treated with refined coal tar, oil asphalt, and tar asphalt covered with sand or stone chips; coal tar stood best; at end of twelve months little of others left; recoated with coal tar and coarse sand half gallon to square yard; stood for twelve months at last Report.

Montgomery County, Maryland (1912):—

BRIEF SUMMARY OF FUNDAMENTAL PRINCIPLES.

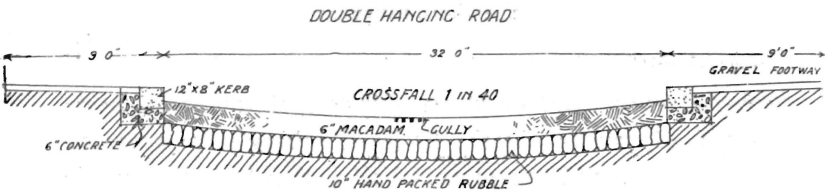
1. Drainage of road bed vital.
2. Sub-grade compacted and of uniform density.
3. Aggregates clean, hard and tough.
4. Fine aggregates (sand) coarse and graded.
5. Rich cement concrete.
6. Materials accurately proportioned.
7. Thorough mixing.
8. Sloppy concrete not to be used.
9. Reinforcement justifiable.
10. Thorough and intelligent supervision.
11. Protect concrete against rapid drying.
12. Traffic not to be allowed on too soon.

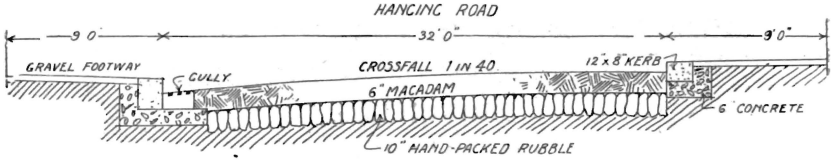
BRIEF ABSTRACT—SPECIFICATIONS.

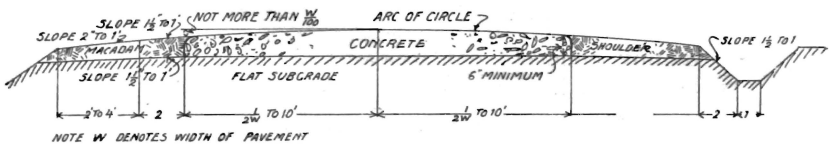
One-course Concrete Highway.—Materials.

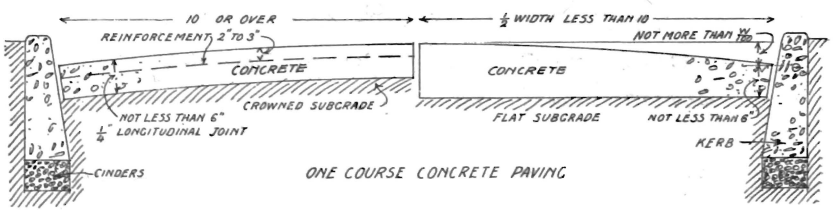
1. **Cement:**—Complying with requirements of British or American standard cement.

2. **Aggregates:—Fine Aggregate:** Natural quartzite, sand or crushed sand from hard and durable rock or gravel; must not contain more than 3 per cent. loam or clay; shall be free from vegetable matter; shall all pass through $\frac{1}{4}$ inch mesh, not more than 25 per cent. shall pass through mesh of 1-50 inch, not more than 5 per cent. shall pass through mesh of 1-100 inch; strength mixed with cement 1:3 at 7 days and 28 days to be equal to standard.









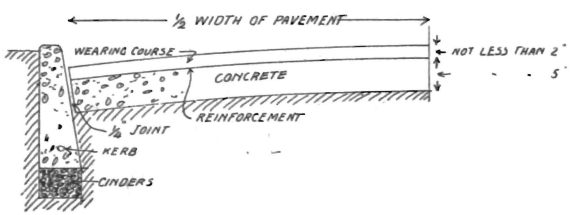


Fig. 4. TWO COURSE CONCRETE PAVEMENT OVER 20' WIDE

Coarse Aggregate: Clean, hard, tough, durable crushed rock or pebbles, free from vegetable or deleterious matter, soft, flat, or elongated particles; shall all pass through 1½ inch mesh, and not more than 5 per cent. shall pass through ¼ inch mesh.

