THE EVOLUTION OF THE MODERN ROAD.

(Read before the Victorian Institute of Engineers on the 7th November 1894, by Mr. A. C. Mountain, M. Inst. C.E.)

"Macaulay's 'History of England,' in the celebrated chapter on "The State of England in 1685," contains a graphic description of the condition of semi-barbarism into which the entire country had then fallen, largely in consequence of the want of proper means of inter-communication. I quote a passage in support of that statement, which suggested to me the title I have given to this paper:—"It was by the highways that both travellers and goods generally passed from place to place; and those highways appear to have been far worse than might have been expected from the degree of wealth and civilisation which the nation had even then attained. On the best lines of communication the ruts were deep, and the descents precipitous, and the way often such as it was hardly possible to distinguish in the dusk from the unenclosed heath and fen which lay on both sides. Ralph Thoresby, the antiquary, was in danger of losing his way on the great North road between Barnby Moor and Tuxford, and actually lost his way between Doncaster and York. Pepys and his wife travelling in their own coach, lost their way between Newbury and Reading. In the course of the same tour they lost their way near Salisbury, and were in danger of having to pass the night on the plain. It was only in fine weather that the whole breadth of the road was available for wheeled vehicles. Often the mud lay deep on the right and left, and only a narrow track of firm ground rose above the quagmire. At such times obstructions and quarrels were frequent, and the path was sometimes blocked up during a long time by carriers, neither of whom would break the way. It happened almost every day, that coaches stuck fast until a team of cattle could be procured from some neighboring farm to tug them out of the slough. But in bad seasons the traveller had to encounter inconveniences still more serious. Thoresby, who was in the habit of travelling between Leeds and the capital, has recorded in his diary such a series of perils and disasters as might suffice for a journey to the Frozen Ocean or the Desert of Sahara. On one occasion he learned that the floods were out between Ware and London, that passengers had to swim for their lives, and a higgler had perished in the attempt to cross. In consequence of these tidings he turned out of the high road and was conducted across some meadows, where it was necessary for him to ride to the saddle skirts in water. In the course of another journey he narrowly escaped being swept away by an inundation of the Trent. He was afterwards detained at Stamford four days on account of the state of the roads, and then ventured to proceed only because 14 members of the House of Commons, who were going up in a body to Parliament with guides and numerous attendants, took him into their company. On the roads of Derbyshire, travellers were in constant fear for their necks, and were often compelled to alight and lead their beasts. The
great route through Wales to Holyhead was in such a state that in 1685, a viceroy going to Ireland was five hours travelling 14 miles, from Saint Asaph to Conway. Between Conway and Beaumaris he was forced to walk a great part of the way, and his lady was carried in a litter. His coach was, with much difficulty and by the aid of many hands, brought after him entire. In general, carriages were taken to pieces at Conway and borne on the shoulders of stout Welsh peasants to the Menai Straits. In some parts of Kent and Sussex none but the strongest horses could in winter get through the bog, in which at every step they sank deep. The market was often inaccessible during several months. It is said that the fruits of the earth were sometimes suffered to rot in one place, while in another place, distant only a few miles, the supply fell far short of the demand. The wheeled carriages in this district were generally pulled by oxen. When Prince George of Denmark visited the stately mansion of Petworth in wet weather he was six hours in going nine miles, and it was necessary that a body of sturdy hinds should be on each side of his coach in order to prop it. Of the carriages which conveyed his retinue several were upset and injured. A letter from one of the party has been preserved, in which the unfortunate courtier complains that during 14 hours he never once alighted, except when his coach was overturned or stuck fast in the mud.” In the introduction to the manual of road-making, Dr. Gillespie remarks that “Roads belong to that unappreciated class of blessings of which the value and importance are so manifold and indispensable as to have rendered their extent almost universal, and their origin forgotten. The later roads under the more scientific direction of Telford, produced a change in the state of the people of England which is probably unparalleled in the history of any country in the same space of time.” Buckle also, in his “History of Civilisation,” alludes to the great influence which the construction of roads had in improving the moral and material prosperity of the people, and when it is remembered that an absolute ignorance of the first principles of road-construction lasted in England up to the beginning of this century, one must admit that—bearing in mind the extent and the character of our present highways and other roads—the development is indeed marvellous. The state of things thus allowed to exist, not only in England but over nearly the whole of Europe, up to comparatively so recent a date, is the more surprising when one remembers the examples possessed by these very countries in the magnificent Roman roads, built some hundreds of years before. The lessons these monuments should have taught were indeed forgotten, for the dark age had set in! It is strange to reflect that, at a time when the Spanish Conquistadores were gazing with wonder and admiration at the ingenuity shown by the native Peruvians in the construction of their national roads of stone covered with bitumen, and their marvellous suspension bridges over ravines (supported by cables up to 200 feet long made out of creepers), I repeat, it is strange to realise that, at this time, a King of France narrowly escaped suffocation by falling from his horse into the ordure of one of the streets of his gay metropolis; and that, in England, it was a more serious matter to move from one county to the next than it is now to go to Coolgardie from this city. France was certainly some forty years before England in commencing
to repair this wretched condition of things, for in 1775 roads (on a very similar system to that subsequently suggested by Telford in England) were adopted which were designed by M. Tresagnet; but when we read of the description given by McAdam of the road construction that existed in the latter country up to 1816, and contrast it with the thousands of miles macadamised, stone, and wood, paved, or asphalted roads and streets of the present day, it is hardly an exaggeration of terms to consider the great change as an evolution. As I myself know of at least 60 books bearing on the history, construction or maintenance of Roads, and as I also find that nearly everybody knows—or thinks he knows—all about such elementary engineering, I find it difficult to write anything original or of general interest on such a theme. The familiar and well-worn ground of the text books must of course be avoided. I have already, in general terms, alluded to the enormous influence of the modern road in promoting commerce, elevating the morals, and refining the manners of a country, thereby becoming a potent factor in its civilisation. Nothing is left me therefore but to attempt a brief account of the principal modes of construction that have been in vogue up to the present time, commencing with the system which was initiated by the man whose name it bears, and which is still in more general use than all other methods put together. I refer, of course to

McAdam.

