bancs, but no motor-buses similar to those so common in London, the number of vehicles counted being over 2,000 per day of ten hours.

The work was done in two halves to prevent stoppage of the traffic, and was much delayed by difficulty in obtaining shingle owing to bad weather, and this resulted in some shingle being used which was not absolutely first class, and also in the street being opened up for traffic sooner than was advisable. This caused the engineer to cease using shingle for aggregate and to substitute broken basalt and sharp sand.

The change was made during the progress of the Park Road job, which was a one-coat pavement of 5 to 1 concrete, 8 in. thick, and the bays done with the basalt and sand aggregate showed enough superiority to the rest of the work to justify the alteration made.

With the exception of a short length of the basalt and sand concrete, the whole surface was treated with a dressing similar to that used on Little Queen Street.

In all the streets paved since 1917 the paving has been one-coat work of concrete composed of clean basalt chippings and screenings varying from $1\frac{1}{4}$ -in. gauge to "fines" mixed with 25 per cent. of sharp beach sand free from shell and gauged with Portland cement in the proportion of 5 of aggregate to 1 of cement, but prior to the concrete being laid the sub-grade is sprinkled with $2\frac{1}{4}$ -in. clean basalt road metal as a measure of economy. In all cases the sub-grade is carefully prepared and rolled solid, and steel rod reinforcement is laid transversely over trenches likely to cause trouble by subsidence.

The cost per sq. yard, of pavement only, for the above three streets worked out at 10s. and 9s. respectively.

In addition to the roads above described, it is interesting to note the other works done to the end of 1919, as scheduled in the accompanying table.

Name of Street.	Length in Feet.	Area in Square Yards.	Thickness in Inches.	Cost per Sq. Yd., Pavement only.	Date of Completion.	Remarks.
Market Roads .	640	1,340	7	8/-	Mar., 1918	Untreated.
Exchange Lane .	140	155	4½	5/3	Dec., 1917	Untreated.
Quay Street Extension	530	3,828	8	9/-	Mar., 1918	Untreated. Intersected by railway sidings.
King's Wharf Rd.	605	2,351	8	9/-	May, 1918	Untreated. Intersected by railway sidings.
Beach Road .	1,896	12,801	8	—	May, 1919	Double-track tramway.
Anzac Avenue .	2,347	9,909	8	—	—	Under construction in March, 1919.
Symonds Street.	3,100	13,427	8	—	Sept., 1919	Double-track tramway.

Total length, 10,453 ft. Total area, 49,372 sq. yds.

In addition to the above an area of over 2,000 sq. yds. in Pitt Street, on which trial lengths of proprietary bituminous pavement had been laid on a 6-in. concrete foundation and had failed, was surfaced on the old concrete foundation with a rich concrete (3 to 1), half of the area being an average thickness of 3 in. and the remainder 3½ in. This was only completed in March, 1919.

Note.—The prices paid for labour and materials were as follows: Labourers 10s. 7d., finishers and machine men 11s. 7d. per day of 8 hours; cement delivered 50s. per ton; basalt chips and screenings 10s. 3d., basalt road metal, 2½-in. gauge, 9s. 3d., and sand 10s. 11d. per cu. yard.

Dealing with the question of concrete mixing, Mr. Bush expresses himself strongly in favour of machine mixing.

Regarding joints he adopted the use of tarred paper, folded



FIG. 67.—Western Motor Track, St. Kilda Road, Melbourne.



FIG. 68.—New South Head, Woollahra, Sydney.







FIG. 69.—View of finished road, St. Kilda Road, Melbourne.

to form two thicknesses, and these were placed approximately 56 ft. apart, the length of bay laid being 14 ft., and four bays a convenient length for a joint.

Out of 35,000 yds. laid, of which only 5,216 had been coated, not a single crack had been discovered between the bays, and only in Little Queen Street and Park Road, in which shingle concrete was used, were there any noticeable signs of wear. The tarred paper joints and those formed by the junction of two bays are coated with asphalt and fine shingle.

Australia

In Australia some experiments in reinforced concrete road construction have been carried out at Melbourne and Sydney in the suburban areas, notably on the St. Kilda Road, Melbourne, and the New South Head Road, Sydney.

St. Kilda Road, Melbourne (West side).—An extended, and what may, so far, be called a satisfactory test with a reinforced concrete road has been made by the South Melbourne City Council on the west side of St. Kilda Road on a section within the council's jurisdiction. It was carried out under the supervision of Mr. A. E. Aughtie, M.Inst.C.E., City Surveyor. Five different, but conjoint, sections of the road were laid with steel mesh reinforcement—longitudinal and transverse, and triangular—supplied by two different makers, and with plain concrete, in order that a comparative test might be made of their relative values. In March, 1914, one chain of road was experimented upon, 33 ft. being laid with plain concrete, and 33 ft. with concrete and longitudinal and transverse steel mesh reinforcement. In June, 1915, 2½ chains of plain concrete road were put down; at the same time half a chain of concrete road with triangular mesh reinforcement was laid. In March, 1916, half a chain of concrete road with longitudinal and transverse mesh reinforcement was constructed.

The reinforcement in the several instances mentioned was laid in concrete 6 in. thick, while the plain concrete road was 6–8 in. The concrete mixture for the various tests comprised four parts of blue stone screenings, two parts of sand, and one of cement. The width of the road so treated is 24 ft., with 3 ft. of channelling on either side. The surface of the various sections was tar painted and sanded.

Reporting on the test Mr. Aughtie said it had conclusively shown that there had been absolutely no wear on the surface, and to all appearances it was as sound as on the day on which it had been laid. A number of transverse cracks, however, had appeared in the plain concrete road and at the junction of the reinforced road, but very few had shown themselves in the latter. Taking the reinforced sections as a whole, the cracks were of a very minor nature and the structure gave evidence of durability.

New South Head Road, Sydney.—Some time ago the Woollahra Council, Sydney, experimented with a section of the New South Head Road, near Mona Road, Darling Point. There is a foundation of a depth of 6 in., consisting of concrete made in the following proportions:—8 cu. ft. of $1\frac{1}{2}$ -in. blue metal, 8 ft. of $\frac{3}{4}$ -in. metal, or "shivers," 10 ft. of blue metal screenings, and 4 cu. ft. of cement. Over this layer of concrete is laid the reinforcement. Above this is the wearing course, which consists of a rich concrete mixture of two parts of blue metal screenings to one of cement. The length of road constructed was 160 ft., with expansion joints 20 ft. apart.

Canada

The Toronto-Hamilton Highway.—This is one of the most interesting examples of concrete road construction in Canada, and is thirty-five miles in length. The former Engineer of the Toronto-Hamilton Highway Commission, Mr. A. E. Wynn, has recently stated that this road represents the best and most modern practice in road building. For this reason we give some brief particulars of its construction, together with illustrations.

The road is a link of the Provincial Government's scheme for a system of main highways connecting the towns, and it carries more traffic than any other road in Canada.

Its construction was undertaken in the autumn of 1914.

The specifications adopted very closely followed those of Wayne County, Michigan, which is the pioneer district for concrete roads. All work was done by day labour under the supervision of the Commission's engineers.

The pavement itself had a standard width of 18 ft., with shoulders



FIG. 70.—The road before concreting.



FIG. 71.—View of finished road at Oakville.

THE TORONTO-HAMILTON HIGHWAY.

3 ft. wide on each side composed of the natural earth, gravel or crushed stone.

The width was increased to meet local conditions, such as through towns and villages. It was 24 ft. wide for a few miles outside Toronto, and reached a maximum of 50 ft. wide through the town of Oakville.

Materials and Method of handling them.—Only tested cement of known quality was used. Before considering any stone for use an inspector visited the quarry, and all details as to the methods of handling, screening, output per day, etc., were recorded. A sample of 100 lb. was carefully selected from different points in the quarry and shipped to the testing laboratory.

Here the following tests were made:—

(1) Resistance to wear—(2) Resistance to impact—(3) Specific gravity—(4) Absorption—(5) Weight—(6) Granulometric analysis—(7) Voids—(8) Cleanliness.

Most of the stone used was limestone or dolomite varying in size from $1\frac{1}{2}$ in. down, and had to pass the above tests satisfactorily before being accepted.

All sands used were tested for cleanliness, grading and tensile strength, and from the result of these tests certain sands were decided upon to be used.

Every car-load of sand or stone was inspected before shipping, and samples were sent in periodically to the laboratory to be tested in order to be sure that they were up to specifications. On these tests, too, was based the exact mixture to be used with a certain aggregate.

The mixture adopted was nominally 1 cement, $1\frac{1}{2}$ sand, 3 stone; but this was checked up by the tests and was varied slightly to suit different aggregates. When there was any change in material the testing engineer gave to the field engineers the correct mixture to be used and the amount of water required for mixing.

At convenient points along the road material yards were built alongside the railway, about eight miles apart. New spurs were run into each yard. The cars of material were unloaded by a clamshell bucket into large wooden storage bins with hopper bottoms.

The material was then transported to any desired point along the road by means of a narrow-gauge temporary tramway; the dump cars being loaded automatically from the storage bins,

The track was laid on steel sleepers and bolted together in 20-ft. sections, so that each section could be easily and economically handled by two men.

The material was deposited along the road, behind the mixer, in such quantities that as concreting progressed and the mixer moved backwards there was always just sufficient material on hand, with no waste or shortage.

Each train load carried cement, sand and stone in the desired proportion, so that there was no delay in concreting due to insufficiency of one of the materials.

The sub-grade consisted of the natural soil, mostly sand. It was rolled flat with a 10-ton roller and thoroughly wetted down to prevent absorption of moisture from the concrete. Side forms for the concrete pavement were 6-in. iron channels, which were accurately lined up and staked in place by instrument, for some distance ahead of concreting. Materials were mixed by half cu. yd. mechanical mixers, steam-driven.

Water was pumped from the nearest available supply. The amount of water used in mixing was accurately gauged by a meter fixed to the machine and was varied to suit different aggregates, but was kept constant for any particular aggregate. This correct proportioning of water is very essential in road work and is a point often overlooked. It ensures a uniform mixture and is an important point in preventing cracks.

The materials were mixed in the drum of the mixer for a specified time, and the concrete was then dumped out into a bucket which travelled along a 20-ft. boom, to be deposited where required.

Construction of Road.—The cross section of the road was a parabola, 6 in. thick at the sides and $8\frac{1}{4}$ in. at the crown, laid in one course. As the concrete was deposited it was levelled off by a template, handled by two men, and resting on the side channel forms.

Following up were the cement finishers, who worked from a wooden bridge spanning the pavement. They floated up the surface with wooden trowels, just sufficiently to bring the moisture to the top.

No attempt was made to render the surface smooth, as a slight roughness gives a better foothold, and too much trowelling will bring the fine particles to the top, which would be liable to cause dust.

All pavement was laid in 35-ft. sections. Between each section

was an expansion joint about $\frac{1}{4}$ in. wide, consisting of prepared asphalted felt.

This felt was laid against the end form, which was set truly in line and vertical, and the concrete was carried up to it, completing one section. Then concrete was laid the other side of the form, and after setting a short time the form was taken out and the space filled with concrete. To ensure the concrete being exactly the same height on either side of the joint, a special trowel was used with a groove to fit over the felt filler which projected above the pavement about $\frac{1}{2}$ in.

After concreting followed the "curing."

The day after the concrete was laid it was covered with 2 in. of dirt and was sprinkled with water daily for ten days.

After about four weeks the dirt was removed, the joint fillers



FIG. 72.—View of finished road, Toronto-Hamilton highway.

trimmed to within a quarter of an inch of the pavement surface, and the road opened to traffic.

At intervals during concreting 1-cu.-ft. blocks were made and left along the road to cure in the same manner as the pavement. They were marked according to their location and were afterwards tested in the laboratory.

The pavement was not carried over culverts until after the fill had thoroughly subsided, and was always reinforced with wire fabric or ordinary fencing-wire, to prevent cracks.

The pavement as a whole was not reinforced except over bad places in the sub-grade.

Building the 3-ft. shoulders was the last operation, the material employed being mostly that used for curing.

On the other hand, all culverts and bridges were built during the winter under the severe climatic conditions that exist in Canada. They were all constructed of reinforced concrete, the longest spans being 125 ft.

Concrete was laid in very low temperatures with no ill effect. The danger lies in using frozen material and in allowing the concrete to freeze before gaining its initial set.

Maintenance so far has been a small item and is easily covered by fines imposed upon motorists for speeding. The cracks are cleaned out and filled with tar, heated to about 225° F. Coarse dry sand is then sprinkled over, an excess of sand and tar being used, and the traffic is allowed to iron it out.

Traffic along the road has far exceeded all estimates.

CHAPTER V

THE GROWTH OF CONCRETE ROADS IN THE UNITED STATES

AMERICAN ROADS AND THEIR DEVELOPMENT UP TO 1920

At the close of the year 1909, there were six miles of concrete road in all of the United States. At the close of 1919 there were 11,400 miles of concrete road. These mileage figures are based on the actual yardage built, and since different roads are constructed of different widths the usual road width of 18 ft. was used for the purpose in hand. So the growth from practically zero to a mileage that would span the continent from the Atlantic to the Pacific more than three times shows how the popularity of these roads has increased.

The study of the evolution of concrete roads cannot well be carried on without at the same time taking note of the development and use of the automobile. In 1909 there were 127,731 cars in the United States, whilst at the end of 1919 a total of almost 8,000,000 was reached, with an annual production of nearly 2,000,000 cars. It will readily be seen that the development of concrete roads and that of the motor-driven vehicle have been side by side. Carrying the motor-car figures a little further, it is found that in the United States there is one car for every fourteen persons, and automobile manufacturers expect production for 1920 to be greatly increased. Motor-cars demand a smooth, rigid road. It was not so with roads when the horse was the motive power. Horse-drawn travel compacts dirt and gravel roads, while motor traffic disrupts these same roads. The speed of trucks and automobiles is at least five times greater than that of the wagon and sully,* likewise the cost of driving intricate and expensive motor vehicles is correspondingly more expensive on poor roads.