3. **Mixed Aggregate**:—Crusher run stone, or bank run gravel, shall not be used; coarse and fine aggregates to be provided separately.

4. **Water**:—Clean, free from oil, acid, alkali or vegetable matter.

5. **Reinforcement**:—Free from excessive scale, rust, paint, or other coating which may destroy bond-adhesion of mortar.

6. **Joint Filler**:—Prepared strips of felt and bitumen, or similar material of approved quality ¼ inch thick; in joints protected by metal plates, joint filler shall be made to conform to cross section of pavement; where unprotected joints used, joint filler shall be at least ½ inch greater in width than thickness of pavement at any point.

7. **Joint Protection Plates**:—Of soft steel not less than 2½ inches in depths, and not less than ¼ inch average thickness, and to have rigid anchor plates.

8. **Shoulders**:—Shall be protected with approved material.

9. **Cuts and Fills**:—In cuts final grade to be determined after rolling with 5 to 10 ton roller; when fill of 1 foot or less is required, vegetable matter to be first removed; embankments to be constructed in layers not exceeding 1 foot in thickness full width between wide slopes, each layer rolled twice all over with 5 to 10 ton roller; no muck, soft clay, spongy or sloppy material to be used; all layers to be worked to finished contour.

10. **Drainage**:—Drainage ditches to be constructed prior to preparation of road bed.

11. **Subgrade:—Construction:** All soft, spongy spots of vegetable and perishable material, to be removed and made good with suitable material, subgrade to be rolled to firm surface by 5 to 10 ton roller, self propelled; subgrade to be sprinkled with water before rolling as may be required; old macadam of gravel road to be broken up, respread over full width, and rolled.

12. **Forms:—Materials:** Metal or wooden, if latter, to be 2 inches thick protected with 2 inch angle iron; secured by stakes, and to be clean, free from dirt or mortar.

13. **Pavement Section, Width, Thickness and Crown:**—The width, thickness and crown shall be as specified, but thickness at edges not to be less than 6 inches, and crown or versed sine not to be less than 1-100 or more than 1-50 of width, contour of finished surface to be the arc of circule.

14. **Joints:—Width and Location:** Transverse joints $\frac{1}{4}$ inch wide, perpendicular to centre line, not more than 36 feet apart, to extend through concrete, and to be perpendicular to surface.

15. **Joint Filler:**—To be inserted during construction.

16. **Protected Joints:**—Of steel plates, when used, to match on either side of joint, and not to vary from surface level of concrete more than $\frac{1}{4}$ inch.

17. **Unprotected Joints:**—When used, to stand at least $\frac{1}{2}$ inch above finished surface, and excess width to be trimmed to stand $\frac{1}{4}$ inch above surface before road opened to traffic.

18. **Measuring Materials:**—To be measured separately, also water; 94lbs. cement to be accepted as 1 cubic foot.

19. **Mixing:**—To be mixed in a batch mixer for at least 1 minute; mixer drum to revolve at rate of at least 12 revolutions per minute.

20. **Retempering**:—Not permitted.

21. **Proportions**:—1 part Portland cement to 2 parts fine aggregate to 3 parts coarse aggregate; quantity of fine aggregate never to be less than half volume of coarse aggregate; quantity of cement in 1 cubic yard of concrete in place not to be less than 6.8 cubic feet.

22. **Consistency**:—Such that mortar will not separate from coarse aggregate in handling, and such that concrete will hold its shape when screeded.

23. **Reinforcing**:—Pavements 20 feet or more in width shall be reinforced; weight not less than 28lbs. per 100 square feet; ratio of amount used each way may vary from 1:1 to 1:4; spacing or mesh not to exceed 8 inches; 25lbs. per 100 square feet may be used if reinforcing wires integrally secured, not by lashing; placed 2 inches or more from surface; to extend to within 2 inches of joints; fabric to be lapped at least 4 inches transversely and 12 inches longitudinally on road; heavier reinforcement for greater widths than 25 feet.