With regard to the universally known macadamised road, which made such a great revolution in public highways and thoroughfares towards the beginning of the present century, for which change the English people have especially to thank Thomas Telford (afterwards the founder of the Institution of Civil Engineers of London) and Jas. L. McAdam; it is unnecessary to say much beyond mentioning the fundamental principles laid down by the above-cited authorities as essential to the success of all road construction; and by adopting which no engineer can go far wrong, even though, in questions of detail, his practice may vary from theirs. These principles may be summed up under the following heads:—(1). Securing prompt drainage of the foundation soil of the proposed road. (2). So arranging the "bed" of stone which is ultimately to carry the final coating and the traffic thereon, as to distribute the load over as large an area of foundation, and as equally as practicable. (3). So to spread the final layer of stone that, with suitable rolling or other means of consolidation, it shall present but little interstitial space for the soakage of water; and that it shall be so arranged in cross section as to throw off water to the side channels. These simple rules appear to us now to be such self-evident truths, that it is hard to realize that a time existed when the highway was a jolting bog, even though it may have had 3 feet of stone in its formation; and when on either side of the road there existed a mound, some feet in height, of materials obtained from the road excavation and (so-called) repairs. An extract from Arthur Young's "Six Months' Tour," published in 1770, gives a vivid description of the state of the roads in the north of England:—"To Wigan, Turnpike,—I know not in the whole range of language, terms sufficiently expressive to describe this infernal road. Let me most seriously caution
all travellers who may accidentally propose to travel this terrible country, to avoid it as they would the devil; for a thousand to one they break their necks or their limbs by overthrow or breakings down. They will here meet with ruts which I actually measured four feet deep, and floating with mud only from a wet summer; what, therefore, must it be after a wet winter? The only mending it receives is tumbling some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts, broken down, in those eighteen miles of execrable memory." "To Newcastle, Turnpike.—A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to avoid this terrible country, which must either dislocate their bones with broken pavements, or bury them in the muddy sand." This condition of things existed even up to 1809, at which time the "decline and fall" of a British road appears to have presented somewhat the appearance of the first four sections shown herewith; from drawings by Mr. Henry Law, M. Inst. C.E., to whose interesting historical notice of old country roads I am indebted for much of this information. From that time what a change passed over the land even up to 1869, when, according to Mr. Vignoles in his address to the Institution of Civil Engineers in 1870, there existed in the United Kingdom no less than 160,000 miles of good carriageable roads. Before leaving this part of my subject, I must not omit to refer to the revolution that was effected in the "laying out" and grading of roads by Thomas Telford, who soon perceived the economy of adopting the road gradients to the best working efforts of the horse; and who on one memorable road in Anglesea, 24 miles long, effected such deviations that he saved two miles in the distance, and reduced the rise and fall of the undulations by a total vertical height of 1283 feet. This branch of engineering surveying has been brought to great perfection since the advent of railways, but its infancy is worth noticing here. The experiments and investigations into the "draught" or resistance to traction of vehicles, made by Morin in France, and by Telford, and Sir J. McNeill, in England, also contributed largely to the success of subsequent road construction. Without desiring to repeat well-known mechanical principles, I may briefly name some of the conclusions arrived at by the above authorities. They found that large wheels are favorable to draught, and cause less wear on the road; that on a hard road once the width of the tire is more than 3 or 4 inches, the resistance is but little affected; on a yielding surface the resistance decreases in proportion to the width of tire. The resistance due to gravity on inclined roads is nearly equal to the gross load divided by the rate of gradient. Irregularity of road surface increases the tractive force to a great extent, the variation amounting to the difference between one thirty-sixth and one twenty-first of the load drawn on the same road as between the well kept and the badly maintained parts. Granite in wet, and limestone in dry, weather gave the least resistance, gravel being always the worst. The use of springs is chiefly of advantage at high velocities. Sir J. McNeill recommended that one inch of tire should be allowed for every 5 cwt. of load on each wheel. Material. The material used in forming a road is of the greatest importance.
both with regard to its ultimate durability, and also to its power to sustain heavy loads without deflection, probably, for "all round" service, the basaltic and trap formations are as useful as any. Granite, unless it is syenitic, is considered to be generally too brittle; the quality aimed at being a combination of hardness and toughness. The same remark applies to quartz. Limestone, especially from the carboniferous formation, is very good, it binds well, and makes an excellent road for moderate traffic. Where the traffic is heavy, and good material is not available in the locality, it is often economical to send some distance for stone for the surface of the road. In that case, the "bottoming" of the road may be of less durable stone. This practice is followed in Sydney, where the body of the road is formed of sandstone (a soft material) either in spalls or hand-packed pitchers, over which the basaltic road metal, obtained from a seaport south of Sydney, is spread. In the same way Gilmore states that in New York, broken gneiss is put below and covered with boulders which cost three times as much to break owing to their greater hardness. Iron slag is of service, if well supplied with binding material. Maintenance. The extent to which a road needs repair depends on—(1). The mode of construction of the whole road. (2). The durability of the surface coating of metal. (3). The nature and extent of