PAPER
THE ECONOMICAL ROAD SURFACE.

By J. T. Noble Anderson (Past President).

GENERAL ENGINEERING ECONOMICS.—The last word in all engineering activities is “will it pay?” and unless our clients find that our designs fit in with the dominant financial note, we labour but in vain.

Good work requires good materials, and the best workmanship. The initial difficulty generally is to persuade the callow client, who has to pay for it, that the cheaper article is in the long run the dearer. While in the case of the wealthy client, who has probably won his wealth by realising that stinting and saving is the worst economy, the difficulty is to persuade him that the dearest article is not always the cheapest in the long run.

“SUPPLY” SHOULD ALWAYS FIT “DEMAND.”—The temptation to the engineer to follow in the footsteps of pioneers whose methods, if successful, are almost invariably extravagant, and preach the gospel to clients, that the best is always the cheapest, is contemptibly weak, because the clients are only too prone to accept the American view, “the best is always what we want,” and from his own selfish viewpoint it is always profitable to follow safe precedents. The pioneers he will then choose to copy will be those whose works have won public approval. Works almost invariably full of features, which any intelligent engineer, following after and studying the lessons to be learnt from them, should be able to improve, make cheaper and simpler in design. To resist the temptation to copy precedent means that he must himself tread the narrow and difficult pioneer path full of pitfalls and dangers, rather than follow the broader track already supplied him by his engineering predecessors.

THE ROAD PROBLEM.—The first question is what is the extent and nature of the traffic which the road is to carry, and then what type of road will give the best value for the money which the traffic toll warrants. In every case one most essential item is draining the road bed, and if the road route is to be a permanent one, and not merely to meet a military or panic demand, it may be taken for granted that the economic aspect of the sub-draining and consolidation of road bed will permit of nothing but the most thorough work, because, even from the days of Telford and Brunel, it has been laid down as an axiom that unless road metal can be kept dry you cannot have a permanent road. This is not only true of a pitched road, but
also of the best consolidated macadam, and even of a concrete pavement, because in all of these there must be some movement in the bed below in response to the impacts of the traffic on the surface. Extending Newton’s "Every action causes its equal reaction," we see that whether the energy of the impact is absorbed by the elasticity of the road crust, or transmitted by a rigid crust on to the bed below, or, as to some extent happens in all road crusts, is most absorbed by a yielding plasticity in the material of the crust itself, it must spend the greater part of itself in friction between the solid particles of the pavement. It is found that in the solid materials used in road making there is little attrition when the friction is between dry particles. The real damage is done by the moisture. This was brought out by the author in a paper read before this Institute,* where he showed that the "ravelling" of macadam road which occurs after long spells of dry weather is really due to the grinding to powder of the harder materials during the previous wet winter, which no longer held together by a coating of colloid or other binding properties, works upwards and is finally sucked out by the contact of the passing tyres. This necessity to keep the road crust dry means primarily having a well-drained formation to bed it on, and secondarily, an impervious surface above it. It is to the latter that we will confine our attention.

Here then comes in the dual functions of bitumen. By painting and surrounding the solid ingredients of the road crust, it helps lubrication and so reduces frictional wear, but also when, as in the case of a bituminous concrete (black concrete) road, it is present in a sufficiently large percentage to fill all the voids, it prevents the travelling of moisture upwards into itself from the road bed below, as well as forming an impervious skin to keep out the rainfall from above. To some extent it would seem that the thorough sub-draining of the road may be unnecessary with this type.

This travelling upwards of moisture, formerly known as capillarity, is more active in proportion to the amount of foreign chemicals which may be present in the bed. Consequently, while ashes form an excellent bed, preventing too rapid changes from wet to dry, they must be regarded with suspicion if obtained from sulphurous coals. Where the author has found the steel reinforcement in a concrete road pavement to have eroded when this was not due to electrolysis, he unmistakably identified it with the sulphurous contents of the ashes on which the concrete was bedded.

*Vol. xvi., pages 104 and 105.
White versus Black Concrete.—The decision to use Portland cement or bitumen is a question of economics pure and simple, and too many factors enter into it to allow of its being satisfactorily dealt with in the present paper. Suffice it to say that since before the beginning of this century, so far as Australia was concerned, the old Telford pitched road had been displaced by the concrete base wherever heavy traffic justified road metal of one foot deep and upwards. Ten years ago the Bates Tests were inaugurated, one of the main points being to determine whether steel reinforcement of the road bed was worth while. It was then found that a sort of critical thickness of concrete at about seven inches worked out as the limit where steel reinforcement was worth while. Beyond that, the concrete stood up to the traffic equally well, whether reinforced or not.