It is particularly interesting, as we bear in mind that concrete roads and automobiles have developed side by side, to notice another fact. Detroit, Michigan, is the centre of the automobile industry,

* A four-wheeled pleasure carriage (commonly two-seated), somewhat like a phaeton, but having a straight bottom.

and Wayne County, which contains the city of Detroit, is generally recognized as the pioneer among counties throughout the entire United States as a builder of concrete highways. At this point it is fitting that recognition should be given to Mr. Edward N. Hines, who, as chairman of the Board of County Road Commissioners of Wayne County, had the vision and foresight to anticipate the need for hard roads, and who by great personal initiative was able to convince voters and taxpayers that a comprehensive system of concrete roads connecting the principal points in the county should be built. At the outset considerable difficulty was experienced in determining the proper width and thickness of the pavement. It was a pioneering venture, and there were few rules or experiences by which to guide their actions.

Many of the first concrete roads were much narrower than those built since highway building experience has become more rounded. Eighteen feet is now considered the minimum as a practical width for country roads. This width gives an opportunity for trucks and automobiles to pass with a good margin of safety at reasonable speed, and in a large measure prevents road accidents.

The history of concrete roads, spanning as it does the short period of a decade, may properly be divided into three parts. First, pre-war construction, which commenced, as we have said, in 1909 and continued until America entered the World War. Second, the period of war construction, which took place from the date of the entry of the United States into the world conflict until the signing of the Armistice. The third period may be called the post-war period of construction, which began at the signing of the Armistice and continues until the present date.

The period of pre-war construction carries us largely through the experimental and educational stage of concrete road-building. From 1909 until 1911 actual construction was limited, and in those two years less than 300 miles of road were built. During 1912 and 1913 considerable stimulus was felt, and from 1914 until 1917 the construction of concrete roads throughout the United States was carried on at a rapid rate. When a graph of the mileage by years is plotted, the curve covering the last-named period becomes almost perpendicular. In the four years ending in 1917, 5,000 miles of 18-ft. concrete roads were built. People were buying cars. Farmers who at first had frowned upon self-propelled vehicles, and had regarded them as a whim of the idle rich, had come to find out that the car and the truck were valuable aids in carrying on their farming



FIG. 73.—A concrete road near Salt Lake City.
($2\frac{3}{4}$ miles long.)



FIG. 74.—Morrison Road, between Denver and Morrison, Colorado.
(About 1 mile long.)



FIG. 75.—Andrews Road, near Atlanta, Georgia.
(6,000 ft. long.)



FIG. 76.—Churchland Road, Norfolk County, Virginia.
(Nearly 2 miles long.)

operations. With the motor-car they could attend to more business than ever before, and with the truck they were able to take care of the increased business that came. Rural communities began to want concrete roads. Now the farmers became consistent supporters of concrete highways for their trucks and motor-cars.

Then came the entry of the United States into the World War. The mobilization of 4,000,000 men for arms and the mobilization of the remainder of the population for industrial work made labour unavailable for continued road construction. Moreover, had labour been available, material and transportation could not have been furnished, since it, too, was diverted to war work. The country at large had, as we have said, become educated to good roads, and now came severe tests that were to prove the soundness of its logic in asking for permanent roads. Particularly around army camps and the roads traversed by military trains pavements were put to the crucial test. Heavy pieces of artillery and endless trains of heavy trucks carrying war supplies rapidly wore down all pavements that were not of the highest class. Gravel and macadam roads failed rapidly. Many other types that were considered fair under peace-time conditions gave way before the strain. It is interesting to observe that where the army engineers reconstructed these military roads they were usually built of concrete and successfully withstood the severe punishment that our military establishments imposed upon them. Reverting to the actual mileage constructed during the war period, we find that 1,533 miles of concrete road were built in 1917 and 1,300 miles in 1918.

The situation, then, at the signing of the Armistice in November, 1918, was this: Before the war the popularity of the automobile had created a widespread sentiment for good roads, and the heavy punishment that roads received under war-time conditions proved that concrete roads were better able to stand the stress than other types.

After the war was over there was a strong, widespread sentiment throughout the United States to build roads. The various States and other road-building units gave large contracts, and in 1919 4,130 miles were built or contracts awarded. It was the premier year for road construction. With hardly an exception every State increased its mileage. The State of Illinois, which contains the city of Chicago, voted \$60,000,000 worth of bonds to build State highways.

The same day that Illinois pledged itself to spend \$60,000,000

in improving its roads, the State of Pennsylvania voted a like amount. The State of Michigan, which, as we have pointed out, was a pioneer in road-building, voted \$50,000,000 additional bonds in 1919. This money will be used in extending its road system. During the same year the State of California voted \$40,000,000, Oregon \$10,000,000, and Alabama \$25,000,000, in road bonds. During the coming year Missouri will vote on the issuance of \$60,000,000 worth of bonds, and Minnesota will vote on the issuance of \$100,000,000 worth of bonds, to be used in improving the roads in the States named. This sentiment prevails in practically every quarter of the United States, and bond issues totalling high into the millions were passed, and all was in readiness for the greatest era of road-building in the history of our own or any other nation. In 1920, \$625,000,000 is available for road work, and the programme will yet, in all probability, be much enlarged. But conditions were such that the building had to be either curtailed or postponed. Labour is very costly and at the same time extremely scarce even at the high wage scale offered. Transportation facilities are to a large extent disorganized and overworked. Their equipment is not sufficient to take care of the present industrial needs of the country, and manufacturers of cement and dealers in road materials find themselves helpless to receive raw material or deliver finished products.

A sketch of the concrete road in the United States would not be complete without mentioning the roads built by the State of California. As Wayne County, Michigan, was the pioneer county in concrete road-building, California stands out in bold relief as the first great State building an extensive mileage of concrete road. California builds her roads almost exclusively of concrete. In this State alone are almost 2,500 miles of roads made of concrete. At the close of 1919 there was a thirty-mile stretch of concrete highway known as the "Ridge Route" in California opened to the public. The cost of this road was something like \$1,200,000, and it was estimated by conservative State officials that with the heavy traffic that would pass over this road the total cost of building would be absorbed in less than 200 days by the saving in petrol, tyres and upkeep on the vehicles passing over it.

As has been suggested, the entire people of the United States are strongly in favour of good concrete roads. The term "concrete" has come to be accepted as the general word designating all that good roads should be. The Federal Government has made liberal

appropriations to help to build roads where States and counties have properly applied and their project has been accepted. The Federal Government assists in building what is known as Federal Aid Projects. The platforms of the political parties have paragraphs endorsing the continuance of building good roads. There is no doubt that of the roads to be built concrete will be strongly represented. When conditions get back to normal, there is reason to believe that the United States will carry on continuously a programme of road building that will not stop until every important highway is paved, and the lanes leading into these main routes will, if not paved, at least be highly improved. It may truly be said that this is the era of concrete roads in the United States.



FIG. 77.—Coast Route, San Francisco to Los Angeles, California.

CHAPTER VI

MECHANICAL DEVICES FOR MAKING CONCRETE ROADS

THE construction of concrete roads in an economical and efficient manner depends, to a very large extent, on the properly co-ordinated use of a number of mechanical devices. It is, of course, possible to make excellent concrete roads without the use of any machinery, but the time required and the cost of such a procedure are excessive. By the use of suitable machinery the drawbacks of hand labour are avoided, the large number of men with wheelbarrows and shovels are unnecessary, and a considerable amount of material as well as time is saved. Consequently, the use of suitable machinery not only reduces the cost of construction, but enables a much larger area of roadway to be laid in a given time.

The mechanical devices used for constructing concrete roads may be arranged in five groups :—

1. Appliances used for preparing the road-bed.
2. Appliances used for preparing the concrete.
3. Appliances used in placing the concrete.
4. Appliances used in striking and tamping the concrete.
5. Appliances used in finishing the surface.

Appliances used for Preparing the Road-Bed

It is essential that the road-bed or foundation shall be properly prepared or the concreted surface will not be durable. Hence great care should be taken to ensure the bed being of the proper width, shape and solidity. This is best secured by digging out the surplus material by mechanical means, giving the bed the correct curve or camber by means of a grading machine, and rolling or tamping the surface, if necessary, to increase its compactness.

Steam-shovels have long been used for quarrying and railway work, but their employment for road-making is comparatively new. They

have now been modified so as either to remove a relatively thin slice of material or to cut their way through a hill. When used for levelling a rough piece of country—as in working a wholly new road or in widening an existing one—steam-shovels are found to be much cheaper and quicker than hand-digging, and far less supervision is required.

A British firm of steam-shovel manufacturers is Ruston and Hornsby, Ltd., Lincoln, whose No. 5 Excavator (Fig. 78), by reason of its remarkable mobility, wide range of movements, ease of control and general utility is particularly suitable for road-making. This excavator is capable of taking a maximum depth of cut of 20 ft. without breaking the top down by hand, and will also successfully deal with very shallow cuts for grading. With the standard bucket-arms this machine can excavate a trench to a depth of 6 ft., and, by the simple expedient of letting out the jib-ties and fitting slightly longer bucket-arms, up to 12 ft. The minimum bottom width of cut with 1 to 1 slopes is 12 ft., and the maximum height of open bucket door from rail level 12 ft. 9 in., the maximum and minimum discharging centres being 22 ft. and 15 ft. respectively.

Small revolving steam-shovels have been in use in the United States for road-making with great success. The sizes which are most popular are equipped with dippers of $\frac{1}{2}$ or $\frac{3}{4}$ cu. yds. capacity. Two such dippers full of material would completely fill the ordinary tip wagon or cart, while three dippers would load a 2-yd. wagon or cart to its maximum capacity.

The shovels revolve through a full circle, permitting the machine to dig or dump at any angle and enabling them to operate successfully in limited space. The latter feature is especially valuable when it is necessary to build one-half of a roadway while the other half is open for traffic. These steam-navvies will excavate any materials which can be penetrated by picks and shovels, and they are also valuable in handling properly blasted rock.

The shovels have capacities in ordinary roadwork varying from 15 to 60 cu. yds. per hour, depending on the depth of cut, class of material, and manner in which disposal of the material is organized.

Traction wheels are generally used on this class of navvy, but any of them can be equipped with standard gauge car wheels, and on some of the shovels continuous tread traction can be substi-

tuted where desirable. It must, however, be recognized that the use of any type of caterpillar traction, while it increases the speed of the shovel in operation, makes moving of the shovel from one job to another very much slower than is the case where ordinary traction wheels are used.

These shovels are sufficiently light to be used for ordinary street and road work without planking, although most of the traction wheels are so arranged that cleats can be attached when necessary.

Several of these machines, in addition to the customary features of steam-navvies, are equipped with special devices for use in shallow cuttings and for automatic levelling and grading work.

While these navvies are generally classed as "one man" machines, it is usually desirable to provide an assistant to take care of the firing of the boiler, keeping up the coal and water supply, and generally assisting in operation. One or two pit men are needed, depending on the type of machine, speed of the work, and the care which it is necessary to give in cleaning and levelling up.

It must be recognized that the output from these navvies depends almost altogether on the skill of the operator. A working speed of from two to three dippers per minute can be obtained by the average operator, although skilled men can obtain from four to five dippers per minute with the same shovel working under similar conditions.

Some navvies of the type mentioned above are the Erie Shovels, manufactured by the Ball Engine Company of Erie, Pennsylvania, and now sold in this country by Gaston Limited and by William Muirhead, Macdonald Wilson & Co. Ltd., the Thew Shovel, manufactured by the Thew Shovel Company, Lorain, Ohio, sold in this country by the Allied Machinery Company, Ltd., and the shovels manufactured by the Bucyrus Company of Milwaukee, Wisconsin, sold in England by Messrs. George F. West & Co.

Cranes and Grabs.—For lifting large quantities of loose materials, such as sand, aggregate and tipped earth, it is sometimes cheaper to use a crane and grab than a steam shovel.

A firm of crane and grab manufacturers in this country is Priestman Bros., Ltd., Hull, one of whose machines is shown in Fig. 79.

A modification of the Erie shovel in which a grab is used instead of a shovel is shown in Fig. 82. A similar crane and grab, made



FIG. 78.—Ruston & Hornsby No. 5 Excavator.

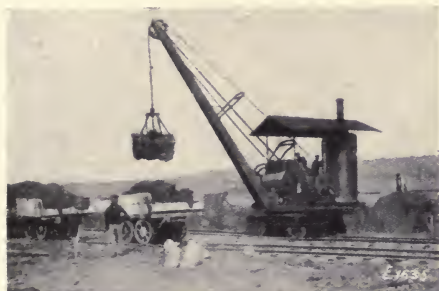


FIG. 79.
A Priestman Grab.



FIG. 80.
Erie Shovel.

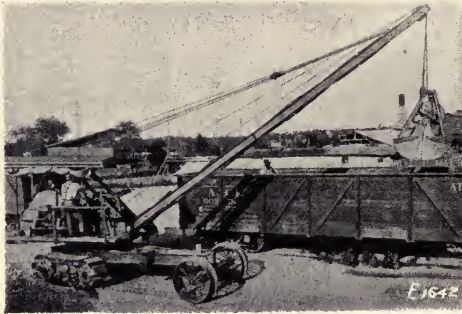


FIG. 81.—Crane and Grab.



FIG. 82.
Erie Shovel with Grab.

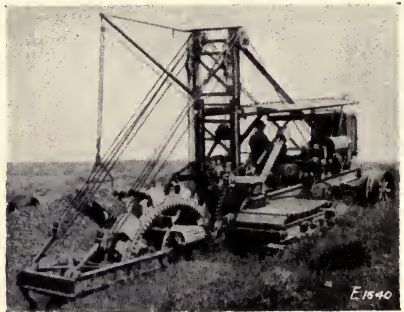


FIG. 83.—Pipe Line Excavator.

by Pawling and Harnischfeger Co., Milwaukee, Wis., and obtainable in this country from Gaston, Ltd., is shown in Fig. 81. This machine is a complete portable locomotive crane with a lifting capacity of $1\frac{1}{2}$ tons at 30-ft. radius. It is driven by a petrol engine and can travel under its own power at a rate of 1 mile per hour.