24. **Placing Concrete**:—Finish off subgrade to an even surface, and thoroughly wet. Spread concrete full width without cessation between expansion joints. When reinforced, top layer of concrete to be placed not later than 45 minutes after mixing of bottom concrete.

25. **Finishing**:—Surface to be screeded off with template, away from expansion joints, finish surface with wooden float operated from platform free of concrete; side edges to be rounded.

26. **Curing and Protection**:—While setting (24 hours or longer), cover surface with canvas; after setting keep moistened till hardened, then cover with 2 inches of earth, and keep moistened for at least 10 days; open for traffic in 14 days in hot weather, and longer in cool weather, but 4 weeks and 6 weeks preferable, respectively.

27. **Cold Weather Work**:—Operations shall be discontinued when temperature below 32 deg. F.

28. **Shoulders, Construction**:—When shoulders required, to be made on subgrade prepared as for concrete.

Two-course Pavement.

29. **Coarse Aggregate**:—As for one-course pavement.

No. 1 Aggregate: For wearing course, same as for coarse aggregate, but broken to pass through ½ inch mesh, and not more than 10 per cent. to pass through ¼ inch mesh.

30. **No. 2 Aggregate**:—For wearing course, alternative to No. 1, and same as above, but broken to all pass through 1 inch mesh, and not more than 5 per cent. to pass through ¼ inch mesh.

31. **Cement Required**:—A cubic yard of concrete base shall contain at least 5.6 cubic feet of cement; of "No. 1 Mix Wearing Course," at least 11.88 cubic feet of cement; of "No. 2 Mix Wearing Course," at least 8.4 cubic feet of cement.

32. **Proportions of Concrete for Base**:—Not less than 1 cubic foot cement to 2½ cubic feet fine aggregate, and 4 cubic feet coarse aggregate; volume of fine to coarse aggregate not to be less than 1 to 2.

33. **For No. 1 Wearing Course**:—At least 1 cubic foot cement to 1 cubic foot fine aggregate and 1½ cubic foot "No. 1 Aggregate for Wearing Course"; volume of fine to No. 1 coarse aggregate not to be less than 1 to 2.

34. **For No. 2 Wearing Course**:—Not less than 1 cubic foot of cement to 1½ cubic foot of fine aggregate and 2½ cubic foot "No. 2 Aggregate for Wearing Course"; volume of fine to No. 2 coarse aggregate to be not less than 1 to 2.

Note.—No. 1 and No. 2 are alternative.

REINFORCEMENTS

Theoretically best near wearing surface to withstand effects of temperature and moisture, and to strengthen haunches:—

Width, feet.	Weight per 100 sq feet.	Transverse Reinforcement in sq. ins. per ft. longitudinally.	Longitudinal Reinforcement in sq. ins. per ft. transversely.
16 ..	40 ..	.090 ..	.030
20 ..	45 ..	.100 ..	.030
30 ..	50 ..	.120 ..	.030
40 ..	60 ..	.150 ..	.030

Reinforcement placed 3in. below surface.

Where any doubt exists as to sufficiency of subgrade, it is always advisable to reinforce; and the above table gives weight of reinforcement recommended.

NOTES ON LOCAL CONCRETE ROAD CONSTRUCTION.

To 31st July, 1918.

In July, 1916, the Woollahra Council put down a length of 160ft. of reinforced concrete roadway on the New South Head Road, the width varying from 12 to 14 feet. This road was put down in two courses, and laid in alternate bays of 400 super feet each. The first course was 6in. thick (1:2:4), and whilst green the reinforcement (No. 11 B.R.C. Fabric) was laid on top, and was pinned into the bottom course with hooked spikes. The reinforcement overlapped at joints. Then the wearing course (1:2) was immediately placed and levelled off. The roadway was allowed to cure for four weeks before being opened for traffic. Another and much longer section was put down on Old South Head Road by the same Council a few months later. This section was composed of the same aggregate, and laid in two courses as on New South Head Road, but without reinforcement. This also was allowed four weeks to cure. After 12 months'

wear, this latter section was surfaced with tar and blue metal. This roadway was not as successful as the New South Head Road section, inasmuch as transverse cracking has developed, although this has not, so far, depreciated the wearing power of the road.