For the heavily trafficked road, say 1000 tons a day on each 9 ft. wide carriage-way, it will probably be conceded that a high class concrete paving, not less than seven inches in depth, and sufficiently rich in cement to be practically impervious to water, is the proper material to pave the road. But the chief economical decision would then rest as to how this would be carpeted. Up to now, even with the fact that wood blocking costs fully twice as much as a good bituminous carpet, it has pretty generally been given the preference. Below this intensity of traffic the case for the black concrete is stronger, and the decision will probably depend very much on the character of the traffic, and the alignment of the road, as well as on the available materials.

In the present market a 2 to 1 cement mortar will cost about as much as a ton of a bitumen and sand mix, and whether made by grouting or by the sandwich method, the competition with black concrete will be fairly keen, and should be governed by other considerations than initial cost. An advantage of at least twenty-five per cent. in favour of the black concrete is obtained in first cost, chiefly because it will require less care in the preparation of the road bed.

Among the radical differences between the white and the black road paving is the nature of margin. Neither will give satisfaction without wearing margins to prevent the severe rutting which otherwise damages the edges of the road. In the case of the cement concrete road, this course should be rigidly set into the sub-base below the course of sand or cinders on which the concrete is bedded, as its office is double, primarily to prevent a dangerous rut alongside the road margin, but equally to prevent the squeezing out of, the foundation from beneath the concrete. Whereas, in the case of the bituminous road, the pitcher course requires to be just as rigid against the
spreading of the road itself. In America timber kerbs are much in use. Latterly, with the bituminous road, a continuous concrete band of several feet wide of white concrete has become rather popular in place of the older type of pitched kerb. These questions in construction are no doubt well worth the close investigation which everywhere is being given to them, but in these days of close economy none of us are likely to get the opportunity of such tests as the Bates Tests. Construction generally, therefore, is likely to slow down until the world wakes up to a fresh fit of enterprise. Meantime, the question of surface maintenance is all the more pressing.

The Chairman of the Victorian Country Roads Board, speaking in another part of this building the other day, said that what was up-to-date practice six months ago in this method of road surfacing is obsolete to-day. The Shire Engineer, who has to be responsible for hundreds of miles of unmetalled road, could not do better than read portions of the Digest of Papers read at the Sacramento meeting of the American Society of Civil Engineers on this subject, e.g., on page 1282, the expressed opinion of an eminent engineer is given that the investigation of colloids would probably develop a method of hardening or toughening of various soils. At present the surfacing of country lanes may be considered an open question, and the author will confine himself to what his recent investigations in Melbourne have dealt with, namely, the surfacing of macadamised or concrete city streets.

The material used as a surface carpet should be plastic, and consequently the inequalities of the resistant surface on which it lies must be repeated sooner or later in the carpet's surface corrugations, potholes, or ruts. In the case of the bare concrete crust, irregularities in the bed on which it lies will exaggerate the internal stresses, and hasten the development of the ultimate break up. This not only militates against the all-concrete pavement, but adds to its cost, because far greater precautions must be provided to care for joints than if the concrete bed is to be covered with a non-conducting, shock-absorbing carpet.

VARIOUS SURFACINGS WITH BLACK CARPETS.—Obviously only two classes of material is available for surfacing a black concrete road, with bitumen or rubber binding. Here the carpeting enables a smoother surface and consequently diminishes the wear, as well as improves the tractive value of the road. Only where the grades are too steep should a black concrete be left bare—the treatment there being to secure a rough in place of a smooth road. Examples of purposely roughed roads
may be seen in Collins Place, Melbourne, and in the new privately paid for road in Upper Macedon, Victoria, where grades up to 15 per cent. are bitumen coated.

In the case of waterbound macadam, if it were only from the point of dryness, waterproof the upper surface with a black carpet is always worth while. Here the material should be either to cut back bitumen, or a thoroughly stillled (24 hour) coal tar prevented from becoming pitch by a cut back oil or more volatile tar being introduced while hot. Several proprietary articles which seem of considerable promise are now on the market, and, in winter, emulsions may be used.