Drag-line Excavators are chiefly used on sticky soils or for lifting loose materials, but they may also be employed for grading roads of which the material is not too hard. As shown in Fig. 84, this type of excavator has an inverted bucket or dipper suspended from the boom by a rope and, on reaching the ground, this bucket is dragged towards the machine till it reaches the limit of its journey; it is then lifted, the whole crane is swung round and the contents of the bucket are discharged. By suitably regulating the suspension and drag lines, the bucket may be made to dig itself into the ground to a convenient depth prior to its being drawn along and a cut up to 8 in. deep obtained. The caterpillar wheels are a special feature of the drag-line excavators made by Pawling and Harnischfeger Co.

Trench Excavators.—As their name implies, trench excavators are specially designed to make deep, but relatively narrow cuts, chiefly for pipes for water, sewage and gas, and electric conduits.

Standard trench excavators are manufactured in various sizes to cut trenches from 12 in. to 76 in. wide and in varying depths to a maximum of 20 ft. at a rate of 6 in. to 40 in. linear per minute, according to the nature of the ground and the size of the machine.

Trench excavators are commonly built in two classes, one being known as the wheel type, the other the ladder type excavator.

Wheel Type Trench Excavators are suitable for trenches not more than 7 ft. 6 in. deep. They consist essentially of a vertical wheel provided with a series of cutters around its circumference, the wheel being mounted on a strongly trussed steel frame which also carries the oil engine, hoist or conveyor for the excavated material and the oil tanks.

The excavator should be provided with a steering gear, so that either right or left-hand curved trenches of any radius may accurately be cut, and a grade-control or lifting device should also be provided, so that the trench is cut to the full depth and the bottom is left at any desired slope or grade. In the wheel excavator (Fig. 83) made by Pawling and Harnischfeger Co., the excavating

wheels are of the open type, i.e., without an axle, and are arranged to obtain the maximum depth of trench with the minimum diameter of wheel.

Ladder Excavators are much more powerful and are capable of digging to a much greater depth than wheel excavators. The ladder excavator usually consists of two endless chains running over an adjustable boom, the chains carrying a series of toothed cutters and buckets. As the chain revolves these cutters penetrate the ground slightly, and the material thus excavated is carried upwards to be discharged as the bucket reaches the top of the boom on to a chute or conveyor, which in turn transports the excavated material to either side of the machine. It can be dumped into a pile for backfilling or direct into tip wagons or carts. Ladder excavators should have ample strength, since excavating deep, wide trenches for sewer and similar projects subjects them to constant heavy strains. Ladder excavators of this type are manufactured by Pawling & Harnischfeger, and sold through Gastons, Ltd.; the Parsons trench excavators sold through the Allied Machinery Co., Ltd.; the Bucyrus sold through Messrs. George F. West & Co.; the Austin sold by the Austin Machinery Company.

Backfillers.—Where openings are made in roadways it is always necessary to re-fill the trenches. This process—sometimes termed backfilling—is often done in an unsystematic and inefficient manner, and, consequently, is unnecessarily costly. Re-filling trenches can be accomplished economically by a mechanical backfiller such as is shown in Fig. 88, which consists of a scraper attached to a light motor-driven crane with a supplementary winding drum. The scraper is lifted and carried behind the pile of earth or other material; it is then lowered and dragged across the hollow portion or ditch into which it discharges its contents, and is then ready to be lifted back preparatory to repeating the operation. Such a machine will re-fill a trench as rapidly as twenty-five to fifty men moving the material a distance of 15 ft. to 25 ft. The machine only requires one man for its operation.

In the backfilling of trenches it is of great importance that the material should be thoroughly rammed or tamped, and although this operation has up till now been chiefly performed by hand, a machine for so tamping and trenching has been designed in America and is actually in use in this country.

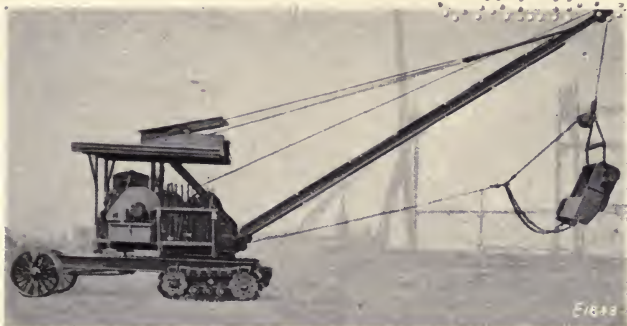


FIG. 84.—Drag Line Excavators.

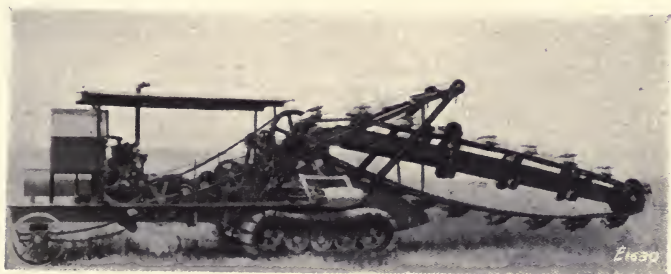


FIG. 85.—Ladder Excavator.



FIG. 86.—Jubilee Wagons.



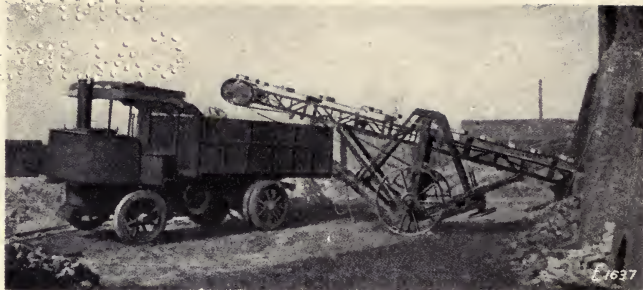


FIG. 87.—Hepburn Conveyor.

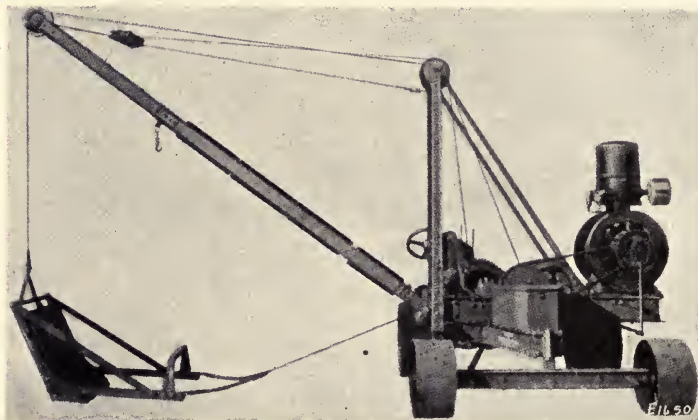


FIG. 88.—Backfiller (Gaston).



FIG. 89.—Adams "Leaning Wheel" Grader.

Wagons.—The excavated material should, wherever possible, be placed directly into wagons, those known as the Jubilee type (Fig. 86), supplied by the Ransome Machinery Co. (1920) Ltd., being very convenient. "Trains" of six or more wagons are hauled away to the tip by a motor or locomotive.

Conveyors.—When circumstances do not permit the excavated material to be placed in wagons direct from the excavator, it should be conveyed on to one side of the road, well out of the way of the workmen by means of a portable conveyor. Several suitable conveyors are on the market, the one shown in Fig. 87 and made by the Hepburn Conveyor Co., Wakefield, being very satisfactory.

Grading Machines.—Grading machines are used to ensure the foundation of the road having the correct inclination and camber. Numerous machines for this purpose have been constructed in various sizes to be operated by horse or mechanical traction. In general they consist of a heavy frame mounted on four steel wheels, the frame carrying a long blade. The position of the blade is universally adjustable to any angle or depth, the useful work of the machine being performed as this blade is drawn forward along the work in such a way as to move the material from the centre of the road to the side, or vice versa. In some cases, larger type machines also are provided with scarifying attachments so that macadam roads can be loosened up and re-graded.

Several successful machines are on the market, among these being the Adams "Leaning Wheel" grader; the Austin Giant type; and the Western Aurora type grader. Fig. No. 89 shows an Adams grader making a cut almost the entire length of the blade and delivering the earth just inside the left rear wheel.

Rollers and Tampers.—In order to consolidate the foundation of a road, especially those parts which have been made by "filling," rollers or tamping devices—operated by hand or power—are employed.

Hand and Horse-Operated Rollers are only suitable for the lightest and smallest work. They are so well known as to need no description here, especially as their use is rapidly diminishing.

Steam Rollers are invaluable where great pressure is required for compacting the foundation. They should be designed so as to

secure the maximum pressure on the roller, whilst still retaining sufficient "weight" on the rear wheels to ensure satisfactory driving up steeply inclined gradients.

For road-making, a steam-roller should have sturdy construction and ample boiler capacity, with the boilers and cylinders mounted so as to facilitate quick repairs.

The design should be as simple as possible, as such machines work continually under adverse conditions and frequently in out-of-the-way places. In order that the roller may be stable, its centre of gravity should be low, yet there should be sufficient space above the ground to prevent the engine being damaged by obstacles which the roller has failed to crush or by the machine having to work on very irregular ground.

As steam-rollers are not required the whole of the time, it is convenient to attach a belt to the fly-wheel and from this to drive a crusher, screen or other machinery which can be operated at intervals.

Motor Rollers in all sizes have been in successful use for a great many years. They are manufactured in both the single and double cylinder types, and some of them can be run on paraffin, the advantages of the motor-rollers being that they can be operated by one man, that keeping them supplied with fuel is less costly, and that they do not require a constant supply of water.

Machines at present on the market are manufactured by Messrs. Barford & Perkins, Peterborough, and the Austin Manufacturing Company of Chicago.

Preparing the Concrete

The chief mechanical devices used in preparing the concrete are crushers for the coarse aggregate, sand washers, screens, measuring devices, appliances used for transporting the raw materials as well as the concrete "slop," mixers and engines for the supply of power. It is convenient to consider each of these separately.

Crushers should reduce the large lumps of stone or other material used for coarse aggregate so as to produce angular fragments of the required size. Machines which produce rounded pieces are useless for road-concrete. Jaw-crushers and gyratory crushers are the most satisfactory; in the former the lumps are crushed between two plates, one of which moves towards and away from



FIG. 90.—Trench Tamper.

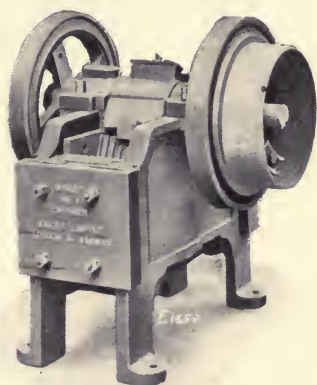


FIG. 91.—A Winget Crusher.

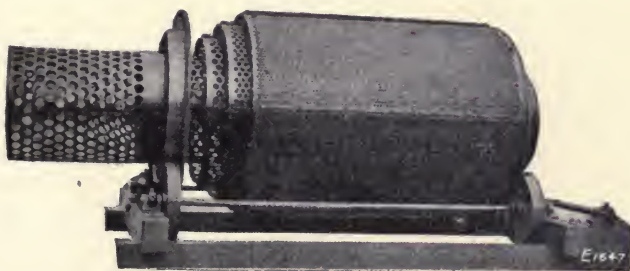


FIG. 92.—Concentric Cylinder Screen.

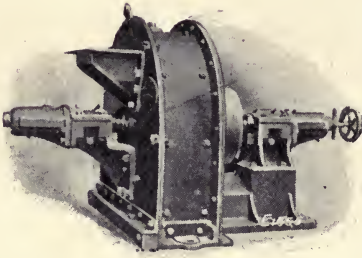


FIG. 93.
"Devil" Disintegrator.

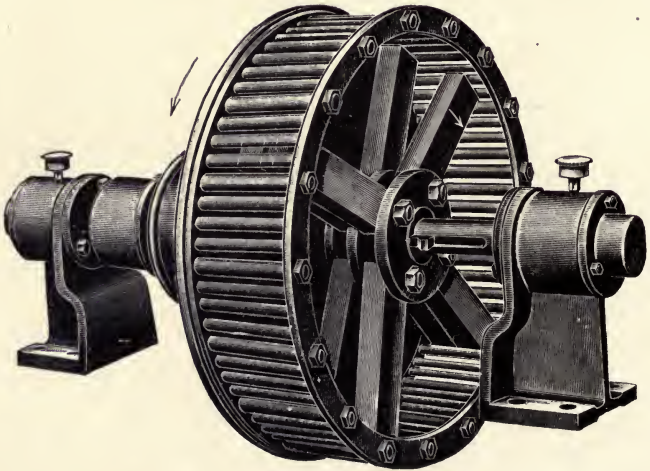


FIG. 94.—C. E. V. Hall's Disintegrator.

the other, whilst in a gyratory crusher the material is broken by the toothed faces of two cones between which it falls. The crushing effect is obtained by a gyratory motion imparted to the cone by the special gearing. Stamping mills and crushing rolls are less effective, and edge-runner mills are quite unsuitable.

Jaw Crushers.—Among the commonest of this type of crusher are the Blake-Marsden (made by H. R. Marsden, Ltd., Leeds) and that made by Messrs. Winget, Ltd. (Fig. 91).

One example of this type of mill is the Heclon crusher made by Hadfield, Ltd.

The crushers just described are suitable for coarse aggregate but not for sand, as they are not economical when used to grind a material to a fine powder.

Disintegrators or Cage Mills consist essentially of (a) a pair of cages revolving in opposite directions, the material being broken between these cages and passing out between the bars, or (b) a rotating shaft carrying loosely pivoted hammer-bars which rotate like the spokes of a wheel and deliver a rapid series of blows on the material contained on a grate until the material is crushed small enough to pass through the grate. These disintegrators (with various minor improvements) are made by several firms. An illustration of the exterior of the "Devil" disintegrator made by the Hardy Patent Pick Co., Ltd., Sheffield, is shown in Fig. 93, and an illustration showing an interior view of another disintegrator made by C. E. V. Hall, Sheffield, is shown in Fig. 94.

Disintegrators are not suitable for grinding to a very fine powder, but are very efficient for reducing hard lumps in sand, and for producing a proportion of fine flour in the sand.