the traffic carried. As to construction, provided the general principles already enunciated as to forming and draining be carried out, the road should be able to support any traffic without danger of cross-breaking or yielding of the subsoil, thus limiting the need of any repairs to making good the wear and tear of the surface metalling. With regard to the durability of the stone used as a wearing surface, I have already alluded to that in the brief description of the class of stone most suitable for road-making, but local conditions affect the wear of a road to a great extent, e.s., on steep grades the action of heavy rains in washing away the binding material and disturbing the cohesion of the stones forming the surface is very apparent, especially in our own country: whilst if a road is so hemmed in with hedges, high buildings, or trees as to be deprived of a proper share of sunlight or the prevalent drying winds, it is always in a more or less soft condition, and more easily damaged by the traffic and disintegrated by the weather. The traffic is, of course, greater on the road which—proportionately to its width—carries the heaviest tonnage. This self-evident proposition is not so fully recognised, however, as one might suppose. How often is the excellent condition of a road perhaps having a dozen vehicles along it in a day, contrasted with the worn and muddy state of a city street of half its width which carries twenty times its traffic? The difficulty of accurately determining the actual "duty" of a road can only be coped with by establishing uniform and carefully prepared records of the number and weight of all loads passing over it, and reducing this to the standard tonnage per annum over each yard in width. This is regularly done in England and Europe; the only attempt at such a systematic register I am aware of as having been undertaken in Australia was carried out, at my instance, in Sydney in 1880. As giving some idea of the traffic carried on some of the main thoroughfares of the world, I may state that G. F. Deacon, M. Inst. C.E, formerly City Surveyor to Liverpool, refers to one street in that town as carrying 360,000 tons a year for each yard of width, "and an average of
0.923 of a ton per wheel including empties, two figures which taken together are, perhaps, not equalled in the world." Another street was subjected to 218,000 tons of traffic per yard in width, and a mean load of 0.679 of a ton per wheel including empties. From Mr. Howarth's return, there would appear to be at least six London streets the traffic on which varies from 310,000 to 420,000 tons per yard in width. This information is obtained from Mr. Stayton's paper on "wood-paving" read before the Institution of Civil Engineers in 1884. In the year 1880, I found that in two main thoroughfares of Sydney, the traffic amounted to 142,000 and 156,000 tons per yard in width per annum. Rolling. The introduction of the steam road roller has largely increased the efficiency of the Macadamized road, by expediting its consolidation and by rendering that consolidation more complete. That this is a matter of considerable importance may be imagined when it is remembered that so far back as 1875, an annual expenditure in England and Wales on roads (nearly all Macadamized) was incurred amounting to over four millions sterling; whilst, during the same period, £280,000 was spent on Macadamized roads in the Metropolis! These figures are given by T. Codrington in his work on "road maintenance." As is well known, the "voids" in a quantity of ordinary road metal amount on an average to about 48 per cent. of the volume of the stone; by efficient rolling this can be reduced to about 28 per cent.; when this is done, it is desirable to fill in the interstitial spaces still left as well as possible in order to produce a smooth and impervious surface. This is effected by sprinkling suitable "binding" material on the metal, and rolling it in with the assistance of water. Silicious gravel is considered to be the best stuff for this purpose, if from 4 to a pinhead in size, and mixed with one-fourth its own bulk of wet sweepings from the road. As that is not always obtainable, coarse sand is a good and clean substitute, failing which chipping or screenings from the same kind of stone that is used in the road may be employed; all clay or earthy matter should be eschewed. A fifteen ton steam roller requiring a driver and two attendants is the most serviceable machine to employ. The method I have found to give the best results is to well roll the road metal in layers of not more than 5 to 6 inches at a time, until the stones are well consolidated and smooth, then spread the dry binding material uniformly in gradual layers amounting in all to a total thickness of not more than one-sixth of the depth of metal; resume rolling, a water-cart and a sweeper preceding the roller until the moisture is brought to the surface. Too much water must not be used, or the foundation may be softened, and care must be taken not to allow the binding material to work down to the bottom of the road metal. On an average the cost of rolling comes to about 0½d. per sq. yard of road rolled. The extent to which our city has benefited by being so fortunately situated in respect of suitable road-making material is well known. Not only has the basalt by which it is surrounded enabled excellent roads to be formed at comparatively small cost; but the work of crushing that rock into road-metal has produced an abundant supply of debris which has formed the basis of a material which has enabled the footways to be paved at one-sixth of the expense of flagging. The principal source of supply of road metal for this city has been the corporation quarry at Clifton Hill, which has been working for 18 years, and is now excavated to a depth of 100 ft.