The better the consolidation of the road the higher the penetration pressure will require to be. The cheap penetration, more properly called painting, on a road already thoroughly consolidated after a thorough cleaning with brushes, will not take more than a gallon of tar to every three square yards. A sort of carpet is then obtained by spreading ½ inch screening and finally salting over with a siliceous sand. In the case of new macadam roads by the penetration treatment, if more than one gallon of tar is used, including the carpeting, then the road will not be good, because the original material has not had a sufficiently dense coefficient. Such badly consolidated road crusts should always be remade, as so many voids filled with oily contents will enable the solids to move too freely internally, with the result of longitudinal waving of the surface, which is so detrimental to the wear of the road itself, and so painful to the passenger.

However, whether it be a concrete road or a water-bound macadam road, unless the voids have been reduced to a minimum the labour has been in vain. So great is the value of a proper mix of the different sizes of the matrix, and so many firms have acquired a plant which enables them to give a thoroughly compacted roadcrust, that the author expects it will not now be long till all road makers will be compelled to come into line in this very essential requirement, and at all costs obtain the best plant. Up to now all that has been done in most municipalities is to provide a mixer in which two, or at most three, grades of material can be gauged by bulk measurement. Road painting is so temporary an expedient that except in the cheaper macadam roads used in the country it is not to be expected that our present system will survive much longer. It was only mentioned here because at present its use is almost universal on water-bound macadam roads.

When Economical to Omit Carpets.—With a bitumen-bound macadam it is only in exceptional circumstances where the surfacing, either by the present established 2-inch bituminous course, or by painting, can be omitted. It is not
only the cheapest and most efficient means of shedding off the rainfall, and securing watertight conditions, but also it gives a smoother road surface which will reduce the road friction to a minimum. And it is just here that the circumstance which often makes its abandonment imperative comes in, namely, when the grade is too steep to be safely used, and the road surface has to be left rough. This question of slipperiness justifies a whole paper to itself. The economic problem, however, is quite otherwise with the white concrete road. Here there are three alternatives, as under:

1. A bare concrete crust, with no protective carpet.
2. A concrete surface, protected by periodical covering with a light carpet of screenings and bitumen.
3. A 2-inch bituminous carpet (the recognised standard here to-day).

The second of these, following the practice of prolonging the life of the wood-blocked road, introduced by Mr. A. C. Mountain, M.I.C.E., for the city of Melbourne as far back as the end of the last century, was adopted at the initiation of concrete street work in Richmond, but in 1922 the author, finding that the cost worked out at more than one shilling a yard per annum, decided to follow the lead of the London Metropolitan Engineers, and to experiment with a bare concrete, which they estimated would, by saving an immediate cost of say 4/6 a square yard, as compared with a black carpet, more than pay for itself if it stood up to traffic for five years. Careful estimates showed that the same type of carpet as cost 4/6 in London would cost us not less than 7/6 here. But to make doubly sure of this economical policy of omitting the carpet altogether, we in Richmond secured an exceptionally hard metal, and hence it comes that we have escaped the heavy surface wear which is recorded in the case of the experimental patch of bare concrete laid down at the same time by the Country Roads Board on the Prince's Highway in the vicinity of Oakleigh. Also our better consolidation of the aggregate in the concrete, and using a 2-inch slump test maximum, probably explained how we escaped the serious cracking and breaking up of the slab at the corners which, unfortunately, at Oakleigh, put this type of road into disrepute.

In any case, no concrete pavement laid down in Richmond since 1922 has as yet justified any carpeting, and far from the American experience, where it costs £22 to £25 for maintaining the concrete surface alone, we have had no maintenance on concrete laid down since 1922 in Richmond, except, of

*See Report by the late W. Calder, Chairman Country Roads Board, on "Road Problems in Europe and America, 1924," page 236.
course, where concrete has been cut for electric, gas, or water services, and also the ordinary maintenance of the paved portions of the roadway, viz., the haunches, side drains, culverts, etc., which always account for half of the maintenance costs in crowded thoroughfares.

In point of fact the Country Roads Board’s Main Prince’s Highway showed that the surface wear on the experimental patch of bare concrete road exceeded the wear of the bituminous road. Of course, the same type of metal was used in both, and this only agrees with what one must expect, since the shock and abrasive effect of traffic on metal rigidly bedded in concrete must be far worse than the shock and abrasive effect on metal bedded in a yielding material.