It is generally preferable to use crushers and disintegrators on the site of the raw material and not in the roadway, though where the latter course is preferred, the crushing machinery may be mounted on a stout truck and driven by a portable engine. Care should be taken, in selecting an engine for this purpose, to choose one which is not readily damaged by the great and sudden variations in the power required. A little consideration will make it clear that each time a hard piece of stone undergoes the crushing process the pressure applied to it increases steadily until it exceeds the maximum resistance of the stone, when the latter yields

suddenly and the pressure being just as suddenly relieved the engine will "race" badly until pulled up more or less suddenly by the next piece of stone. This jerkiness of action is largely inevitable; it is much less serious in a steam-engine than in a gas, petrol or oil-engine or an electric motor. If one of the last four is used, it should be much more powerful than is strictly necessary in order that it may not be suddenly stopped, and possibly damaged, by a stone of unusual hardness.

Where very finely powdered material is used, an entirely different type of crushing apparatus is required; this cannot suitably be used on the site of a road, and such special material—which is seldom required—should therefore be bought ready for use.

Washers.—As the presence of some kinds of clay is detrimental to the setting and hardening properties of concrete, and as it is always desirable to wet both the fine aggregate and sand thoroughly before putting them in the mixer, it is convenient to wash them prior to use, though this process is often omitted on account of its cost. Such washing consists essentially in stirring up the material with a sufficiently large volume of flowing water to bring the clay and "dirt" into suspension and to carry it away. Washing machines used for this purpose therefore consist of some form of container fitted with agitators and some means of carrying the sand forward in one direction, whilst the water, bearing away the clay, etc., flows in another.

A considerable number of types of washers are used in various industries, but they require adaptation before they can suitably be used for the fine aggregate and sand used for concrete.

As all types of washers necessarily require very large volumes of water, they cannot usually be employed on the site of a new road, but are preferably erected on the site where the fine aggregate or sand occurs or at some central site to which it is taken, treated and then delivered in a washed state to the road-makers.

The Baxter Ballast Washer and Grader, illustrated in Fig. 95, is, however, being used on the site by the Southwark Borough Council, London.

Screens are essential for the production of a properly graded aggregate, and failure to use them has, on several occasions, resulted in

the production of concrete of such low quality that its failure to withstand the strains put upon it was inevitable.

The coarse aggregate should be passed through a series of steel cylinders, the perforations in which are arranged so as to form a series of sieves or riddles through which the material passes consecutively, a portion of it being separated by each screen.

A commonly used device consists of a single cylinder, 6-14 ft. in length, the circumference of which is divided into four or more



FIG. 95.—Baxter's Ballast-washing and Grading Machine, fitted with petrol motor. The machine, which is taken from street to street as required and connected to the nearest hydrant, was used by the Borough Council of Southwark for washing and grading the material from the old macadam roads.

sections, each of which consists of a series of perforations of definite size, the finest being at the entrance end of the cylinder. When an ungraded coarse aggregate is passed through such a cylinder, the smallest fragments pass out through the smallest perforations, the remainder travel forward as the cylinder revolves, pieces of increasingly larger size being separated until the largest "stones" fall out at the exit end of the cylinder and are returned to the crusher for further treatment. The chief objection to such an arrangement is that the separation or grading is very inefficient. The slope or inclination of the screening cylinder and the speed at

which it revolves impel the material much too rapidly through it, with the result that, instead of all the pieces of aggregate of any given size passing through the desired perforations, some of them are carried forward and pass through larger openings. Even when baffles are inserted in the cylinder the grading—though better—is far from satisfactory.

To avoid this serious objection, Messrs. Johnston and Chapman Co., U.S.A., supply a screen which consists of three or more concentric cylinders (Fig. 92), arranged so that the outermost ones have the smaller perforations. By this means the largest pieces are separated first, and no pieces can pass to the next section of the screen unless they are of the proper size to do so. Such an arrangement has the further advantage of only allowing the smaller pieces to come into contact with the finer portion of the screen, so that these can be made of thinner metal and they are not so rapidly spoiled by wear and tear.

Rectangular screens are occasionally employed—chiefly for small quantities and for relatively crude grading. If properly arranged, however, a series of rectangular screens can be made to work with remarkable efficiency especially for the finer aggregates, and with little or no expenditure of power. Rectangular screens may be of two kinds, horizontal or inclined, the latter being usually more satisfactory and requiring less labour. An excellent type of inclined screen is the “Newaygo” screen made by Messrs. Sturtevant Engineering Co., Ltd., which consists of a sheet of perforated steel plate inclined at an angle of about 45 degrees and arranged so that it is vibrated by a number of hammers which rotate on shafts above the sieve and periodically strike raised projections on the sieve provided for the purpose, thus keeping the apparatus constantly in a state of vibration. The material is supplied to the uppermost end of the sieve by means of a screw conveyor, and as it falls down the incline the small particles pass through the perforated plate whilst the coarser ones run down either into a box below or on to a coarser screen. The vibration of the screen prevents the holes in the sieve becoming clogged, unless the material is very sticky.

In some cases, several screens of varying fineness are suspended one below another, so that the material passing through one sieve passes on to a finer one below it, and so on until the whole of the material is satisfactorily graded, when it may be mixed in the required proportions.

Elevators are particularly useful for lifting the road-materials from the ground level to trucks, etc., and where sufficiently large quantities are involved. Their use is much cheaper than that of hand-shovels. These elevators consist essentially of an endless band or its equivalent, on which is mounted a series of slats or buckets which carry the material. If the height to which the material is to be lifted is not great, a plain band-conveyor will suffice, but for greater angles of elevation buckets are preferable.

A self-contained wagon loader, supplied by Messrs. Winget, Ltd. (Fig. 97), will fill a 3-ton lorry in twelve minutes. It is specially designed for filling trucks and wagons with sand, gravel, crushed stone and similar materials, and is driven by a $2\frac{1}{2}$ -h.p. petrol or benzol engine, or, if desired, by electric motor.

The belt-conveyor made by the Hepburn Conveyor Co., Ltd., Wakefield, shown in Fig. 87, is equally useful where an elevator of this type can be used.

The addition of two rotary discs (as in the loader supplied by the Allied Machinery Co.) (Fig. 96), converts a bucket elevator into a self-feeding machine and so greatly enhances its value in road-making. The two horizontal steel discs set close to the ground revolve inwards towards the conveyor.

Transporting the Materials.—The raw materials, consisting of stone or gravel, sand and cement, are usually brought to the roadway in motor-lorries, wagons or carts. Where the materials must be dumped in the roadway, these should preferably be of the self-tipping type, so as to reduce to a minimum the labour required in emptying them.

Among the large number of tipping wagons available the "Constable" Patent Side-Tipping Wagons (Fig. 100) of Messrs. Tuke & Bell, Ltd., may be mentioned. During the operation of tipping, an angle of 50 degrees is obtained, which is sufficient to eject any class of material. The door on the side of the body automatically remains in its normal position and out of the way of the material being tipped. The load is discharged in 90 seconds.

The material tipped on the side may be transported in wagons or carts; or an automatic feeder and conveyor system, such as the Barber-Greene Loader (Fig. 96) may be employed for this purpose.

It is convenient when reloading materials on the site to use wagons, carts or boxes which also act as measures.

It is of the greatest importance that the transporting, proportioning and distribution of the materials should be effected systematically and with a minimum of labour, as it is easy, through carelessness or absence of suitable appliances, to spend a double amount of money on these portions of the work.

Keeping Aggregates Clean.—One of the essential but too often neglected features in constructing concrete roads is the delivery of clean aggregate to the mixers. Engineers rightly insist on the use of clean stone, sand and cement ; therefore, wherever possible, the material should not be dumped on the sub-grade or on the side of the road, since in re-handling it to the mixer it is quite possible that a considerable amount of sub-grade or shoulder material may become mixed with the aggregate.

This may largely be avoided by combining the measuring and delivery of the stones, sand, etc., with the transportation of the material direct from the source of supply to the mixer. In most road jobs this can be accomplished by placing the material for a complete batch in specially constructed boxes or carts. These boxes or bodies can be built, or can be obtained from manufacturers in several sizes; the material is automatically measured to ensure accurate proportions, and so that they can be easily dumped directly into the mixer or into the mixer loading skip.

In addition to ensuring the cleanliness of the material, this method of charging the mixer is usually much more economical than dumping the material on the grade ahead of the mixer, since it eliminates a double handling of all material.

A fixed measuring hopper is supplied with Ransome Mixers (supplied by the Ransome Machinery Co., Ltd., London). The hopper is of such dimensions that it contains the requisite quantity of aggregate to form the batch in each size of machine. The door is operated by a hand-lever. Every Ransome Mixer, unless otherwise specified, is also despatched with a water-measuring tank attached.

Various mechanical measuring devices suitable for concrete road materials are on the market, though most contractors will find the divided wagon previously mentioned, or separate "boxes," quite satisfactory and free from great liability to error or serious



FIG. 96.—Barber-Greene Loader, supplied by the Allied Machinery Co., Ltd.



FIG. 97.—Winget Self-Contained Wagon Loader.



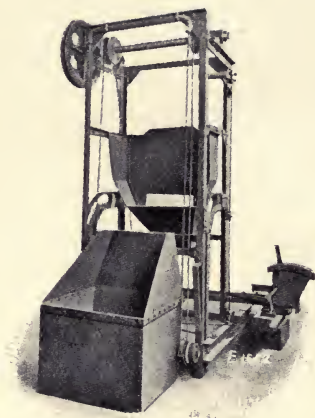


FIG. 98.—Ransome Elevator.



FIG. 99.—Ransome Hand Mixer.



FIG. 100.—Constable Wagon.

misuse ; they do not require any power, such as is always the case with mechanical measurers.

The Measurement of Water is most satisfactorily effected by means of a tank of the required capacity which is fixed at a suitable height above the mixer, and is so arranged that a definite quantity of water—neither more nor less than is required—is delivered on opening the tap. An ordinary water-saver syphon tank with a ball-valve controlling the feed is excellent for the purpose, as it delivers the water with the utmost rapidity and can be refilled automatically from a larger tank without any trouble. Water-measuring tanks fitted with taps are often troublesome, and the delivery of the water is usually too slow.

The water tank used in connection with a concrete mixer should be of ample size, yet not excessively large. For the size of mixer most suitable for road work, a tank delivering 17 or 18 gallons is satisfactory.

Elevators.—The cement, aggregate and sand must usually be lifted from the ground level to a short distance above the inlet of the mixers. If the material is transported by means of a conveyor no further arrangement for raising it is needed, but in other cases some form of elevator is desirable. Such elevators may conveniently form a part of the mixing plant. The use of an elevator reduces the cost of charging the mixer and, under certain conditions, increases the output by reducing the time required to charge the mixer. The advantage is very marked when the mixer is located at a considerable elevation above the level at which the aggregate, etc., is delivered.

Many elevators which have been in use in the past are primitive and crude in design and arrangement, but several more recent designs are quite satisfactory. Among the latter is the Ransome Elevator (Fig. 98), which consists of an elevating skip of rectangular form to avoid undesirable clogging when discharging its contents. The skip is controlled by a single lever, by the use of which all operations of lifting, discharging, lowering and steadying during its descent are controlled.

Mixers.—The machines used for mixing concrete are arranged in two classes, according as they are operated by hand or mechanical power.

Hand-Mixers are chiefly useful for small repairs, as they are very

portable and essentially "one-man" machines. A convenient machine (Fig. 99) for this purpose is made by the Ransome Machinery Co., Ltd.; it has a capacity of about 2 cu. ft. and an output of $2-2\frac{1}{2}$ cu. yds. per hour. The mixer is of such dimensions that a standard navy barrow can be readily placed beneath the drum in order to receive the batch when discharged.

In the "Smith Hand-mixer" (Fig. 101) made by Messrs. Stothert and Pitt, Ltd., the mixed concrete is discharged on to a board placed ready to receive it, or into wheelbarrows. In the latter case it is advisable to remove the wheels, placing the machine on timbers sufficiently high to allow wheelbarrows to pass underneath and receive the charge. When desired, the mixer can be placed so as to discharge its contents into a trench, and being portable can readily be moved along as the work progresses, discharging each batch exactly where required. Two men are required to drive this mixer, which has a capacity of $3-3\frac{1}{2}$ cu. ft. of unmixed material, and an hourly output of $2\frac{1}{4}-3\frac{1}{2}$ cu. yds. of concrete.

Power-driven mixers have replaced the hand-driven machines for all except the smallest jobs, as they not only mix a larger quantity of concrete at a time with greater certainty, but they can be arranged to discharge it precisely at that part of the road where it is required. Power-driven concrete mixers are of two chief types, (a) continuous and (b) batch mixers. Continuous mixers are seldom satisfactory for road-making, as the conditions are not usually favourable; batch mixers should, therefore, be used in most, if not all, cases. In a batch mixer, definite measured quantities of all the ingredients are placed in a hopper or skip provided for the purpose, and this quantity of material—termed the batch—is introduced into the mixer, in which is added a definite and proper quantity of water. When the process of thoroughly incorporating the ingredients is complete the mixed material is then completely discharged from the mixer, which is ready to receive the next measured batch which has, meanwhile, been prepared in the hopper or skip previously mentioned.

Mixers which are especially adapted for road-making have been developed to a very satisfactory and economical point. The introduction of the material into the mixing drum usually requires its elevation to a considerable height; therefore, most of the satisfactory road mixers are equipped with some type of power-operated elevator. They are also equipped with means for

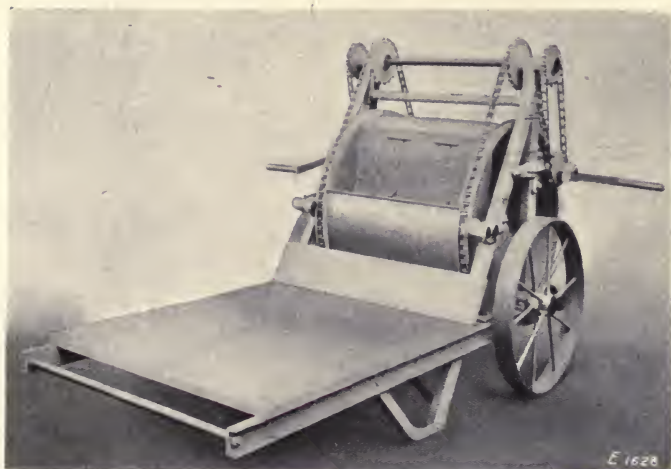


FIG. 101.—Smith Hand Mixer.