below the surface level. By improvements in the machinery and by careful management, a steady reduction has been effected each year in the cost of production, until I find that for the first 9 months of this year the ‘all round’ expense of quarrying, spalling, raising, and crushing both metal and screenings, and discharging same into the receiving bins is only 2s. 10d. per c. yd. As one-third of this quantity consists of screenings, both coarse and fine, worth at the present time quite 4s. 6d. per c. yd., (the remaining two-thirds being the 2½” metal) it follows that the proportionate cost of the road-metal is barely 2 shillings per c. yd. The cost of carting and spreading on the street varies, according to the part of the city to which it is taken, from 1s. 3d. to 1s. 7d. per c. yd.; binding, rolling, and watering will come to perhaps 6d. more, so it is readily seen that the cost of spreading a coat of quarry-metal 6 inches thick over a Melbourne street is only from 8d. to 9d. per superficial yard, according to its situation. I know of no city where the price is less than this, for equally good material. The plant at the corporation quarry consists of Hope’s stone-breakers; four 16 x 9, and two 15 x 7, machines; one “band” steam drill elevator to bins, two mixers for tarring the screenings, tar-pump, quarry-pump, &c. These are driven by a 34 h.p. high pressure horizontal engine. The stone is raised to the machines in side-tip trucks working on an inclined train-road, drawn by the usual steel wire rope and drum, worked by a 14 h.p. winding engine. The steam power is obtained from two steel boilers working together at an average pressure of 72 lb., one being a Cornish multitubular boiler 24' 6" x 6' 0" dia., the other being a multitubular 14' 0" x 6' 0" dia., with a monkey dome 7' 0" x 2' 6", similar in design to the boiler installed at the Working Men’s College. As the stone is broken at the crushers, it falls on an endless travelling band and is carried to the elevator which lifts and discharges it into the ordinary type of cylindrical screen, where it becomes sorted and carried by separate troughs to the proper bins, according to its gauge. An apparatus is also provided for drying and heating the screenings and tar, and mixing the same, capable of turning out upwards of 20 tons of this material daily. The mechanical arrangements were, I believe, originally carried out by Mr. Boddington of this city, and have answered their purpose well, with some minor modifications in detail. The establishment at the quarry is able to manufacture about 60,000 c. yds of metal and screenings per annum, but at the present time is only being worked to about two-thirds of its full capacity. In constructing a road, whilst formerly it was the practice to give a “good barrel” to it, it is now generally admitted that a cross-fall of 1 in 40 is sufficient to take the water off a well-made carriage way, seeing that no side-slope will prevent water being retained in hollows on one improperly maintained. On the matter of gradients, I feel almost afraid to quote the recommendations of engineers of the older countries, as I have travelled in Australia over well-made roads of varying grades, culminating in one which—for more than a mile—had a uniform incline of 1 in 8. I may however, just mention that all engineers agree that, if possible, the maximum slope should be 1 in 30, the minimum slope, 1 in 125. The former is the limit permitted in England in the formation of turnpike roads, although 1 in 20 is allowed on roads of lighter traffic. The late City Surveyor of London declares that neither of these gradients are good for a paved town road. The latter is the very least fall that can be
given to enable the carriage way to free itself of water: this is even flatter than most engineers in England advocate, their limit being 1 in 8.6. This, then, in a necessarily brief and sketchy manner, gives a general description of the main principles which underlie the construction of the hundreds of thousands of miles of road that so soon sprang into existence in all civilized countries, after the fact was clearly proven that stone broken small and disposed in a certain way, would make a more permanent, and much more agreeable, roadway than was before thought to be possible. But, excellent as it was, as increasing population and commerce created populous cities and developed traffic, it was found that the cost of keeping the macadamized road in order—its “maintenance”—became heavier each year, whilst the discomfort attendant on the irregularities caused by wear, and by the manufacture of mud, or dust, as the case might be, became objectionable, especially in the streets of cities. This led to the substitution, in some of the London thoroughfares, of Boulder pavement; which, however, was very noisy and rough, and was in turn superseded by cubed granite, or “sets”, which were first introduced by Telford in 1824 at Hanover Square. These were, in the first instance, of larger size than those now used for paving purposes, being from 6 to 8 inches wide, 10 to 12 inches long, and 9 inches deep. About 1850 these dimensions were reduced to from 3 to 4 inches in width, not more than 12 inches long, and 7½ deep, which are the standard measurements at the present day. From being originally laid in the subsoil, it became the practice to lay them on a bed of broken stone, or brick, cinder, &c. (known as “hard-core”), from 9 to 15 inches in thickness; and more recently still, a foundation of cement concrete for all streets of heavy traffic was provided. The wear became so severe that only the very hardest granite was used for the most important streets, the best being brought over from Guernsey. The City Surveyor of Edinburgh, D.C. Eroudfoot, has expressed his opinion that no mode of constructing a city carriageway for heavy traffic can excel the following:—Foundation of cement concrete 9 inches thick, granite sets 3 inches thick by 7 inches deep, built into a bed of fine concrete about 2 inches thick, laid over the concrete foundation, the whole of the joints filled in with p.c. grout. His estimate for this work in Edinburgh is £1 per square yard, and he further states that no repair will be needed for 10 years; but as the durability of any roadway must bear a distinct relation to the extent of the traffic it sustains, this last statement is of little value unless the latter factor is given. After 13 years’ wear, Guernsey granite sets used in paving Blackfriars Bridge only showed a wear of a quarter of an inch; Aberdeen granite sets laid alongside being worn 1½ inches. The exceptionally heavy traffic over this bridge rendered it necessary to select the very best material; but the majority of the principal streets of London were paved in the first instance with Aberdeen granite at a first cost of 16 shillings a square yard, and estimated to last, according to the nature of the traffic, for periods varying from 8 to 20 years. The well-known bluestone, almost entirely in use about Melbourne, furnishes most excellent material for sets in streets of moderate traffic. Some stones taken from Flinders-street after 15 years’ wear, show a wear of 6 in., (sample exhibited) which indicates that a more durable material is needed in such a thoroughfare.
It is proposed to try some of the local granites for this purpose: those from the neighbourhood of Somerton, Whittlesea, and Trawool being within reasonable distance of the city by rail.