This introduces a very important question of the sort of carpet which is best suited for protecting a concrete surface. The general trend of opinion agrees with the policy adopted by Richmond in 1922 of abandoning the thin bituminous carpet. Since that date Richmond has given a large number of agents and advocates of different bituminous mixtures, both hot asphalt and cold asphalt emulsions, opportunities to carpet our concrete street surfaces with painted grits from one gallon to the yard up to $\frac{1}{2}$ gallon to the yard, and none of these has come up to the guarantees which would have enabled them to claim payment for the material which they supplied.

Consequently, the position is the same to-day as it was in 1924, when the Richmond Council finally decided that the 2-inch thick asphalt carpet, costing 10/= a square yard, was too dear to be worth putting over our bare concrete roads. The quotations to-day are slightly less than then. I have a quotation from one of the largest contractors in Australia that a bituminous carpet will cost 10/= a square yard, with a five years’ guarantee, and believe this can be reduced to 7/6. I have also records to show that a bituminous carpet of over 2\(\frac{1}{2}\) inches thick was laid down on a concrete base between four and five years ago by an adjoining municipality for a very low cost, without standing charges, for 7/6, which with all standing charges would be less than 9/= per square yard. I do not think that, even with the excellent mixtures now put down, the ten years’ guarantee which would be necessary to warrant covering concrete at the first operation at an initial cost of 10/= a square yard, the contractor to pay for all repairs incurred during its ten years’ estimated working life, would be worth while. Assuming money at 6 per cent. interest and amortisation of loan at ten years this will amount to over 1/= per annum. The net result then justifies the statement made by Mr. Alfred Dryland eight years ago, that even if the bare concrete surface would have to be carpeted in five years, the saving in first cost
would go a great deal further than justify any extra cost which subsequent carpeting might involve, with the advantage that each year brought improved methods. The earliest date when Westminster streets, under exceptionally heavy traffic, have had to be carpeted was about two years ago, so Mr. Dryland's foresight has been more than vindicated.

Here in Richmond, by using exceptionally hard basalt in the matrix, and taking care that in the handling it should come up as a rough mosaic pattern to the surface, we bid fair to double this five years, though quite a lot of concrete laid down prior to November, 1923, which was designed for a carpet, is now almost ready for replacement.

When the higher grade concrete (1923 to 1928) will come to be carpeted, it will be interesting to find whether it will be better, after a mechanical re-surfacing, to cover this surface with a white cement mortar skin, or with a carpet of say 1⁄4 or 1 1⁄2 inch thick compressed asphalt. As to the asphalt carpet, the writer has a general bias towards quality as against quantity, and without sufficient experience to dogmatise, he throws it out from what he has seen elsewhere as being well worth while to pay an even higher price to get a more thoroughly compacted carpet of, say, 1 1⁄4 inches thick than a more yielding carpet of 2 1⁄2 inches thick. In no case should the orthodox 6 per cent. of bitumen or tar compound in the carpet be exceeded, and the nature of this preparation is one of the most crucial matters to be worked out to-day. And here he wishes to say a few words on the very pertinent question of the part played in all modern engineering works by the great proprietary corporations.

THE POSITION OF CONTRACTING FIRMS.—It was at the close of the last century that thinkers began to realise how the old view of monarchical influence and parliamentary control were all astray. However carefully hidden behind diplomatists and secret agents they were, the hands of those who really controlled the destinies of the world were sometimes seen pulling the strings, and these were not the hands of the heaven born nor of the elected rulers. To mention some of the last generation. There were the Chairman of the Canadian Pacific in Canada, Harriman and Pierpoint Morgan in North America, Limantour in Mexico, together with Cecil Rhodes in Africa, Thomas Sexton in Ireland, and David Syme in Victoria. In our own profession only one man had the independent position which enabled him to utter a trumpetlike warning of how the profession was becoming the slave of mechanisation. The late Professor Sir John Perry, when President of the Institution of Electrical Engineers, thundered at the subservience of engineers to a few great electrical corporations, who were dominating the electrical
world. The professor did not realise that even then the conditions which in the past gave the experienced, practical engineer his pre-eminent position had gone, and the standardising of every specification and most appliances altered the position of a resident engineer to that of a well-educated inspector, and the position of chief engineer to a corporation was approximating to that of the chief engineer of a boat; and that the function of the consulting engineer in future must be not so much to design works himself, as to advise which contracting firm, or set of appliances will best serve the needs of his clients, and as far as possible protect his purse from monopolistic prices. The great difficulty to-day is that the younger engineers have little choice between a purely theoretical University training, or to affiliate themselves with some one of the big contracting or manufacturing firms. Those of them having outstanding abilities become part of a commercial machine. The rank and file must content themselves with routine or executive work in subordinate posts.