The New South Head Road section was laid in midwinter, and the Old South Head Road in midsummer, which may account somewhat for the transverse cracks in the latter work, due to too rapid drying and setting of the conerete, and consequent lack of key between the two courses. I understand the Woollahra Council is about to lay a concrete road on the New South Head Road at "Cranbrook," where a start is to be made in the scheme of widening this road throughout the whole length to 100ft.—an area of about 20,000 square yards of all concrete road.

The Public Works Department laid a concrete roadway on the Glebe Island Bridge approaches during February and March, 1917. This was laid in one course 6in. thick (1:2:4), finishing with a 1:2 topping, one-eighth blue metal screenings, and was reinforced with No. 9 B.R.C. Fabric, laid two inches from the bottom of concrete and overlapping at joints. The concrete was put down in alternate bays 50ft. in length for a total length of approximately 400ft. on both sides of tramway. This was allowed to cure for three weeks.

The traffic is very heavy on this roadway, and after 15 months' use the results are very satisfactory. No cracks appear anywhere, but in some few places there have been pockets, which may have been caused by faults in mixing, or through presence of foreign matters, which have had to be dug out and replaced with carefully mixed concrete, and those spots have given no further trouble. These faults occurred on the north side, and whilst the work was in progress sudden squalls came up, and the

heavy rain washed the dirt from the tramway right across the green concrete, and formed pools which had to be baled out. On the south side, which was laid a month later, no faults have shown. Malthoid was used at joints, and at the edges there is a tendency to break away, but this is not serious, as it is easily filled with a coating of asphaltum or tar and sand. Observation has been taken as to whether the surface had a tendency to greasiness in wet weather, but no signs have been observed; in fact, there is no record of a horse falling on the concrete section in wet weather, though they are constantly slipping on the adjacent wooden blocks. Neither has any skidding or swerving been observed with the motor traffic, which is very large.

The Sydney City Council has recently put down some small sections of concrete, both reinforced and unreinforced, the reinforcement used being plain bars. This work has been done, I understand, with a view of testing more particularly the wearing qualities of the concrete surface.

In Victoria a reinforced concrete road was laid in March, 1914, on the St. Kilda Road, South Melbourne. The subsoil is clay, subject to soakage from plantations alongside. Cinders were laid on the clay and well rolled. Concrete 6in. thick (4:2:1) was put down for a length of 33ft., width 24ft., No. 610 B.R.C. Fabric, laid 2in. from bottom, and a wearing pad ½in. thick of 1:1 (sand and cement) was put on top of the 6in. concrete, and afterwards tarred and sanded. Heavy motor traffic leading to the city is constantly passing over this road. Recently surface cracks are showing owing to the cold weather, and the richness of the cement mortar used, but in the springtime these will not be visible when the road is given a further coat of tar spray and sand.

o

On St. Kilda Road, St. Kilda, a further length of 100 feet was laid in February, 1916, consisting of the same aggregate and reinforcement. This was surfaced with Gilsonite (a bitumen compound) for 2in.; the traffic is also the same as on the first section laid.

The South Melbourne Council also put down a further section in March, 1916, adjoining the first section. This was reinforced with No. 67 B.R.C. Fabric. The concrete was the same as the previous section, and a wearing pad of 1in. 1:2 (sand and cement) was placed on top, and surfaced with tar and sand.

In January, 1918, the South Melbourne Council put down another section of reinforced concrete roadway at Yarra Bank Road. This is alongside the river wharves, and carries the heaviest traffic to wharves and engineering works, etc.

The subsoil is river silt. Five inches of 1:2:4 were laid, and then 2 inches of 1:3 (toppings and screenings) placed on top. This was reinforced with No. 10 B.R.C. Fabric, and surfaced with bitumen, but as this was laid in cold weather it peeled off. At present the surface is coated with distilled tar and sand, and shows no signs of wear, although the concrete was exposed for a month or six weeks. This test section is 50ft. x 50ft.

The aggregate for the concrete which was laid on the New South Head Road, Woollahra, was measured and mixed by hand close to the site, and then barrowed on to work. After tamping down, this was brought to an even surface by using a template (of wood), and then trowelled over to fill in any voids. The subgrade was well watered before work was begun, and on top of finished surface bags were laid and kept constantly wet for two to three weeks. The aggregate was composed of graded bluestone, gravel from overseas, and Portland

cement, but I have no data as to how the proportions were arrived at.