**Wood.**

In dealing with the question of wood as a street-paving material, I am rather embarrassed at the outset by the enormous amount of matter which it is difficult to compress into the limits of such a paper as this. It has encountered severe and, in cases, even virulent opposition. On sanitary grounds, some English, Continental, and American engineers condemned it; the Society of Arts in London published a report adverse to its use; and, later in the day, a Board appointed by an Australian Government pronounced adversely. This condemnation, however, in all cases save the last, proceeded on the assumption that soft wood (principally pine) was used for the paving, and was emphasized by the very unsatisfactory results that had arisen in many of the cities of America, where not only was the pine unsuitable but it had been very badly laid, the foundations being admittedly defective, in many cases in America consisting merely of a layer of boards on sand. Notwithstanding all this, wood-paving has continued in favor, and is now being more extensively used than ever in Europe, England and Australia. The prejudice against it in America will take some time to entirely die out, but this is not the main reason why its development has not been equally great in that country; the asphaltum roads—made principally from a preparation of Trinidad bitumen—are much in favour there, and are not so expensive. I am not prepared to urge that, under all and every condition, the use of wood for street paving is advisable. I can quite conceive that a damp climate would soon rot softwood blocks, for instance. But I do certainly maintain, after 15 years’ careful investigation of the subject and practical dealing with the work, that in such a climate as ours, well-selected Australian hardwoods, if properly laid on good concrete and grouted solidly in the joints, will make a road that will be good for, at least 12 years, under such traffic as the most busy of the streets of Melbourne or Sydney support. I further think that it is absurd to see cause for alarm to public health from the use of such a pavement. So far back as 1839, some wood-paving was laid in the “Old Bailey” in London. It was not until 1872, however, that it came to be extensively used. From that time onward a number of patents and methods were advocated by firms and companies, which tendered for works under the Commissioners of Streets and Sewers and other authorities, with conditions of maintenance for a term of years. Space will not allow me to describe the varying systems; but a brochure prepared by me in 1881 for the City Council of Sydney—a copy of which I have pleasure in asking this Institute to accept—will be found to contain considerable information on this subject. Wood-paving was first laid in Australia in 1880, when an experimental section was laid with various kinds of wood in King street, Sydney; this was followed within a few months by the paving of the intersection of Collins and Swanston streets in this city, with red gum. In both cases the main principle of obtaining a firm and impervious foundation of concrete was adopted, and a ¾ in. joint between the rows of blocks was provided for. This latter was determined on at the desire of some of the authorities (who were naturally anxious to prevent a failure of the unknown
material through slipperiness), but was soon found to be not only unnecessary but detrimental to the life of the road, as it enabled the toes of the horses' shoes to work on the arrisses of the timber until, in time, the effect of a corduroy surface was produced, making the roadway very noisy. In 1885, perceiving this, I reduced the joint to \(\frac{1}{2}\) in.; and, in 1886, still more narrowed it to \(\frac{3}{8}\) in. A matter of fact, experience has shown that, with proper attention to cleanliness, there is not much more danger, on the score of want of foothold, with hardwood than with sets, and that the joints may be regarded as adding but little to the safety of the road. In practice the paving in Melbourne has been laid for some years past with \(\frac{1}{2}\) inch joints, with the exception of one section where the blocks were simply tarred and laid close together; but the great expansion of our red gum renders it doubtful whether there be any real advantage in this method. The woods pre-eminently suited for wood-paving in Australia appear to be—Tallow-wood (E. microcorys) of New South Wales, Black-butt (E. pilularis) of New South Wales, Red Gum (E. rostrata), of Victoria and New South Wales, Karri (E. diversicolor) of Western Australia, Jarrah (E. marginata), of Western Australia. The blocks are sawn in lengths of six inches out of 9 x 3 planks, and are laid on a foundation of good Portland cement concrete, varying from 6 to 9 inches in thickness according to the nature of the ground, brought to the proper gradient and convexity, the latter generally one in fifty, and worked smooth on surface by means of a "floating" or rendering of cement mortar. The length of six inches was chosen for the blocks, not because it was essential to have that depth to ensure a firm and substantial coating to the street, which it had been demonstrated can be obtained with a 4-inch block, but in order that when much worn on the top the blocks may be cut down in length and re-used on the work. In Melbourne both the red gum and the karri have been largely used; also the New Zealand kauri (Dacrycarpus Australis) has been laid as an experiment. This latter, though not a hard wood, forms an excellent roadway, and will, I think, prove more durable than the soft woods in use in England. The section laid down is in Spencer-street, near the railway station, and at the present time is looking well after 5 years' traffic. A small sample of Tasmanian blue gum (E. globulus) has recently been tried, but it has been laid for too short a time to warrant my expressing an opinion as to its durability.

Samples exhibited, showing—

<table>
<thead>
<tr>
<th>Material</th>
<th>Location</th>
<th>Traffic Years</th>
<th>Wear Length (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Gum</td>
<td>Flinders Street</td>
<td>13(\frac{1}{2})</td>
<td>2 in</td>
</tr>
<tr>
<td>Karri (W.A)</td>
<td>Spencer</td>
<td>4(\frac{1}{2}) yrs</td>
<td>0(\frac{1}{2}) in</td>
</tr>
<tr>
<td>Karri (N.Z.)</td>
<td>Spencer</td>
<td>4 yrs 8 mos.</td>
<td>0(\frac{1}{2}) in</td>
</tr>
</tbody>
</table>

As regards the cost of wood-paving, the latest work done in this city has been carried out, including excavation and 6 inches of concrete foundation, at the rate of 16s. 6d. per square yard. I have no knowledge of any similar work that has been done so cheaply. Even at this price, which is about four times the cost of a good macadamized road in Melbourne, it will readily be perceived that ultimately the wood becomes the cheaper pavement, if its durability is such that the saving in annual maintenance (as compared with the cost of keeping the macadamized road in order) be more than will cover the difference between the original outlay cost of the two materials. This is entirely apart from the question of public
comfort, cleanliness, and wear and tear on horse and vehicle, which must surely be valued for something. Thus, taking a wood roadway that lasts for 12 years, nominally without costing anything for repairs; it is then relaid with blocks for a further period of 12 years; and, taking the state of accounts during 20 years, we have—First cost, say 17s. per square yard; renewal of blocks at 12 years, 11s. per square yard; allowance for repairs in 20 years, 4s.; total, 32s., or at the rate of 1s. 7¼d. per square yard per annum. During a similar period, a macadamized road costing, in the first instance, 5s. per square yard to construct, would under heavy traffic cost at least 1s. 6d. in renewals and repairs every year, making in 20 years a total outlay of 33s. 6d. for a much less satisfactory road. The renewals of blocks would be much reduced in price if the old blocks were originally of such length—say 6 in.—that, as previously mentioned, they could be cut down to a shorter length and relaid. To those members who desire to study this question of wood-paving, I would refer them to a very exhaustive paper on the subject by G. H. Stayton, M. Inst. C.E., in 1884. I have only here time to quote from that paper the following remarks on the subject of cost:—"The author has frequently been asked whether the wood-pavement laid in Chelsea has proved economical as compared with macadam, the answer to which may be found in the following statement, which is based upon the assumption that the average life of the wood-blocks will be seven years, and which shows that the first cost, repairs, renewals, and cleansing, if spread over a period of 20 years, amounts to 1s. 9d. per square yard, whereas the previous cost of repairing, renewing, and cleansing macadam, but exclusive of first cost, amounted to 2s. 10d. per yard...