CONCLUSION.—The author invites the most critical discussion. He has not loaded the paper with proofs of his statements, but will be very pleased to give such as he may have on every question raised, and hopes after debate to have the opportunity to add some important illustrations of his meaning.

Since writing this paper the author’s attention has been called to the very clear statement of the case put before the Institution of Civil Engineers by Sir Henry Percy Maybury in his “James Forrest” Lecture on “Roads and Transport” (page 305, vol. 228), as follows:

“There is no ‘best road surfacing material’ for all purposes. Each case should be dealt with on its merits, having regard to subsoil, climate and rainfall, and last, but not least, to the volume and weight of traffic which may reasonably be expected to be upon the road in question. I have seen materials costing up to 20/ a super. yard laid upon a highway where a fifth of such expenditure would have sufficed, and had the work been executed at the lower figure the life of the material laid might well have been from eight to ten years, without, in the interim, any charge upon annual maintenance account.”
APPENDIX.

PRESENT PRACTICE IN GREAT BRITAIN.

The following is an abstract from "The Contractors' Record and Municipal Engineering," 12th March, 1930, page 321:

"INCREASED CONCRETE ROAD CONSTRUCTION IN THE BRITISH ISLES.

"During last year approximately three million super. yards of all-concrete road work, equivalent to 254 miles of 20 ft. carriage-way, were laid in the British Isles. This figure constitutes a record for this type of construction, and shows the substantial increase of 25 per cent. over last year's figure.

"In the lighter trafficked areas the cement-bound road is gradually gaining interest, and approximately 164,651 super. yards were laid during the year. This work has necessitated the production of at least 10,000 tons of steel, 120,000 tons of cement, 230,000 tons of sand, and 460,000 tons of broken stone. Further, for the manufacture of the cement and steel approximately 80,000 tons of coal were required."

From the above it is evident that Mr. Dryland's experiment in Westminster has borne fruit in other places than in Richmond. From correspondence with municipal engineers in Great Britain and Ireland he assumes that the cement-bound roads have been laid down on the sandwich method, which he has advocated as a better rival to the bituminous concrete road than the cement mortar penetration method which is being advocated here.

The President said engineers who were directly interested in the design and construction of roads would find Mr. Anderson's paper interesting and of very great value. He believed many members, and particularly those who were municipal engineers, would wish to contribute to the discussion. To country members an invitation was extended to contribute discussion in writing for presentation to the next meeting.

Mr. W. Ison moved a hearty vote of thanks to Mr. Anderson for his paper. The paper bore the impress of wide experience, and could with advantage be accepted in the nature of a text book by engineers studying road construction.

Mr. C. H. Gough, in seconding the vote of thanks, said he had followed every word with great interest. Road construction was daily becoming a question of greater importance.
Methods of design and construction constantly changed in the light of experience, and in the future roads would play an enormous part in the development of the country.

The President said many matters had arisen in recent years that had completely revolutionised the design of roads. Mr. Anderson condemned the use of ashes with regard to roads on the ground of their corrosive effect on the reinforcing, due to the seepage upward by capillarity of the moisture. He would like to add his condemnation of the use of ashes because of their corrosive action on water and gas pipes. He hoped there would be an interesting discussion of the paper at the next meeting.

Mr. W. R. Pollock said he had listened to the paper with great interest. His experience had been connected with wood block roads, but he had noticed the great success that had attended the concrete roads in Richmond and Port Melbourne. He thought the carpeting of roads should be carried out with as thin a carpet as possible. St. Kilda Road was covered frequently with a somewhat thick carpet, with the result that the carpet became rolled up, making it difficult for vehicles to drive over it. He thought the bare concrete painted with a thin carpet of bitumen would be preferable. That surface would protect the road from the steel shod vehicle or horse's hoof, whilst probably it would last for ever against the rubber-tyred motor or other vehicle.