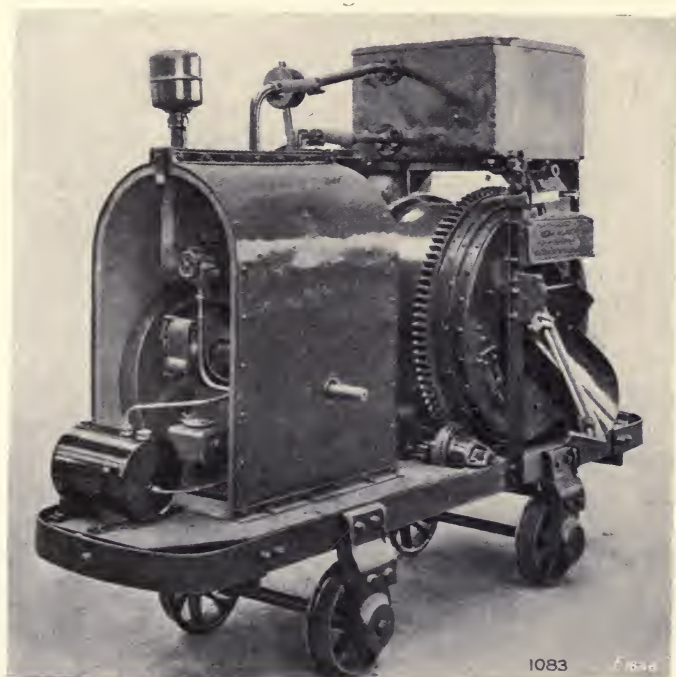


FIG. 102.—Ransome Self-Contained Mixer.

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FIG. 103.—Ransome Mixer.

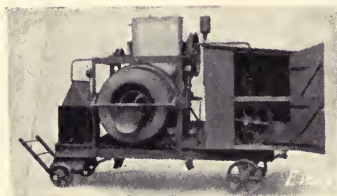


FIG. 104.—Victoria Mixer.



FIG. 105.—Rex Mixer.

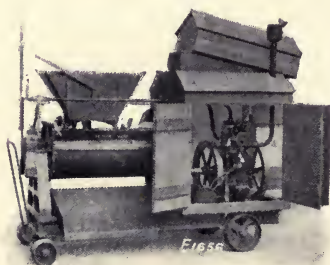


FIG. 106.—Winget Mixer.



FIG. 107.—Winget Chain Spades,

mechanically distributing the concrete after the mixing is completed. This is accomplished by means of a pivoted chute into which the material is dumped from the mixing drum. A wider range of distribution can be effected by means of a boom and bucket arrangement. These booms are made in varying lengths to 25 ft. A bucket attached to an endless rope is drawn in towards the mouth of the mixing drum and receives its charge; the winding gear is then reversed and the bucket drawn out along the boom to the point of discharge, where an automatic trip arrangement causes the bottom doors of the bucket to drop open. As the boom is pivoted so that it will swing through 180 degrees, a very large area can be covered. Since road work requires that the mixer should be moved frequently as the work progresses, it has been found advisable on most paving mixers to arrange for power traction derived from the engine which operates the mixing drum. Certain types of mixers are also arranged so that from the same source power is derived for steering the machine during the moves.

Mixers of the above type can be supplied by the Ransome Machinery Co. Ltd. (Figs. 102 and 103), by Messrs. Stothert & Pitt, Ltd. (Figs. 104 and 108), Messrs. Gaston, Ltd. (Figs. 105 and 109), and by the Allied Machinery Co., Ltd. (Figs. 113 and 114).

The "Winget" Mixer, which has a capacity of 3 cubic feet, has been fitted with special mixing arms (in place of the chain spades illustrated in Figs. 106 and 107) for wet concrete, and is as suitable for road work as for site concrete and trench concreting.

Laying the Concrete

The mechanical devices employed in laying the concrete on the roadway include: (i) The forms or shuttering boards which prevent the material from flowing outside the prescribed limits and also determine the thickness of the layer of concrete; (ii) distributing devices used for applying the concrete to the road surface; (iii) the devices used for spreading the concrete.

The forms or shuttering boards are held in position by clamps of any convenient pattern. As wooden forms easily warp, they can only be used a limited number of times and are more costly than appears at first sight, it is usually more economical in every way to use steel forms, such as the Blaw forms, made in America, but which may be obtained in this country. These are shown in Figs. 110 and 112.

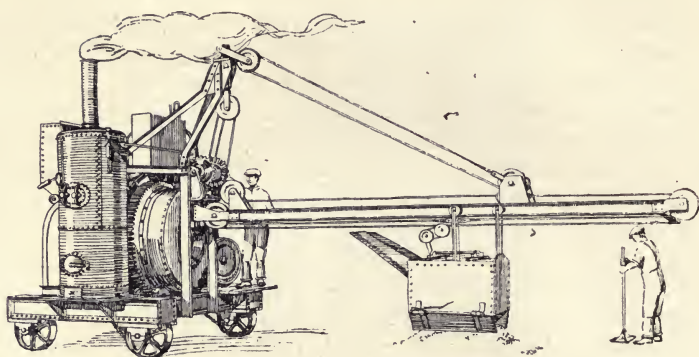


FIG. 108.—Victoria Mixer with Bucket Distributor.

Tamping and Finishing the Concrete

In the United States, a self-propelling template and tamper (see Fig. 115) is sometimes used. This is now being introduced into the United Kingdom by the Allied Machinery Co., Ltd. At the front of the machine is a strike-off board which levels up the concrete, leaving the surface about half an inch high, a power-driven tamping-bar then consolidates the concrete, and a power-driven belt finisher at the rear of the machine smooths up the surface to a trowel finish.

The surface of a concrete road may be finished with a wooden float or trowel applied by hand, the workman kneeling or lying on a suitable "bridge."

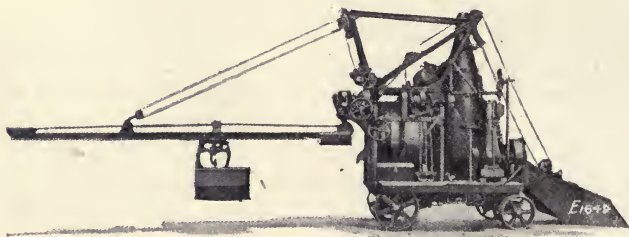


FIG. 109.—Rex Paver,



FIG. 110.—Special Road Forms.



FIG. 111.—Use of Lute to place Concrete.



FIG. 112.—Special Road Forms.



FIG. 113.—The Milwaukee Paver, showing method of loading.



FIG. 114.—The Milwaukee Paver, showing method of discharging.

It is, however, preferable, when a sufficient length of roadway is constructed to justify the expense, to mount the bridge on end wheels, and to provide it with a simple propelling mechanism. A particularly effective arrangement developed by the Walker-Weston Co., Ltd., 7 Wormwood Street, E.C.2, used in constructing concrete roads at the Victoria Docks of the Port of London Authority, is so arranged that once the road-bed is graded and the reinforcement laid thereon there is afterwards no necessity for any machines or men to stand on the road formation (see Figs. 116 and 117). It consists of a light timber framework structure completely spanning



FIG. 115.—Showing self-propelling Template and Tamper.

the whole width of the road, and carried on either side on a bogie mounted on rails. One bogie mounted on a track of 4 ft. 8½ in. gauge carries an electrically-driven concrete mixer, and also an electric motor driving a pair of friction winches. The bogie on the other side of the road is mounted on a 24-in. gauge track and carries the other end of the framework. This framework is covered over with tarpaulin, and its interior can easily be lighted or heated so that work can proceed, if necessary, by day and night, and also in frosty weather. To the under side of the ridge of the framework structure is attached a cableway actuated by friction winches, by means of which the concrete skip is conveyed from the concrete mixer to any part of the road under the "tent." Boards laid opposite each other, transversely across the "tent," form a platform or bridge on which stand the two men who work

the strike board for smoothing the concrete surface. Roads 30 ft. wide are "struck" or screeded in three strips, and when screeding the crown or centre strip, each end of the board rests on two fixed

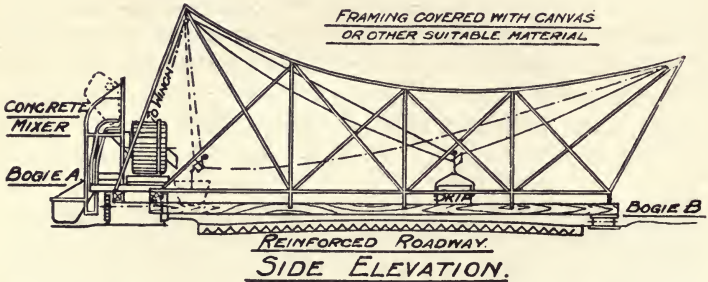


FIG. 116.—Road-laying machine used for concrete by the Port of London Authority.

angles carried transversely across the base of the "tent" and parallel to the longitudinal axis of the road. These angles are easily adjusted

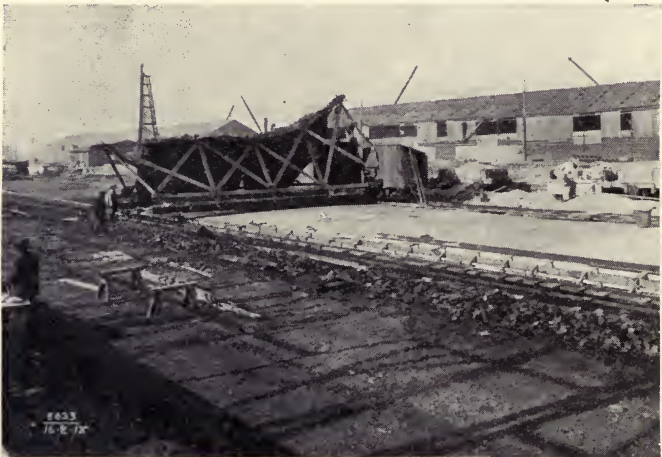


FIG. 117.—Reinforced concrete road in course of construction, showing the Road-laying Machine in use.

and fixed to the correct height to enable the board automatically to strike off the surface to the correct level. The strips of road on each side are treated in a similar manner, with the exception that

the gutter-end of the board rests on a board fixed to pegs in the ground and graded to the levels required for the gutters.

Some engineers prefer to finish the surface by rolling, using a roller made of light sheet steel 8 in. diameter and 6 ft. long and weighing about 70 lb. The roller has a handle of such a length that the operator can stand at one side of the road and push or draw the roller completely across it, or two ropes may be attached to the shaft of the roller, so that it may be drawn across the road by a man on each side of the latter.

The roller should not cross the road at right angles, but at such an angle that it advances about 2 ft. along the road at each crossing. It is usually necessary to roll the surface three times in this manner.

An alternative method consists in drawing a belt of rubber or rubber-faced canvas at least 2 ft. longer than the width of the road and 8-12 in. wide, to and fro and longitudinally across the surface. The belt should be moved in strokes about 12 in. in length, across the road, the movement along the road longitudinally being very slight. In a second, similar application of the belt, the strokes should be quite short—only about 4 in.—and the movement along the road much greater than before.

A popular method of finishing road surfaces in the United States is a combination of the two processes just described.

REINFORCEMENT NOTES.

The roads at the following places mentioned in this volume were reinforced with the **British Reinforced Concrete Engineering Company's Fabric**: Abergavenny, Bath, Belfast (3), Buckhurst Hill, Cardiff, Chester (3), Chisledon, Deptford, Dunfermline, Gravesend, Greenhithe, Loch Doon, Longhoughton, Melbourne, Mountnessing, Newbury, Newport—Cardiff, Portsea Island, Purfleet, Southampton, Swindon, Sydney, Taunton, Tilbury, Totnes—Paignton, Tredegar.

The **Expanded Metal Company's Rib Steel Reinforcement** was used in the following roads: Roberts Lane, Chester; Marine Drive, Exmouth; Fish Quay, Padstow; and on the sea front, Sidmouth.

Triangle Mesh was employed in the B road Portsea Island Gas Works, and Goods Yard, L.B. & S.C. Ry., East Croydon.

The **Walker-Weston Patent Pyramidal Interlocked Reinforcement** at the Royal Victoria Dock (Port of London Authority).

The other roads were reinforced on non-proprietary systems.

CHAPTER VII

CONCRETE KERBING

CONCRETE kerbing and channelling have been used extensively in many of our counties, and the practice adopted by surveyors in Surrey, Brighton and Aylesbury, may serve as a useful guide as to the method for making kerbs of concrete.

Aylesbury.—Mr. W. H. Taylor, Borough Engineer and Surveyor of Aylesbury, gives the following account of concrete kerbing in his district :—

The Aylesbury Corporation have made concrete kerb and channelling for the past eight years. The kerbs are 5 in. by 10 in. by 3 ft. long, and the top face is chequered to give a good foothold. At the commencement the kerbs were cast in wood moulds, but after a time the moulds became warped and iron moulds were obtained.

The channel-blocks are 9 in. by 4 in. by 15 in. long, and the upper face is slightly dished. They are cast in wood moulds face downwards.

The materials used for making both the kerb and channel-blocks are one of Portland cement to three of Cleve Hill granite chippings $\frac{1}{4}$ in. to dust. In mixing the materials, great care is taken, as it has been found from experience that this is most essential, or the results are not so good.

The aggregate is measured and well mixed with the cement both before and after the water is added. As the moulds are being filled the material is rammed gently by means of a small wood rammer, and if this is done a good surface is obtained.

Many thousand yards have been laid and the first length is still excellent.