If the cost be spread over a period of 15 years only, the figures will be increased to 1s. 8¼d. per yard per annum for the wood, plus 5d. for cleansing, or a total of 2s. 14d." This comparison is made on roads bearing a traffic of from 500 to 750 tons of traffic per yard per day of 16 hours, or say 156,000 to 235,000 tons per annum. The cost of this work is given at 10s. 6d. per square yard; but provision is made for renewal of blocks (which were, of course, of pine) in every seven years. From the above quoted authority I learn that, at the time he wrote, out of 1718 miles of public streets under the maintenance of the various authorities about London, there were "573 miles paved with macadam, 280 with granite, 58 with wood, 13½ with asphalt 798½ with flints or gravel." The metropolitan traffic was conducted by, approximately, 100,000 horses, and 40,000 vehicles, of which 10,381 were licensed cabs, and 2,223 were omnibuses, representing, with harness, etc., a total value of £5,000,000!

Asphalte.—We now come to the great rival of the materials already referred to as a road-pavement, viz., Asphalte. The extent to which this material is now being used in the old world and in America justifies some allusion to it here, even though it has not been much known in Australia in connection with carriage-ways. It would appear that it was first laid down, in modern times, in 1854, on a street in Paris, although Mr. Ellice Clarke, M. Inst. C.E., mentions that a piece of asphalt had been previously laid on the Morand Bridge, Lyons. No details of the wear of this latter are, however, in evidence. As to the former paving (that in the Rue Bergère) it would appear that "after 15 years' wear, portions
of the road were removed, and it was found to have lost 5 per cent. in
weight, and to have been reduced \( \frac{1}{2} \) -inch in vertical depth." No record of
the traffic passing over this street appears to have been taken. This
asphalt consisted of what is now known as the " Val de Travers Com-
pressed " variety (a specimen of which is on the table for inspection
by members.) Since its introduction in France asphalt has had the usual
number of failures resulting from want of experience in dealing with a new
material, but its use for roads has steadily increased to such an extent
that Paris is now known as the " asphalt city," whilst the other European
capitals have also largely adopted it; and, in London itself there have
been miles of streets paved with it. The American cities have also largely
adopted the use of a special variety of asphaltum prepared from Trinidad
bitumen. The popular application of the word " asphalt," in Melbourne,
to all preparations of tar will, perhaps, render it necessary to point out
that there is no connection between the two things; rock asphalt being a
bitumenous limestone obtained by quarrying. This is crushed in the
usual way, passed through a disintegrator, heated in revolving cylinders,
and conveyed to the work (in especially prepared vehicles called " heaters ")
at a temperature of about 120° Fahr., and spread on the road by specially
trained men. This is, briefly stated, the method of using the compressed
asphalt, the mastic (which is principally used for foot-ways, damp
courses, cellars, floors, etc.) being a preparation of the above described
bitumenous limestone, when ground to powder, with a fixed proportion of
bitumen, varying in proportion to the quantity of bitumen contained in
the natural rock. M. Leon Malo, whose work has been for years the
recognised authority on the subject, has clearly defined the proper nomen-
culture that should be used in describing the different forms of asphalt.

1. Asphalt is a natural product, a bitumenous limestone, consisting of
carbonate of lime and mineral bitumen, intimately combined by natural
agency. 2. Asphaltic mastic is the rock ground to powder and mixed with
a certain proportion of bitumen, similar to that originally contained in the
rock. 3. Gritted asphaltic mastic is asphaltic mastic to which washed or
river sand, free from all earthy matters, has been added. 4. Asphaltic or
bituminous concrete is gritted asphaltic mastic in a hot state, mixed with
dry flint, or other stone. 5. Bitumen is a mineral product found in
asphaltic rock in Trinidad, and other places." Asphalt contains from 5 to
15 per cent., by weight, of pure bitumen composed of 85 parts of carbon,
12 hydrogen, and 3 oxygen, having a specific gravity of 1-13, and is
found principally in the valley of the Rhone, and in isolated parts of
Sicily, Italy, and Hanover. W. H. Delano gives chemical tests to deter-
mine the purity of asphalt. This appears to be specially necessary in
view of the number of imitations of the genuine article that are passed off
on engineers. He explains: "It is not gas-tar, nor Stockholm tar,
neither is it pitch from suets and fatty matters, nor shale or petroleum." An
absolutely rigid foundation is necessary for the success of asphalt
paving; from 6 to 9 inches of cement concrete is the usual bottom
provided. It has been found that lime concrete has a deteriorating effect
on the asphalt. The concrete must be quite dry before the asphalt is
laid. This latter is generally laid, for streets of heavy traffic, of a thick-
ness of \( \frac{3}{4} \) in. I have a piece of compressed asphalt, originally laid down
in Cheapside, which showed after 13 years wear a thickness of 0.55", or a diminution of 3/8", part of which was due to compression, as was apparent by microscopic examination of the section. Compressed asphalt—preferably from the Val de Travers or the Sessell Pyrmont Mines—is used principally for road-ways; mastic asphalt being reserved for foot-paths. An explanation of the methods of preparation and treatment of this material is not within the scope of such a paper as this. Before speaking generally of the advantages and disadvantages of asphalt as compared with other paving materials, I will briefly mention the American asphalt which is being prepared from the Trinidad bitumen, and the manufacture of which has been in operation for some years in Australia. The asphaltic pavement principally used in the American cities may be most clearly described as being an attempt to artificially produce, by the aid of pure bitumen obtained principally from the Island of Trinidad (but also from Cuba) the mechanical blending of bitumen and stone, which is done by nature in the case of the rock asphaltes already referred to. It is evident that, in this case also, very careful chemical analysis is necessary to ensure not getting an inferior material. By the courtesy of the Engineer Commissioner for the District of Columbia, I am enabled to state that his practice is to mix 20 to 30 parts of distilled heavy petroleum oil with 100 parts, by weight, of pure Trinidad—or Cuban—bitumen, as the case may be. This forms what he terms "asphaltic cement," which is used for the paving in the following way:

<table>
<thead>
<tr>
<th>Material</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphaltic cement</td>
<td>from 15 to 18 parts.</td>
</tr>
<tr>
<td>Sand</td>
<td>15 .. 17</td>
</tr>
<tr>
<td>Pulverised carbonate of lime</td>
<td>70 .. 65</td>
</tr>
</tbody>
</table>