Mr. Edgar Thompson said the paper had been most interesting, and especially the comments with regard to bitumen and bare concrete roads. In America, where there was an enormous motor traffic, miles of bare concrete roads were being constructed not only in making new roads, but also in replacing old ones. In the light of America's experience of motor traffic there must be some reason for such extensive use of bare concrete in road making.

Mr. E. J. Michaelson said too much emphasis could not be placed on the manner in which foundations were laid down. He had noticed suburban roads being made with 9 inches of metal and 3 inch aggregate. Under such conditions the surface material would drop into the holes. But with the use of one inch metal the roads had lasted four or five years and were still in good condition. Another matter of importance was the expansion of concrete roads. On the roads constructed by the Country Roads Board the expansion joints were placed at right angles to the road. When a heavy vehicle passed over it the joint sustained the impact of both wheels together. That caused shock. But when the joint was placed diagonally the impact of only one wheel at a time was felt, and the wear was
correspondingly less severe on the road, and fewer cracks were found at the joint.

The President said the point raised as to the hardness of the aggregate was most important. He wondered if granite or some other acid igneous rock would not be better than basalt. He assumed that the term bituminous roads signified any asphalitic compound.

Mr. Anderson said that was so.

The President asked if the rolling up of the carpets might not be a question of the proper mixture of the bitumen and its aggregates.

Mr. J. T. N. Anderson, in reply, said the waved surface occurred not only in bituminous roads, but also in gravel. It was undoubtedly due to internal movement. Modern high speed traffic caused the appearance of distorted waves. Inequality of the road caused a bump of the car, which by the rebound was repeated in several places farther on. Granite was the ideal material for topping roads, but there were granites that were very objectionable because they would not bind. Granite was now being used in England for surfacing concrete roads, and was being used there by most of the big quarrying companies. With reference to Mr. Pollock's question as to the thickness of the carpet, the usual carpet on a macadam road was about ¼ inch. That was the type of carpet they had tried to adopt in Richmond, but none of it lasted more than six months. The harder the concrete the quicker the carpet wore off. The carpet was between the hammer and the anvil. He believed the best thickness to be about one inch. The National Roads Congress specified a great number of carpets, but the most effective appeared to be the French material, Val-de-Travers. That material was laid in strips much as linoleum was laid on a floor; strips about 16 inches wide were laid down and treated with a hot iron. It would be necessary to come to something of that sort here. He thought that when their roads became sufficiently worn to justify surfacing they should be levelled with some such material and receive a ¼ inch dressing with hard silica sand. With reference to the question of diagonal joints, an examination of the most recently-built concrete streets at Richmond would show that the joints were all diagonal. They tried at first to avoid joints as far as possible by laying alternate strips. By that method very little joint was observed. The south side of Bridge Road was laid by that method. They certainly obtained an excellent result, but it was too costly, so they adopted the 33 ft. length between the joints. He wished to place a red gum sleeper under every joint, but that was disallowed on account of the cost. The American method was
to use $\frac{1}{2}$ inch reinforcement across the joint, bedded in solid concrete. Every joint rose and fell as the traffic passed over it, and the shear of the steel must be very severe, so he proposed to place instead of the steel a sleeper running longitudinally with the joint. About 1925 he indented the material "Lastite" to place in the joints, and since then they had given very little trouble indeed. He had not considered the longitudinal joint that was in use in America, because the season here was not so severe. It was not the hot weather that caused damage to the joints, but the excessive cold. The use of ashes was found to be very uneconomical in Richmond. He used a uniformly thick mixture of cement, and had a gauge made giving two inches of impervious concrete based on the ashes. Unless that precaution was taken ashes were dangerous to use with reinforced concrete.
DISCUSSION