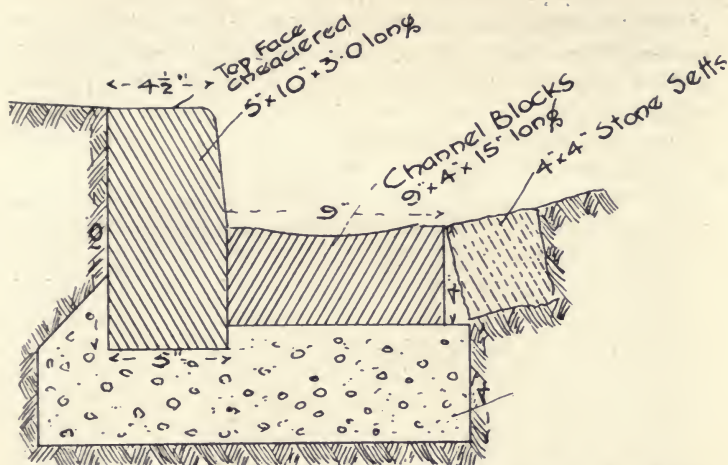


FIG. 118.—Concrete kerb and channel in the Borough of Aylesbury—Section.

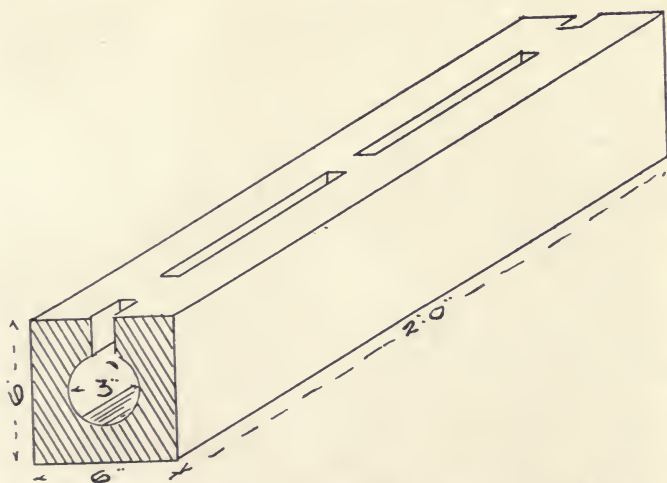


FIG. 119.—Concrete pavement gutter in the Borough of Aylesbury.

Pavement Gutters.—During the War it was found impossible to obtain iron pavement gutters and therefore experiments were made with concrete gutters. They are cast in a wood mould with a 3-in. iron pipe running through the mould. If care is taken in the casting and when being fixed they are found equal to iron gutters. Fig. 119 shows a gutter of this type.

Brighton.—In 1878 the Corporation commenced making concrete kerb and “pitchers,” and the first street was laid with concrete kerb and pitchers in that year. Since that date many streets have been laid with that material.

The kerbs and pitchers have been made in the Corporation’s own stores in iron moulds by hand and without pressure, the kerbs 30 in. by 11 in. by 5 in., and pitchers 18 in. by 6 in. by 4 in. They have been found to be a very useful and cheap substitute in the case of roads having ordinary traffic. They were at first made with beach shingle and cement, 3 parts shingle, 1 part sand, and 2 parts cement, but afterwards, owing to the slippery nature of the shingle, granite was substituted. These, with granite, were made at a cost of 8*d.* per foot lineal, against Purbeck stone at 1*s.* 3*d.*, and granite at 1*s.* 6*d.*

Concrete slabs were also made by hand, and the first were laid in 1881 in one of the busiest streets of the town and are still in existence; York stone laid adjoining has been replaced on two occasions.

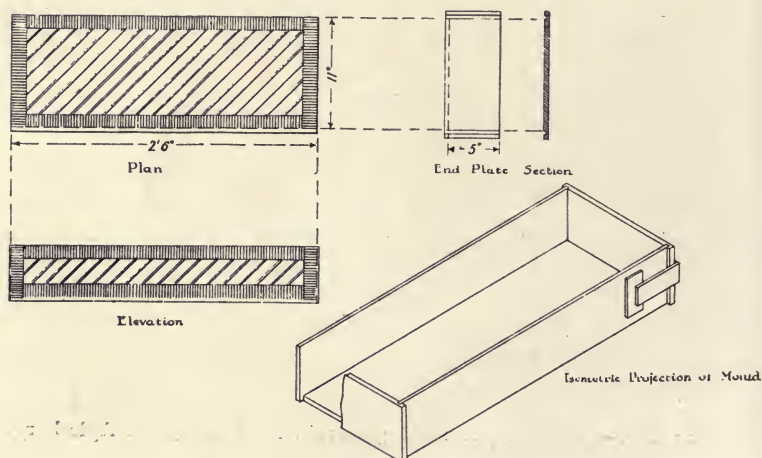


FIG. 120.—Moulds for kerbs at Brighton.



FIG. 121.—Concrete kerb and pitcher, and cement paving laid in 1878, in Brighton.



FIG. 122.—Concrete kerb laid in 1881 (and cement paving laid later), in Brighton.

Concrete has been much used in Brighton. The wall at the south side of Marine Parade was built in lime concrete by a local builder in 1830-1834. This wall, in places, is 50 feet high, has a batter on the face of 1 in 6, is 2 ft. thick at the top, and the back is vertical. This cost about £100,000.

The first cement concrete groyne for sea defence was built in 1865, and at the present time all the wooden groynes have been removed and concrete groynes substituted.

Surrey.—Mr. Alfred Dryland, M.Inst.C.E., late County Surveyor of Surrey, now of Middlesex, has furnished us with the following interesting details and illustrations of the method adopted by him :—

The first kerb put down in Surrey was a reinforced concrete submerged retaining wall or abutment to the carriage-way, and was evolved from considerations of, and investigations into, the apparent weakening of the road crust at the sides by movement or "creep" in the cross-fall direction where the roadside wastes were soft or the ditches unpiped, and was primarily intended to remedy such defects as arose from this cause. The kerb was laid *in situ* and was 9 in. deep by 4 in. wide and reinforced with two steel rods $\frac{1}{4}$ in. diameter in the positions shewn in Fig. 123.

The kerb was put down to levels to coincide with the finished top or carpet coat of the carriage-way when laid. A trench 8 in. wide was excavated to required depths and 9 in. by 2 in. deal shuttering held in place with iron road-pins was fixed in proper position four inches apart. Concrete composed of four parts clean crushed ballast to pass half-inch mesh sieve, two parts clean sharp sand and one part British Standard Specification Portland cement (all measures by bulk) was deposited between the shutters and tamped and trowelled off on top and the reinforcing rods inserted in their proper positions as the work proceeded. The shutters were painted with soft soap and were allowed to remain for three days, when they were removed without difficulty and without detriment to the concrete kerb, which was immediately covered over with a small mound of earth and left to set for at least 28 days. Where the ground was sufficiently deep and compact and could be cut in a straight regular face, no shuttering was used on the back face. At bends or curves in the road 9 in. by 1 in. shutters were used to obtain an easy sweep. The kerb was continuous and being practically submerged, and therefore not liable to great changes in temperature, no expansion joints were con-

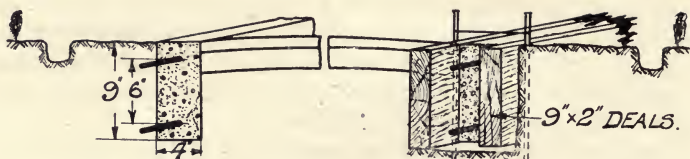


FIG. 123.—Method of constructing submerged concrete kerb in Surrey.

sidered necessary, this conclusion being substantiated by the total absence of cracks, damage, or movement so far as observations can detect. This retaining kerb performs its functions successfully and is one to be recommended in rural areas where building developments are slow. For use upon main roads and others in districts where, in anticipation of housing schemes, footpaths are essential in the completed road, an elaboration of this kerb was adopted, and is designed not only to retain the road crust but also to keep traffic within the boundaries of the carriage-way and form an edge to the footpath. It is shown in Fig. 124.

The trench in this case is dug 9 in. wide and generally to a depth of fourteen inches below the intended path level, and a layer of concrete 9 in. wide and 5 in. thick composed of five parts ballast to pass a 1-in. mesh sieve, two parts broken clinker and ashes, one part clean sharp sand, and one part Portland cement, is laid in the trench. The shutters, which are again 9 in. by 2 in., planed on one face, and coated with oil or soft soap, are secured in position on this bed of concrete to show 5 in. between faces. The reinforcement is fixed in the line of neutral axis on a vertical plane in order to resist as far as possible reversals of normal stress which undoubtedly occur, and although not in conformity with theory, it was contemplated that in this position it would oppose the necessary tensile resistance to any bending and unbalanced stresses brought to bear upon it in any direction and avoid the cost of two lines of reinforcement. It consists of a strip of "Exmet" expanded metal $\frac{3}{4}$ -in. diamond mesh 9 in. wide, cut in lengths of about 16 ft. for convenient handling. To ensure continuity of the reinforcement an overlap of about 2 in. is arranged at each join, but to provide for expansion of the concrete, joints are made at every 15 to 18 ft. by introducing a layer of tarred felt into the cross section of the kerb. This is slit and passed over the reinforcement. Five to one concrete is then poured in to such a height as will bring the kerb

to road level, and above the road level a three to one concrete consisting of one part $\frac{1}{2}$ -in. crushed ballast, one part $\frac{1}{8}$ -in. to dust granite chippings (to give "case hardening"), one sand and one Portland cement, is added and tamped against the shutters and smoothed off on top. To eliminate the sharp angular edge a chamfer is trowelled on the kerb about one inch wide, or to effect the same purpose a hard wood fillet can be nailed to the front shutter. On gradients where traffic in many instances uses the kerb to form a "drag" upon the vehicle, a protecting steel strip is embodied in the kerb immediately below the chamfer. It is

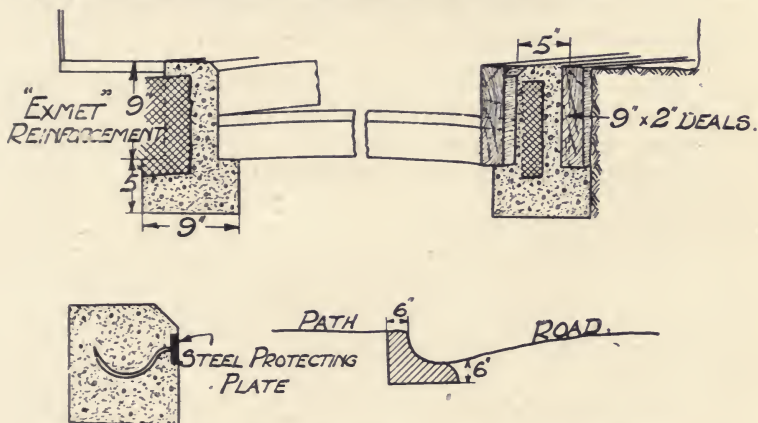


FIG. 124.—Method of constructing concrete kerbs in Surrey.

$1\frac{1}{4}$ in. by $\frac{3}{16}$ in., and is secured every 2 ft. by bent wire nails as shown in Fig. 124.

The nails are countersunk into the steel and are finished flush, so that no "bite" can be got of them by wheels, which would cause damage difficult to repair.

It is essential when removing the shutters to cover over the kerb for at least a month to ensure thorough setting, as it is subjected to a considerable amount of grinding and buffeting from the wheels of vehicles. Many miles of this kerb have been laid and give every appearance of proving entirely successful, both from a constructional and financial point of view, the cost at present prices being little more than one-third the cost of granite. For this class of work a gang of eight men is required, and, when experienced, 50 to 60 yds. per day can be averaged. The shutters can

be used many times over, and by hooping the ends before use the life of the boards is greatly increased.

Integral Kerb.—Where concrete footpaths are laid, a method more recently adopted is that of forming the kerb *in situ* as part of the footpath itself. This is done by erecting a planed 3-in. plank along the kerb line in a trench, the kerb and paving being laid together with a joint every six feet. In this method the greatest care is required in the alignment of the planks. They must be very rigidly supported with stakes, or bulging will occur. The cost is rather less than when the kerbing is moulded separately.

There are many other examples of concrete kerbing which could be mentioned, as this class of work has been carried on for many years. In Gravesend and Northfleet, for instance, concrete kerbs were put down more than thirty years ago.

CHAPTER VIII

SUGGESTIONS FOR A FORM OF SPECIFICATION FOR CONCRETE ROADS

IN submitting the following suggestions, it must be clearly understood that they are put forward more in the light of a useful guide when drawing up a specification for making concrete roads, than laying down any hard and fast formula.

There will always be found, from time to time, certain conditions in road construction requiring special treatment, and undoubtedly these are matters which will naturally engage the close attention of the road engineer, surveyor or contractor in charge of the work. It may be stated, however, that the suggestions set out have been compiled after much study and observation of concrete road work in this country, and in addition, valuable aid has been rendered by those who have had considerable experience in the most modern and successful methods of concrete road-making in America. These notes are, therefore, presented in the full belief that they will be found reliable and instructive in framing the definite principles of a specification.

Materials

- 1. Cement.**—The cement shall be supplied by a British manufacturer of repute, and shall comply with the requirements of the British Standard Specification for cement in force for the time being. It shall be of the "slow-setting" quality as defined in that specification. Conditions as to testing, delivery and storage shall be agreed between the vendor and purchaser.
- 2. Aggregates.**—Great care shall be taken in the selection of the aggregates. The actual materials to be used must depend upon local circumstances, subject to the following limitations:—

No natural deposits of sand and gravel shall be used without washing, screening, and grading to comply with the conditions hereinafter laid down.

If crushed stone is used it shall be screened, graded, and, if

necessary, washed, to comply with the conditions hereinafter laid down.

No aggregate shall be used which is not hard and tough, or which is laminated, and upon crushing breaks down into flat or elongated particles. Soft or porous materials, such as broken brick, breeze, etc., shall be prohibited.

All aggregates used shall be clean and free from clay, dust, vegetable and other foreign matter. Care shall be taken that the aggregate is not contaminated with mud, etc., after delivery to the site of the work.