"The sand and asphaltic cement are heated separately to about 300° Fahr. The pulverised carbonate of lime (while cold) is mixed with the hot sand in the prescribed proportions, and then mixed with the asphaltic cement at the required temperature. The pavement—which has a foundation of concrete in the usual way—is laid in two coats, making a total thickness of 2 3/4 in., when rolled, the asphaltic cement being brought to the work in "heaters," as in Europe, and laid similarly to the mastic asphalt already alluded to. This work has been carried out, with a five years' guarantee, at an average cost of 9s. 5d. per square yard. In the year 1883 more than 58 miles of asphalt and "tar" streets existed in the district of Washington. The engineer does not say what proportion of this was of the Tar variety. In New York more than 27 miles of streets paved with asphalt existed in 1892. It would appear that some of these streets are not in a satisfactory condition. The only instance in this city where any of this Trinidad asphalt has been laid down to sustain wheel traffic is in a lane off Little Collins-street, and is only just finished. This work was at the cost of private owners, under my supervision, by the Melbourne agent for the New South Wales Asphaltum Company, and certainly presents an admirable appearance as a smooth, impervious, and noiseless road surface. The question as to its durability is one which time can alone settle—but the contractor guarantees to maintain it for three years.
SUMMARY.

On the broad question of respective merits of the various materials used for road-paving, it would appear that the increased desire for comfort and cleanliness which accompanies civilisation and worldly prosperity has led to a demand for something superior to the macadamised method. In cases where the traffic is very heavy, and where, in consequence, the cost of annual maintenance and cleaning is high, it has been demonstrated that the luxury thus asked for can be obtained without an increased ultimate cost. English authorities fix these standards at 40,000 tons of traffic per yard width of road per annum; and in money at 2s. per square yard in maintenance annually. When either of these figures are reached, it is probably cheaper in the long run to construct a more permanent roadway than broken stone can produce. In the mere matter of durability it is doubtful if anything will last longer than the best granite used in London (Guernsey and Aberdeen) which has been known to stand the enormous traffic of that city for 15, and even 20, years. But the granite is very noisy; it is severe in its action on horses, and on vehicles, and is apt to be slippery, generally causing a nasty fall to a horse when he comes down. With reference to this question of slipperiness, the result of a series of very careful observations (undertaken by the late Wm. Heywood, M. Inst. C.E., City Surveyor of London), in 1873, shows that the distance travelled before an accident occurred on the several classes of pavement was—

<table>
<thead>
<tr>
<th>Material</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite</td>
<td>132 miles</td>
</tr>
<tr>
<td>Asphalte</td>
<td>191 &quot;</td>
</tr>
<tr>
<td>Wood</td>
<td>446 &quot;</td>
</tr>
</tbody>
</table>

thus showing that granite is much the most slippery. The wood here referred to is soft wood; probably Australian hardwood will be found to give a result nearly midway between the softwood and the asphaltite figures. The slipperiness of asphaltite is undoubtedly its great disadvantage. It is essential that special and perfect cleansing be provided to keep it safe for travel. It needs gravelling during wet weather, and cannot safely be laid on any steep gradient. As regards cost, although I think the first expense would be probably about the same as wood, there is doubt in my mind as to whether it would last as long—as to that point I do not speak with certainty. There undoubtedly is the disadvantage that it is a material which has to be imported, and which requires specially trained men to lay and to repair it properly, therefore the only satisfactory way in which it could be introduced here would be on the large scale, and under such conditions as would make it obligatory on the contractor to maintain the road during a term of years on an annual maintenance rate, as is done in Europe and America. All things considered, therefore, it would appear that up to the present time Australian hardwood possesses the greater advantages. If properly laid it need not be noisy; it is durable; it can be kept clean; and is safe on gradients even up to 1 in 25 (with moderate sandings.) It is less severe on a horse in the event of a fall than is either granite or asphaltite, and it is not greatly inferior in point of impermeability. Could our city streets be suddenly transformed (as a whole) into asphalted thoroughfares, so that our horses would travel without shoes, and our vehicles without metal tires, I am quite prepared to
admit that the ideal carriage-way would then be obtained, and such a
result may be in store for posterity as a further development of the modern
road. But accepting the existing state of things where various kinds of
paving materials are in use in the one city, it would seem that for many
years to come our Australian forests and quarries will plentifully supply
us with satisfactory wood and stone for our streets. In closing these
remarks, I am conscious that I have, of necessity, been compelled, to a
large extent, to travel over well-trodden ground, much of which is most
probably already familiar to my listeners. In attempting to trace the
gradual development of the modern road, however, I felt it impossible ot
abstain altogether from quoting the opinions of men to whose scientific
knowledge and experience we stand indebted for so much that is now
known on the subject. It remains for other members to carry on the
story, and to describe the continued and higher development of the road,
under the form of "tramway" and "railway," both of which are
descendants "in the right line" of the simple carriage-way which I have
endeavoured to talk about this evening.
DISCUSSION ON
THE EVOLUTION OF THE MODERN ROAD.

FLEMINGTON ROAD
3 CHAINS WIDE.

SCALE

TYPES OF MELBOURNE ROADS.

1/2 CHAIN STREET

1 CHAIN STREET.

ST KILDA ROAD 3 CHAINS WIDE

FLEMINGTON ROAD 3 CHAINS WIDE

SCALE
DISCUSSION ON
"THE EVOLUTION OF THE MODERN ROAD."

Wednesday November 7th, 1894.