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Mr. T. C. Mathieson, Engineer, Country Roads Board, said he had read Mr. Anderson's paper with interest, more especially as reference had been made to the experimental section of the concrete road at Oakleigh, which was opened in 1922. He had from time to time taken measurements of wear on that road; and Mr. Anderson had drawn the conclusion that the original construction was somewhat defective, and resulted in heavy wear. He considered the original design was at fault. It was due to ignorance on their part. The road was only six inches thick at the edges and eight inches in the centre. Had they their present knowledge when they built that road it would have been made eight inches thick at the edges and six inches at the centre. They would have secured 60 per cent. greater strength for the same money. They used hard basalt from Alphington. They did not measure the slump, but a recent test of the concrete made at that time had broken at 5000 pounds to the square inch. The wear was an average of 0.4 of an inch. That was in six and a quarter years. That seemed to indicate that in the last few years the wear had been very slight indeed, due possibly to the increased strength of the concrete laid and also to the decrease in the amount of steel tyre traffic. He had inspected a piece of road in Richmond recently, and he had noticed one or two manhole covers raised slightly. If they were laid flush originally the wear must have been about half an inch. He noticed slight depressions similar to those experienced at Oakleigh, and thought the wear at Richmond was much the same as at Oakleigh. Mr. Anderson had suggested it was economical to lay a concrete base and allow it to take the wear over a number of years, and then surface it with bitumen. He thought the trouble in such a case would be the difficulties of the levels. If a two-inch bituminous carpet were laid adjacent to the edge of the tramway track there would be difficulties. There was also the difficulty of making the bitumen stick to the smooth concrete surface. Mr. Anderson had summed up the problem when he said the first question was what was the nature of the traffic, and what type of road would give best value for the money. He thought that was the main question, and it was the same with every engineering problem.

Mr. J. T. Noble Anderson, in reply, said the Richmond road mentioned by Mr. Mathieson was constructed before his association with Richmond. In Bridge Road, where they had hard metal, the measurements were taken from the manhole
covers, and the average wear noted in seven and a half years was one-eighth inch. In Church Street, where they had a better stone, after six years the measurement showed an average wear of one-twelfth inch. These results compared remarkably well with what he had based his remarks upon. He took the measurement of the concrete put down by the Tramway Trust in 1913 in Swan Street, and found it corresponded in ten years to the extreme wear of half an inch. He had thought from the start that to put more than one inch bitumen carpet was excessive, and his arrangement with the Tramways Board was for one inch. One inch was quite satisfactory over concrete. But he thought when it came to replacement it would be replaced with concrete. The important point was the wear. The point was even more important in Richmond, where more than 30 per cent. of the traffic was still horse drawn, which was very severe on concrete. He had observed that some concrete laid down with a mixture rather richer than six to one ten years ago was breaking up already. It would have to be replaced with a bituminous road or a new concrete road. That was no reflection on the concrete road, however, for it had been made nearly three years before they had present data.
THE ECONOMIC ROAD SURFACE

Paper by Mr. J. T. Noble Anderson.

Mr. Anderson said he agreed with Mr. Mathieson that "we bid fair to double the five years'" age given by Mr. Dryland when bare concrete would probably require carpeting; and he pointed out that the worn portion of concrete referred to by Mr. Mathieson was laid down in 1923, prior to his association with Richmond, when the concrete had been designed for a carpet, and not for the hard-wearing surface required in an uncarpeted road. But even this concrete bids fair to last ten years without requiring a carpet provided the joints are occasionally filled with a bituminous filler. Mr. Anderson pointed out that in those portions of the road laid down with the denser mixture, less than one quarter inch wear could be discerned, and that was at the joints, and could have been greatly reduced if they could sooner have secured a good tar base cover such as that now available. Observation indicated that the above concrete would have more than sixteen years before it required resurfacing. One circumstance he greatly regretted was that the extent of the work did not justify a mechanical grader and surfacer, as it was only in the latter part of the work that the labourers acquired sufficient skill in screening to avoid a waving surface, which is detrimental, and must greatly shorten the life of the material. It was noteworthy that while his paper was being read in Melbourne, practically the same subject was under discussion in Washington, and it has transpired that the conclusions of the International Road Congress at Washington are in perfect agreement with those in the paper here under discussion. Mr. Anderson read extracts from a report of their proceedings illustrating the concordance.

Another method mentioned in that report was noteworthy, namely, that of introducing a cement binder into a macadam surface by rolling a dry sand-cement mixture into the road and then wetting it and rolling until the mortar is flush with the surface. The details were not disclosed, and the method seemed new in Australia. This was the cheapest method yet introduced, and would be practicable where traffic was rubber borne, and not too heavy. This could best be carried out during cold weather.