Coarse Material.—For one-course roads no aggregate shall be used which will not pass through a screen having square openings of 1 in. ; but for two-course roads the bottom course may contain aggregate the largest stones in which will pass through a $1\frac{1}{2}$ -in. square opening. None of the coarse material shall pass through a $\frac{1}{4}$ -in. square opening. The grading from the maximum to the minimum sizes shall be regular, and no material shall be used which contains a large proportion of stones of approximately one size.

Sand or fine material shall all pass through a $\frac{1}{4}$ -in. square opening, but not more than 10 per cent. by weight shall pass a sieve having 50 meshes per lineal inch. The grading from the maximum to the minimum sizes shall be regular, and no material shall be used which contains a large proportion of particles of approximately one size.

Representative samples of the approved coarse material and sand shall be retained by the surveyor in charge of the work, and all deliveries shall be required to conform strictly to such samples.

- 3. Concrete.**—The average compression resistance of not less than three test pieces of the concrete shall not be less than will comply with the following formulæ :—

When 4 weeks old :— $C\ 1 = 2,800 - 200\ V$, and

When 13 weeks old :— $C\ 3 = 3,600 - 200\ V$, where

$C\ 1$ and $C\ 3$ = compression resistance in lbs. per sq. in.

V = Volume of sand and coarse material per volume of cement.

For determining the compression resistance, tests shall be made on cubes or cylinders of not less than 6 in. each way. The preparation, setting and maturing of the test pieces shall, as far as possible, conform to the conditions that will obtain in the actual execution of the work, provided that care must be taken to see that the conditions for all test pieces are as uniform as practicable, and that none of them is exposed to frost during setting and maturing. The compression resistance of any test piece which gives such a

low result as to indicate a faulty specimen shall be eliminated in arriving at the average of the results for any test.

4. **Water.**—The water shall be fresh and clean, and shall be taken from a public drinking water supply or from other source of known purity.
5. **Reinforcement.**—All metal for reinforcement shall be free from oil, paint, excessive rust, or coatings of any character which will tend to destroy the bond with the concrete. The metal shall develop an ultimate tensile strength of not less than 60,000 lbs. per sq. in., and withstand bending when cold 180 degrees around one diameter and straighten without fracture.
6. **Joint Filler.**—Joint filler must be an elastic waterproof material, which will not lose these properties under extremes of weather conditions.

Preparation of the Existing Surface

7. **Foundation.**—The preparation of the foundation will necessarily vary with local conditions, and must be determined by the surveyor in charge of the work. Any necessary embankments or fills shall be executed to the satisfaction of the surveyor, and shall be thoroughly consolidated, so that there is no possibility of settlement at any point. Any soft or weak places must be excavated and filled up with hard stone or other suitable material, so as to obtain solidity equal to the remainder of the surface. The surface shall be finally rolled to the required contour with a roller of not less than 10 tons in weight. It should be noted that the use of concrete for the road cannot be assumed to do away with the necessity for a good and even foundation over the whole surface.

The surface thus prepared shall be regular and may be flat, or with a slight cross fall as may be specified by the surveyor.

When the road is not supported by kerbing on either side, a channel may be dug, longitudinally, immediately inside the edge of the prepared base, so that the concrete when placed has a cross section at this point as shown in Fig. 125.

Immediately before the concrete is placed, all foreign matter shall be removed from the prepared surface, which shall then be thoroughly watered.

8. **Drainage.**—Where local conditions require, a suitable drainage system shall be provided to the satisfaction of the surveyor.

Concrete

9. Proportions.—The coarse material and sand shall be used by volume in such proportions, one to the other, as are found by trial with several mixtures of the same total quantity measured separately, but of varying proportions, to give the least volume of concrete when mixed with the prescribed quantity of cement and tamped into a mould of known capacity.

For one-course roads not more than 5 parts of coarse and fine aggregate, mixed as provided, to one of cement shall be used. Generally speaking, where severe traffic conditions are likely to be met, the concrete for a one-course road should be in the proportions of 1 part of cement to $1\frac{1}{2}$ parts of fine aggregate and 3 parts of coarse aggregate. For two-course roads not more than 8 parts of coarse and fine aggregate, mixed as provided, to one of cement shall be used for the lower course, and not more than 3 parts of fine aggregate to one of cement for the upper or surface course.

10. Measuring the Materials.—The method of measuring the materials for the concrete, including water, shall be one which will ensure uniform proportions at all times. The cement shall be taken by weight on the basis that 90 lb. is equivalent to a volume of one cu. ft.

11. Mixing.—The concrete shall be mixed in a batch concrete mixer of an approved type. The mixing shall continue until the ingredients are homogeneous and plastic throughout. The drum shall be completely emptied after mixing each batch.

12. Consistency.—The quantity of water to be added to the concrete shall be such as to secure a plastic mixture which can be easily worked, and so that only light tamping shall be necessary to consolidate when placed in position. Care shall be taken to prevent an excessive amount of water being used, and the concrete shall not be so sloppy as to cause a separation of the coarse aggregate from the mortar during handling and laying.

Any concrete which has partially set before being placed in position shall not be used. To avoid waste from this cause, all concrete which is mixed ready for placing in position immediately before the dinner hour or other stoppage of the work shall be placed and finished before stopping. Under all circumstances as little time as possible shall elapse between the mixing of the concrete and placing and finishing.

Placing the Concrete

13. Weather Conditions.—So far as is practical, all work should be done during the summer months, but in the event of concrete roads having to be laid when the thermometer is below 39° F., care shall be taken that the sand and stone shall be heated before being introduced into the mixing drum, or that an intense heat shall be brought to bear on the concrete during the mixing process. During such weather conditions, after material is put in place on the road, care should be taken that it is thoroughly protected, preferably by tenting with canvas under which steam pipes or braziers shall be introduced to ensure that the temperature of the concrete will remain above freezing point until the concrete has had time thoroughly to set.

The concrete shall be deposited over the whole width of the road at one and the same time, except in cases where it is impossible to divert the traffic for the time being. The sides of the road, where there is no kerb, and the end of each day's work, shall be supported by a wooden or metal form sufficiently strong and properly supported to resist straining out of shape under the pressure of the concrete. All mortar and dirt shall be removed from forms which have been previously used, and the forms shall be greased or oiled before any concrete is deposited against them. The side forms shall remain in place until the concrete is set sufficiently hard to permit of the removal of the forms without damage to the edges. In removing the form at the end of the previous day's work, in order to resume operations the next day, very special care will have to be taken to see that the concrete is not damaged, and, furthermore, in beginning the deposition of concrete special care must be taken with the tamping of the concrete to see that the previous day's work is not disturbed or damaged in any way. This will, inevitably, be one of the most critical points in the road and will merit the very closest attention and supervision. If desired, joints filled with material complying with paragraph 6 may be provided between each day's work, but shall not exceed $\frac{1}{4}$ in. in thickness. The value of these joints, however, is not proved, and they undoubtedly introduce weak points into the road. Longitudinal joints similarly filled may also be provided alongside the kerb or channelling (if any) if desired.

14. Thickness.—The total thickness of concrete for both one and two-course roads shall be specified, and it will be found that, under average conditions, a total thickness of about 6 in. will probably be sufficient. The surface course of two-course roads shall be approximately 2 in. thick.

When a two-course road is being laid the upper course or wearing surface shall be spread on the lower course immediately after the latter is deposited and before it has begun to set.

15. Consolidation.—Immediately after being placed in position in a roadway, the concrete shall be struck off to approximate grade and camber and shall then be thoroughly consolidated to eliminate all voids and all surface moisture. This consolidation is to be effected by tamping or punning the surface of the concrete, either mechanically or by hand, or it may be done by rolling. In no event shall any tamping device be used which necessitates a penetration below the concrete surface.

16. Surface.—Failing the use of a mechanical tamper, the wearing surface shall be struck off to the finished contour by means of a double template, of which a suitable type is shown in Fig. 126. This template shall be drawn over the concrete with a combined longitudinal and transverse motion, so as to produce a surface free from depressions or inequalities of any kind, and this surface shall not afterwards be disturbed by floating off or in any other way. The finished surface shall have a cross fall only sufficient, in the judgment of the engineer or surveyor, to ensure that the surface water will pass off the roadway quickly, and shall not vary more than $\frac{1}{4}$ in. from true shape. It will be found that, at the most, a cross fall of 1 in 60 will be sufficient.

No cessation of work of more than an hour's duration shall be permitted, except at the end of a completed bay.

In cases where it is impossible to divert the traffic and the concrete has to be laid on one-half of the road at a time, the edge of the concrete in the centre of the road shall be left with a rough vertical edge, and immediately before filling in the concrete for the second half this edge shall be thoroughly swept, watered, and painted with a thin coat of neat cement and water in equal proportions. The concrete shall then be applied immediately.

17. Reinforcement.—The concrete may be reinforced with steel reinforcement of a type approved by the surveyor. When, in the opinion of the surveyor, reinforcing is necessary, such reinforcing should be equivalent to 0.05 square inch per foot width of the concrete. In cases where one-half of the roadway is laid at one time, the reinforcement should be carried beyond the centre edge of the concrete first laid so as to provide a positive connection between the two halves.

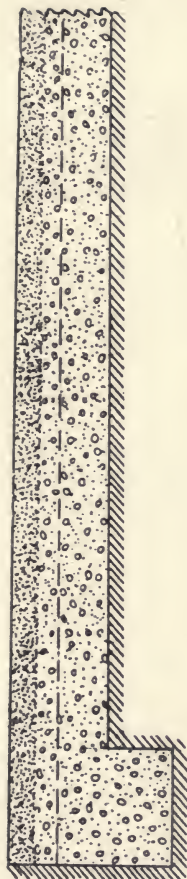


Fig. 125.—Cross-section of part of concrete road, showing suggested section of out-side edge where not supported by kerbing.

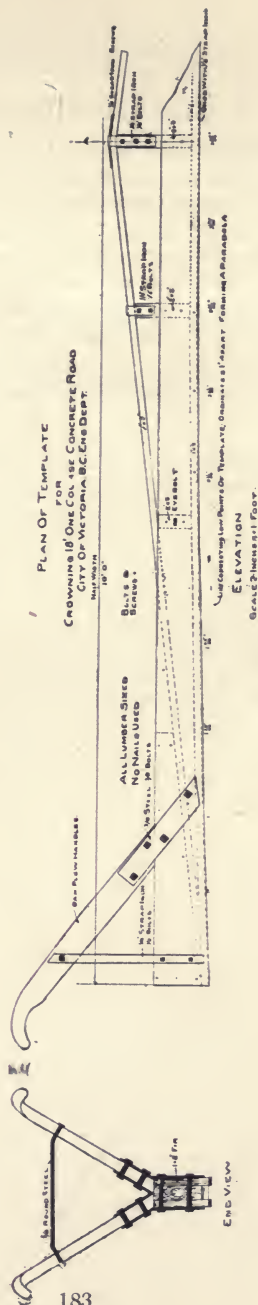


Fig. 126.—Showing Template.

This drawing shows one-half only of a template suitable for a road 20 ft. wide with a crown of about 1 in 45. It will be noted that the arrangement really comprises two templates, and the first template should be just a little higher than the second, so as to remove the bulk of the surface concrete but leaving the latter to do the real finishing. The template should be drawn over the surface with a combined cross-wise and longitudinal motion, making a longitudinal progress of about 2 inches for each transverse motion. Care must be exercised when approaching the end of a concrete bay to avoid damaging the edge and at the same time remove the surplus concrete. The second template must be set to the finished grade of the road and will give an excellent finish if the concrete is mixed to the right consistency.

The subsequent use of a wooden float is apt to produce flat or hollow places on the road surface and for this reason is not recommended.

Curing and Protection

18. Watering Surface.—The surface of the concrete shall be sprayed with water as soon as it has sufficiently hardened to withstand pitting, and shall be kept wet until covered as hereinafter provided.

The surface of the concrete shall be covered within 24 hours with clay, earth or other easily obtained material, which shall be kept thoroughly wetted for a period of at least 10 days.

When sunshine, a drying wind, or other conditions make it desirable, in the opinion of the surveyor, the freshly laid concrete shall be protected by canvas laid on a wooden framing or other covering until set sufficiently to be watered and protected as prescribed.

19. Opening to Traffic.—Under the most favourable weather conditions the concrete road shall not be opened to traffic until at least twenty-one days after it is laid, and when the weather is cool or wet this period shall be increased for such additional time as may be necessary in the opinion of the surveyor.

Where the road is constructed in two halves owing to the impossibility of diverting the traffic, the traffic should not be concentrated on to the first half which has been concreted until at least thirty-five days after completion, or longer where weather conditions make it desirable in the opinion of the surveyor.

CHAPTER IX

THE USE OF CONCRETE FOR ROAD ACCESSORIES

Introduction.—In reviewing the constructional methods of the past, nothing, perhaps, will be found to be more striking than the large and ever increasing variety of uses to which concrete, during recent years, has been applied for the production of articles and structures of a permanent nature which were formerly made of timber, brick, iron or steel. The reason for this is undoubtedly to be found in the improved methods of making and handling concrete, which have resulted in a fuller appreciation of its superiority for many purposes, over other materials of which it is rapidly taking the place.

Structures or articles made of wood, iron, or steel, soon begin to deteriorate, and unless paint or other preservative is used will depreciate very quickly. Concrete, on the other hand, not only requires no paint or preservative of any description, but actually improves with age, becoming stronger and stronger over a long period of years.

Thus it will be seen that, although the initial cost of concrete may, in some cases, slightly exceed that of other material, this is more than compensated for by its great durability and low cost of maintenance.

If any evidence were wanting as to the efficiency and economy of concrete, it would be found in the extensive way in which the great railway companies and some municipal bodies have adopted this material for a large variety of uses, and for which purpose they have laid out and equipped their own concrete yards. In this connection special mention should be made of the work being done at Taunton by the Great Western Railway Company, who were the pioneers of this type of construction; at Exeter by the London & South-Western Railway Company; at York by the North-Eastern Railway Company, and many others which might be quoted. Excellent examples of this class of work may be seen at the Permanent Exhibition of Concrete Products which has been installed

at 143 Grosvenor Road, London, S.W.1, by the Concrete Utilities Bureau of 35 Great St. Helens, London, E.C.3.