Mr. J. M. Coane said he would like to refer to a few points in the paper read by Mr. Mountain. In the binding of macadamised roads he had mentioned that one of the fundamental rules was to admit of no clayey matter at all. He thought that clay binding in some cases was very useful—for instance, it had been used in connection with the steel road track which had been formed for carts on the road to South Melbourne by the side of the tram track. He had used the clay found at Moorabbin and Brighton, well mixed with the ordinary metal between the tram plates he had mentioned, and had found it to stand very well indeed. In some roads he had made some years ago he had adopted this plan, taking the ordinary gravel of the district and mixing it well with about 50 per cent. of its own bulk, spread out and rolled, and he had found it excellent binding. There was a large portion of loose sand amongst the gravel, and this, when mixed with what was called Moorabbin clay, had formed a very good road. In wet weather there was a certain amount of discomfort arising from the clay dissolved by the rain, but he thought that was a very small matter. He had found that this clay had the effect of making the road almost impervious to the influence of water. With regard to the setting and ramming of the pitchers in fine concrete; some years ago, while on some work of this kind, he had set a layer of fine concrete, and had had the pitchers rammed in, and the effect of this was that the joints were filled for a depth of two to three inches from the bottom with fine concrete, the remainder of the joint being filled from the top with tarred sand. There was one point which Mr. Mountain in his paper had left untouched, that was the width of tyres. As the roads all over the country were being cut up he thought a Width of Tyres Act would be very beneficial, and there would be a very great improvement in the roads. He had often seen a load of three tons on a dray with 3-in. tyres. If that load had a tyre 4½ or 5 inches it would be a very much easier matter, both for the horses and the owner of the dray, and the public would be benefitted by the saving of the road. In regard to wood paving, he said that sanitarians had raised objections to it on account of the probability of disease germs lodging in it. It would be interesting to know Mr. Mountain's experience on the subject. He thought red gum would be a very unpleasant place for germs to live, and that the idea was rather far fetched; generally speaking, he thought that the importance of the subject of roads could not be over-rated; the Institute was constantly discussing bridges and other structures, and as they had 50 to 100 miles of roads to only one mile of bridges, he hoped the subject would be thoroughly discussed. He had seen some of the roads in Brighton on a market day in almost as bad
ROAD EVOLUTION.

a state as those described by Mr. Mountain of a century ago. Therefore he trusted that the discussion of the paper before them would result in a great improvement in road making here. Mr. J. S. Pirrie said that the description of the roads of a hundred years ago in England would almost be called a flattering description of the roads in Gippsland at the present time. He had had some experience there during the last two months. In one place a lady crossing from one side of the road to the other got stuck in the middle, and it took four of them with planks to "excavate" her.

One of the members of the Institute, a shire engineer in Gippsland, said that, like the Israelites, he could not make bricks without straw, or rather roads without metal. He had formed a road out of the material on hand, but the traffic was so great that in a short time the road was in a worse state than it was before, but that road in summer was one of the best roads in Gippsland. After a year's wear, it had set down quite hard. With regard to the space between the blocks, he had seen the experiment carried out at Hamilton Square in London, of setting the blocks at different spaces apart. Further trials had been carried out there, by placing the blocks diagonally. He read the following extract from "The Engineer" of 28th September, 1894, on the question:

"Some little time ago 43 officers of the Metropolitan police were deputed to make certain observations concerning road traffic generally during the discharge of their daily duties in the busiest thoroughfares of the world. These observations extended over fifty days, every day for 12 hours each; viz., from 8 a.m. to 8 p.m., granite, asphalte, and wood paving were considered. In one day of 12 hours no fewer than 12,366 horses and vehicles passed along Cheapside, and 5350 along Canon-street. During the 50 days upon which observations were taken, 512 accidents took place on wood pavement, 719 on granite, and 1066 on asphalte. From these figures it was estimated by an expert, that a horse could travel 350 miles on wood pavement during the 5 days without meeting with an accident, 191 on granite, and 132 on asphalte; therefore the great superiority of wood pavement in places, at least where horses are concerned is at once apparent. Altogether 1054 falls were recorded and an analysis of this number, "London" says, affords some curious information. On asphalte 247 partial and 190 complete falls took place; on wood pavement 326 but only 39 complete falls; roughly for every fall on wood pavement 4 took place on granite and asphalte."

The question of the most suitable timber had caused considerable discussion at home, and he hoped it would be in favour of Australian timber. The quality of the timber depended a great deal upon the soil on which it was grown. There was another pavement which had been talked about recently, that of cork pavement. Some of it had been laid in different parts of England; he had seen some in London in Liverpool-street, and it was spoken of in the highest terms. With regard to asphalte, from his experience of it at any rate it did not impress him very favourably, being constantly broken and never seeming to be unbroken at some portion or another, both rolled and compressed; it seemed to him to have the same effect. According to the American News it had been a failure in Philadelphia, but it was what was called the "imitation asphalte," as described by Mr. Mountain. The contractors had blamed the wet weather for its failure, but he did not think that the Council of Philadelphia could afford enough umbrellas to cover it. (Laughter.)
Mr. A. M. Henderson, (a visitor), said he did not know very much about the subject of road making, but had gathered some information with regard to the width of tyres. He had spent some of his holidays at Cape Schanck, and a friend of his there, Capt. Anderson, had fitted wide tyres 4 in. to his drays, and he found that his horses could take 50 per cent. more load, and the roads did not suffer. His horses could take a load heavier than a team with narrow tyres and go gaily along while the other teams with a lighter load could scarcely drag along. It had been a great success there, and a number of the other farmers had already adopted the wide tyre.

Mr. A. E. Phillips said it was very pleasant to travel on a good road, and very nice to listen to such a very interesting paper. Other countries also were desiring better roads. The King of Persia had once a good road made by the side of the common road, and this had led to the term of “The Royal Road.” They had also heard the Royal road to learning, which he thought had the same origin. They now wanted progress, especially in roads. With regard to the maintenance and repairs of roads, when he was home in England two or three years ago he had seen a method in use there of binding and sacrificing by the use of an American machine made of a huge piece of cast iron with several teeth in it. He would like to know if there was any advantage in its use and was there any possibility of Melbourne following in the wake of our American cousins with regard to its use. Already some of their road machinery had been used with success in some of the country districts.
Library Digitised Collections

Author/s:
Mountain, Adrien Charles

Title:
The evolution of the modern road (Paper & Discussion)

Date:
1900

Persistent Link:
http://hdl.handle.net/11343/24241

File Description:
The evolution of the modern road (Paper & Discussion)