The cross fall of road is 1 in 12 for 2 feet from kerb, and 1 in 60 towards the tramway. To protect concrete at the junction of macadam and at side near tram, 2 inch jarrah wood was used, but this is not a success. Expansion joints were placed between the bays, but these were only for experiment, and were not repeated in the same way on the Old South Head Road, which, I understand, was laid with the same aggregate, but machine mixed, the aggregate being barrowed on to work and the machine placed as near as possible, and moved on as work progressed.

At the Glebe Island Bridge abutment the subgrade was well watered before starting with concrete. The aggregate was carted and dumped close to machine mixer, which was on the site of work, and then barrowed to the various bays. The concrete falling directly into barrows.

The concrete was well tamped down during the process of laying, and afterwards a template was passed over, and the surface trowelled. The aggregate was 1½in. and ¾in. blue metal mixed, Nepean sand and cement, finishing surface with topping of 1-8in. bluestone screenings in proportion of 1:2.

REINFORCED CONCRETE ROADS AT MILITARY CAMPS IN GREAT BRITAIN.

In July, 1917, a reinforced concrete road was constructed at Loch Doon School of Aerial Gunnery in Scotland, being about 16ft. wide and about 600 yards long.

The road was built across a peat moss, directly on the grass. The peat was drained, but previously it was practically a bog, and a man walking on it would sink up to his knees.

Macadam roads constructed close by, on rather better ground, gave a great deal of trouble, and were very expensive, in many cases having to be filled in layer after layer to a depth of several feet.

The road was constructed by the contractors, Messrs. McAlpine, to a special specification drawn up by The British Reinforced Concrete Engineering Co., Ltd., and was reinforced with B.R.C. Fabric. It was surfaced with tar spray and granite chips, and it was considered at the time that it would be as severe a test as possible for a reinforced concrete road.

In May, 1918, the camp was dismantled, and the Superintending Engineer wrote to the contractors as follows:

"You will be pleased to hear that the reinforced concrete road across the peat moss at Loch Doon has been an unqualified success. Continuous traffic of Foden steam waggons is going on at the present time, in connection with the dismantling work there, and loads of 10 tons on four wheels are being carried without the slightest detriment to the surface. If you have an official photographer in the district, I should be much gratified if you could have a couple of photographs taken of this road, which is in many respects unique."

At Manston, near Margate, a road was constructed of concrete 6 inches thick reinforced with No. 9 B.R.C. Fabric. This is at a camp, and was laid directly on the fields. The authorities coated the surface with tar spray and granite chips, and the road has had exceptionally heavy traffic continually passing over it.

The authorities required crushed cinders for the manufacture of concrete blocks, and crushed cinders on the road with the aid of a steam roller.

The road has shown no signs of wear, being as good as when first constructed.

Similar roads are in use in the United Kingdom, including Chiseldon Camp, in Wiltshire (over 1½ miles laid in July, 1915), and at numerous Seaplane Stations for the Admiralty, carrying all stores, equipment, ammunition, and machinery, etc.

Discussion.

MR. POOLE: I am sure we have listened to-night to one of the most admirable addresses that have been delivered before this Association. The lecture, which is very complete in detail, has been given by a gentleman who is an acknowledged master as a constructor of modern road pavements.

I shall not go into details of the address, but wish to confine my remarks to one or two points outside of what has been stated.

We look upon the Roman Road as the forerunner of our good roads, and it is remarkable that these excellent examples of road construction, and their great advantage to the State, were ignored through so many centuries in Europe. Good roads have been a necessity in the large military empires of the past. We now know from records that have recently been made available that in the old Persian Empire there was a great system of roads radiating from Babylon to all the important Provinces, such as through Asia Minor, through Syria to Egypt to the country which we now call Turkestan, and to the frontier of what is now Modern India.

Coming back to our own State, we are much indebted to that great master road builder, Governor Macquarie. Among his more important roads are the Main Western Road over the Blue Mountains, the Bathurst Main Southern Road to Goulburn, and that heavy, but almost forgotten undertaking, the Main Northern Road through Wiseman's Ferry to Maitland.