With regard to bridge decks, Mr. Anderson contributed the following note:—After discussion with Mr. B. A. Smith on our joint design for rebuilding the Victoria Bridge over the Yarra, we decided to adopt a reinforced slab concrete deck, carried on steel girders, instead of the usual Hennebique type of R.C. deck. For wearing surface a 3-inch timber paving bedded on 1 inch of sand grouted with just enough Portland cement to
hold it till the timber is properly and evenly bedded. The big problem in that bridge, however, was the expansion over a length of 340 feet, on a grade of 1 in 36. For this we submitted a joggled joint, opening so as to allow all detritus and foreign matters falling on it to fall through an opening of nearly one inch, so checkered that it would not be unsafe for traffic. This because an intimate examination of a great number of bridges disclosed the fact that all the former expansion joints after a few years became choked up, and quite inoperative. And the general effect of our temperature strains, where the structure probably decked at a moderate temperature of less than 60° F., is subjected to sun temperatures of up to 130° F., created stresses which subjects the reinforced concrete to internal strains, appreciably lessening its useful life, and whose only external relief will be by damaging the roadway at the lower abutment.

The expansion joint was to have been placed over the last pier on the downhill side, on which pier an unusually large rocking truncated globe was to have carried the main girders, because here again we found that the orthodox rollers, having too great a pressure per square inch, had usually become inoperative. They generally have allowed the girders to expand, but not to contract, thus putting an added longitudinal tensile strain on to them during winter. Drainage scuppers and cross section grading were to be in accordance with the usual practice. As a justification for the shallow wood blocking in preference to a bituminous carpet of the same weight, the chief point to be considered is that we have experience of wooden blocking where reconditioning was only necessary after 29 years’ use. And obviously, on so important a highway, even the smallest of blocking of traffic for recondition costs more to the general public than the difference between the cost of any two carpeting materials. On this question of cost of traffic, Railway President Lewis gives as a general value per minute the following:—Trucks, 2.3 cents per car min.; light commercial vehicles, 2.1 cents per car min.; non-commercial vehicles, 1.0 cent per car min. Thus a week’s delay during carpeting operations on the surface, and holding up for an average of three minutes each vehicle, would in the case of this bridge cost the outside travelling public over £100. Thus the cheapest quarter-inch protecting carpet, renewable twice annually, at a cost of 6d. a yard each renewal, is the dearest expedient, with 33% more against it than what has been said against it for ordinary highway use.
DISCUSSIONS

The President said they were indebted to Mr. Anderson for his further valuable contribution. Mr. Anderson had brought forward a new point in his consideration of the expansion joint, and the difficulties encountered in making the expansion joint work effectively.

Mr. Wm. Chas. Rowe said he had to thank Mr. Anderson for his very valuable paper. With reference to the protection of expansion joints from the intrusion of foreign material, he had experienced the same difficulty in the tops of weighbridge tables. Those tables should be cast in one piece. Sometimes they were supplied in two pieces, and the penetration of gravel in the joint would in time force the sections apart. Could not the foreign matter be kept out of expansive joints by keeping something else in, such as graphite or some such material?

The President said the sketch that had been circulated showed that a rubber-like material had been used for filling the joints in the concrete road.

HOW A MANUFACTURING PLANT WAS EVOLVED FROM A CHEMICAL FORMULA.

Paper by R. J. Bennie and H. E. Grove.

The President, in reopening the discussion, said that the methods of treatment of tar in the manufacture of bitumen were developing so fast that that which was brought forward in the paper might perhaps be regarded as academic twelve months hence.

Mr. R. S. Andrews, Chief Chemist of the Metropolitan Gas Co., said he had been very interested in the paper, owing to his close association with the development of the process, and he would like to take the opportunity of adding his praise to the gentlemen who had designed and erected the plant, which had been in operation for about three months. The design was both unique and unorthodox as regarded tar treatment, and numerous visitors had been much enamoured of it. The development of the process and the design of the plant were the outcome of a rather peculiar set of circumstances. It appeared inevitable that when a radical change was made it brought a series of difficulties, and when the Gas Company adopted vertical retorts they were faced with the problem of marketing an inferior tar. The bulk of the tar was expelled before the coal reached the hotter zone, and that tar naturally had a large percentage of low temperature products in the form of paraffin and unsaturated hydro-carbons. So in developing
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