No book on concrete roads would be complete without some suggestions with regard to numerous accessories to roadways which might well be made of concrete, and the following hints are submitted in the hope and belief that they will be of interest to the reader.

Pavements.—Modern requirements demand that the ideal footpath or pavement shall be smooth without being slippery, even, durable, clean and unaffected by climatic conditions. These requirements are met in a striking manner by concrete, provided that the material itself is of the first quality, and that the job be carried out in an intelligent and workmanlike manner. Little, however, need be said here about concrete footpaths, since these, either in the form of slabs or concrete laid *in situ*, are rapidly replacing those of other materials, and they have been so long before the public that their strength, durability and general efficiency have been convincingly proved.

Kerbs and Channelling.—This subject, a very important one, has been fully dealt with in Chapter VII.

Fig. 127, showing a tree-guard for pavements, illustrates another use for concrete as a substitute for iron. As will be seen from the photograph the tree-guard is in the form of lattice work, each bar of which is reinforced by a single steel rod.

Reference has already been made in Chapter VII to the pavement gutters produced in concrete by the Aylesbury Borough Council.

Culverts.—In connection with rural roads concrete culverts are coming into general favour. If constructed *in situ*, they should be built during the dry season, if possible, or the water may be diverted during their construction by building a dam above the culvert and conveying the water away from the work by means of temporary troughs or pipes.

A method often adopted is that of employing pre-cast culvert blocks or half-pipes, which, when cemented together, form the culvert. No reinforcement is used in structures of this nature. Fig. 129 is an illustration of this type of culvert.

Sewer Pipes and Water Mains.—Considerable economies can be effected and increased efficiency secured by the use of concrete sewer pipes and water mains. These are being adopted here and in various parts of the world with great success.

Concrete pipes are usually made either in vertical iron moulds, or are cast on the centrifugal method in horizontal moulds.



FIG. 127.—Tree Guard.



FIG. 128.—Manhole.



FIG. 129.—Culvert.



FIG. 130.—Telegraph Post.



FIG. 131.—Station Name-plate.



FIG. 132.
Lamp Post.

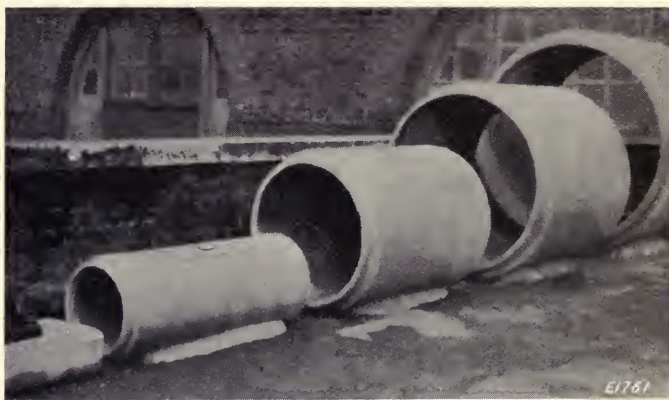


FIG. 133.—Concrete Pipes.

The advantages of concrete over iron for pipes are the low initial cost, and the fact that concrete does not corrode. Modern scientific research suggests that the corrosion of iron pipes is largely due to electrolysis; in a properly made concrete pipe in which the reinforcement is completely embedded this danger is eliminated, with the result that the life of such pipes is indefinite.

In order to avoid disturbance of the concrete roadway, in all cases where it is possible to do so, sewer pipes, gas and water mains and electric conduits should be laid under the pavement where they would be more accessible, and a minimum of interference with the traffic would be caused when repairs were necessary.

Manholes and Inspection Chambers.—Fig. 128 shows a concrete manhole. This, of course, could be moulded *in situ*, but a more convenient form of construction is that adopted in the case of the manhole shown in the illustration; that is to say, a series of pre-cast concrete rings which, when the excavation has been made, are lowered into position, one on top of the other until the surface is reached, the joints being grouted if necessary according to circumstances. It will be seen at once what a saving of time is effected by this method over the old practice of bricking up the manhole.

Inspection chambers may be constructed in the same way with pre-cast concrete blocks.

Fence Posts and Gate Posts.—The value and importance of good fencing are appreciated by all who are responsible for the enclosure of land and who know from experience what constant attention, time and expense are required in order that the fences may be kept in proper condition.

The material most commonly used for fencing is wood, but this is not only high in price and increasingly difficult to obtain, but, used for this purpose, it has a short life, is expensive to maintain, and is not fireproof. For these reasons, wood is being rapidly and extensively replaced by concrete since this material meets all the demands made upon it. The reinforced concrete post is reasonable in first cost, it may be made on the spot if so desired, local unskilled labour can be used in its construction, it may be moulded to any design, is hard and strong, does not decay, requires no painting, is fire-resisting, and with ordinary usage is practically everlasting; indeed, after a period of years when a wooden post would have to be renewed, the concrete post is stronger than when it was first put into the ground.

The utility and the economy of concrete for this purpose are demonstrated by the fact that this form of fencing is being adopted to an increasing degree by municipal bodies; and those who travel

by rail must have been struck by the great and growing mileage of concrete fence posts which are rapidly replacing wooden ones along the lines of practically all the companies. These facts point to the suitability of concrete fencing for rural highways.

Telegraph and Telephone Poles, Electric Light Standards and Transmission Poles.—Concrete, owing to its great strength and durability, forms an efficient substitute for iron or wood in the making of telegraph and telephone poles, electric light standards and transmission poles. In early days when poles of this description were made solid their great weight was found to be a disadvantage, but with improved methods of moulding and reinforcing these articles are made much lighter and their adoption is being rapidly extended. In addition to their low initial cost, the advantage of course lies in the fact that concrete does not decay as wood does, nor does it require painting, which is necessary in the case of the iron pole in order to prevent corrosion.

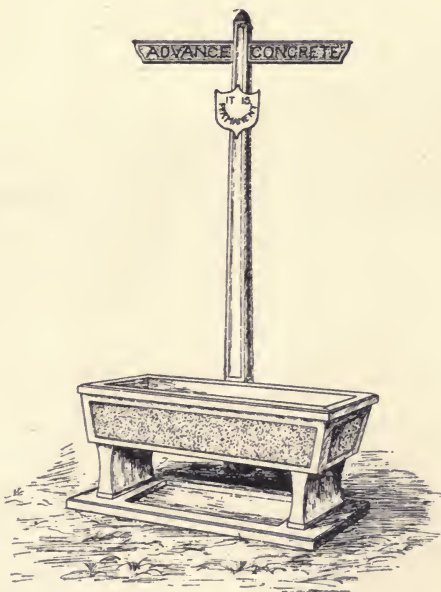
Lamp Posts.—Concrete being in its wet state a plastic material, is one which can be moulded to any shape. It is not surprising, therefore, that artistic lamp posts may be fashioned of concrete, and if properly made and suitably reinforced are an effective substitute for the iron post. This is a direction in which municipal authorities might, with advantage, adopt a method of construction which is at once efficient, economical and pleasing to the eye. Examples of concrete lamp posts may be seen at the Permanent Exhibition of Concrete Products to which reference has already been made.

An example of a concrete telegraph post and of a lamp post made by the L. & S.-W. Railway Company, are shown in Figs. 130 and 132.

Street Name Plates.—Street name plates can be made with advantage in concrete. It is not generally known that concrete can be made in any colour. In the case of the railway station name boards which are now being made of concrete, the lettering is of permanent black concrete on a light-coloured concrete background, so that no paint is required, and all that is necessary to keep the name plate clean and legible is an occasional wash. If this type of sign has been found to be satisfactory in the case of railway station name boards, why should it not be adopted for street name plates, which are easily made and if moulded on glass are perfectly smooth and polished ?

Road Signs.—Since concrete has been found suitable for railway station name plates, it can also be readily adapted for road signs,

whether in the form of direction posts or of the various cautions and danger signals adopted by the Automobile Association and Motor Union. These, as we have suggested, could be made entirely of concrete. Black letters on an approximately white ground would be sufficiently clear to the passing motorist, and the economy effected by the use of a material which needs no expense for upkeep should appeal to the authorities who have control of these road signs.



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The Daily Telegraph.

ENGINEERING NOTES.

DECEMBER 15th 1920.

In an interesting article on

REINFORCED CONCRETE ROADS

*The subject is referred to in the following
manner :—*

“The adoption of reinforced concrete in the construction of roads, although never taken up with the same enterprise in this Country as in the United States and Canada, is becoming more general, and amongst road engineers the opinion is gaining ground that if efficiently constructed of proper materials a reinforced concrete road is capable of proving very durable even under the heaviest of traffic and can also be made to present a surface upon which the necessary tractive effort is reduced to a minimum, which is an important matter relative to modern methods of motor transport. . . .”



**Patent Double-
Layer Interlocked
Reinforcement**



**for Concrete Roads
and
Foundations.**

This System is used by
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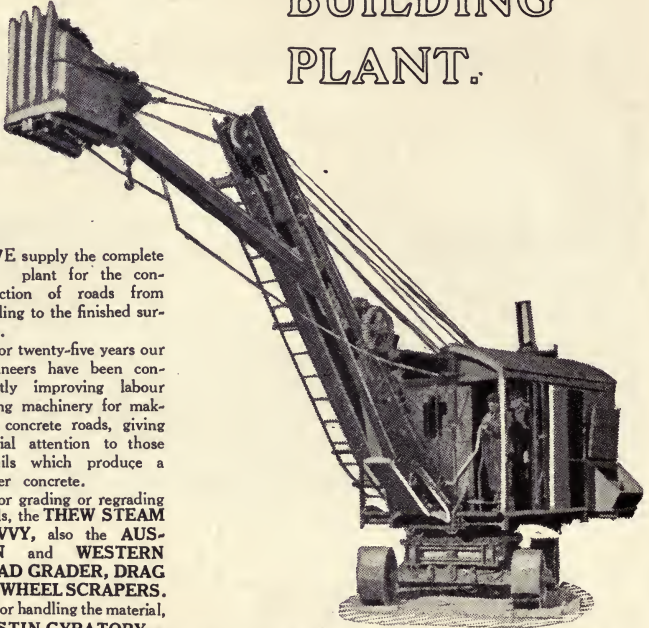
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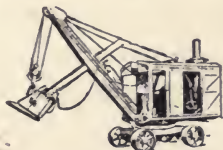
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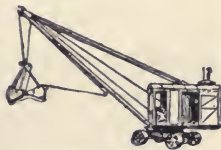
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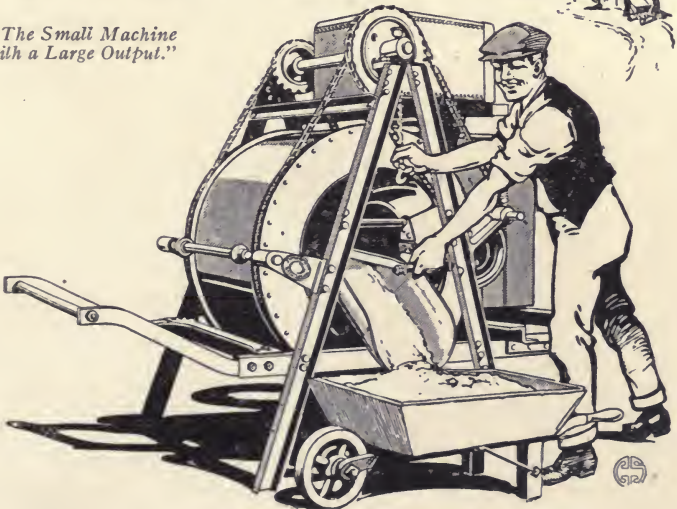
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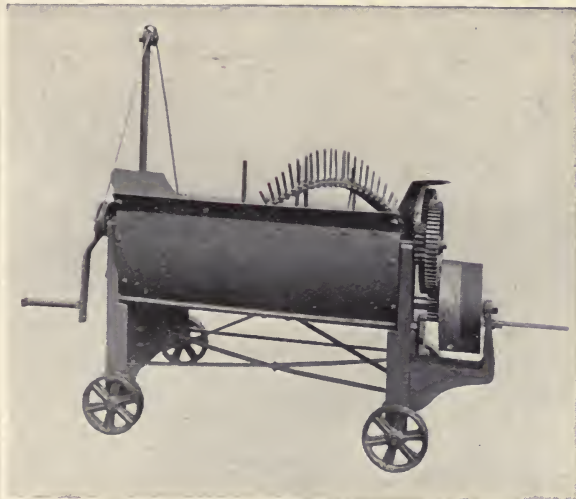
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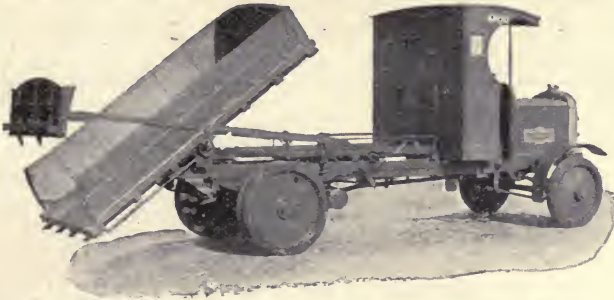
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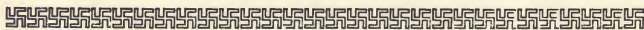


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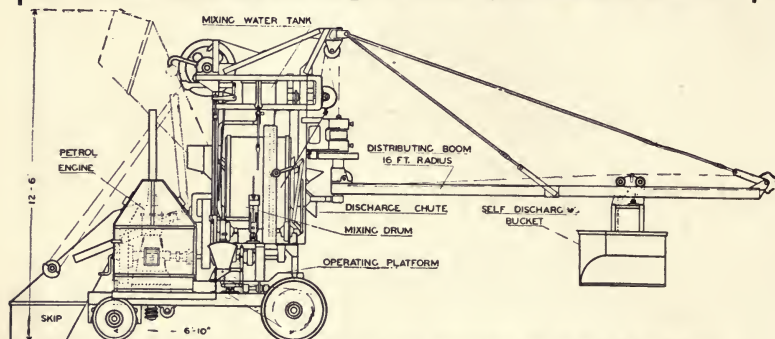
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