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MODERN ROAD PAVEMENTS.

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The historical aspect of paved roads is, perhaps, more interesting than serviceable, except that they generally indicate a high state of civilization, and usually connote especially a cycle of advancement in engineering attainments, and are associated with organisation, control, and management by engineers.

Perhaps, the first pavement, of the existence of which there is strong presumptive evidence, is that of remains discovered in the vicinity of the Great Pyramid in Egypt. Along this supposed road leading across a sandy waste, Pharaoh, of the fourth dynasty, is thought to have conveyed material for the construction of that monument 4,000 years B.C. Subsequently, we read of the broad-paved road which led from the city of Memphis to the Great Pyramids, and which was about six miles long. Judged from the modern standpoint, as paved roads these must have been of the crudest description.

Not until somewhere about B.C. 600 do we approach the period of authentic record. The Carthagenians, at this date, were probably the first to systematically "construct and maintain" their roads. With the destruction of Carthage by the Romans in B.C. 146, the latter began to make history—and roads—after the art of the Carthagenians.

About B.C. 300, the Appian and Flaminian ways were commenced by the Romans. They were said to have been built with stones and cement mortar, which in places

attained a depth of several feet and lasted probably a thousand years. The Romans constructed roads concurrently with conquest, and in Great Britain alone they made 2,500 miles of roads, also many miles in Palestine, and elsewhere.

In the new world, excellent foot roads were constructed by the Peruvians and Mexicans centuries ago.

After a long interval the mantle of the Romans seems to have been assumed by the French, and they are deservedly reputed for the excellence of their roads and systematic maintenance of same. The first paved roads in Paris date back to the reign of Phillip Augustus about 1184, the population then being about 200,000. A new era in road-making was marked when in the sixteenth century Henry IV. established the office of "Great Way Warden," whose duty it was to control and keep in order the public roads in France.

In Spain, Cordova is credited with paved roads dating back to 850 A.D., but the first constructed subsequent to the Roman era were made in 1749 by Fernando VI., from Santander to Reinoso. In 1749, a special bureau was constituted in charge of all road work. The first actually systematic arrangement was not, however, attained until after the establishment of a school of engineering in 1834.

In 1555, the first Highway Act was enacted in England, while the first pavement in London was the Strand, constructed in the fourteenth century.

Up to nearly the end of the eighteenth century, the Roman system of broken-stone pavements was adopted for the best work; but subsequently several modifications were introduced, culminating in the universal adoption, more or less in its entirety, of the method instituted by Macadam.

In concluding this historical introduction it will, therefore, be proper to advert to the times of Tresquet, the great French road engineer, and Macadam and Telford, the illustrious English engineers to whose genius the early conceptions and inauguration of our present system is due. Macadam pavements, on account of their low first cost, are everywhere the most general form of road-construction now in vogue.

The systems practised by the Romans produced an equally good road surface, at any rate for their purposes, yet they were extremely costly; and it remained for John Loudon Macadam to devise a systematic and rational method of constructing broken stone pavements in a thoroughly scientific manner, so as to entail a minimum of expenditure, and be economic in maintenance.

In 1775, M. Tresquet adopted a system of road-making very similar to that devised by Telford 25 years later. Prior to 1775, the broken stone pavements of France had been made after the Roman fashion, according to which the ground was excavated level to a depth of about 2ft., then large stones were laid on flat in two or three layers to form a foundation; on these small stones were laid and beaten down, and, finally, a course of smaller stones was laid and beaten down firmly. Tresquet altered this by excavating the ground to a depth of about 1ft., with the bottom curved the same as the finished surface, then stone pitchers were laid by hand edgewise up and lengthways across the road, and beaten to an even surface and finished off as before.

In 1784, Macadam was appointed a road trustee and manager of a district in Ayrshire, where he practised the method of road-making which still retains his name. His system consisted of spreading 2in. stones wherever pos-

sible on—not below, as in the case of Tresaquet and all others—the properly levelled and drained road surface to a depth of 10in., and the convexity given was only sufficient to properly shed the rainwater readily to the side drains. In 1815, he was appointed surveyor of roads in Bristol, where he metamorphosed some 178 miles of roadway. By his system, local finances, previously embarrassed, were placed on a sound basis. So marvellous were the results obtained that other authorities consulted him with equal success. The road trustees of the Carse of Gowrie turnpike road in Perthshire became almost insolvent owing to the cost of maintenance. They secured the advice of Macadam and re-made their roads accordingly, and their funds were soon restored to a financial position. In 1850 Macadam's system was adopted throughout France, perhaps the greatest compliment he could have had.

In 1802 Thomas Telford undertook his first great piece of work in the Highlands of Scotland, involving the expenditure of £450,000 and embracing 920 miles of road. According to his system, the formation was levelled, as in the case of Macadam or excavated as in the case of Tresaquet, with flat bottom, then pitchers were hand-packed across the surface with base down and standing 7in. high in the centre, reduced to about one-half at the sides; over this foundation was spread a coat of $2\frac{1}{2}$ in. metal to a depth of 7in. in the centre and somewhat less at the sides. The bottom course was carefully levelled, graded, and compacted with small stones by hand to keep earth from working up through road metal and ruining road, as might readily happen on soft ground; the top coat was covered with lin. of gravel. This system is specially adapted to weak foundations.

CROSSFALL ABOUT 1 in 17



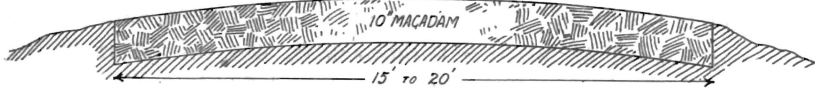
36 ROMAN FEET
ROMAN ROAD

CROSSFALL ABOUT 1 in 9



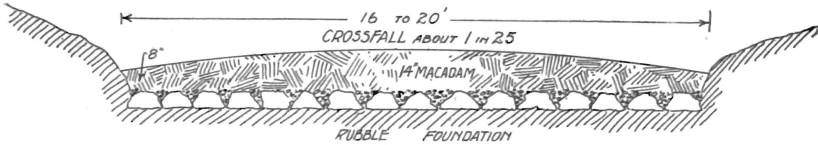
ENGLISH ROAD 1809

CROSSFALL ABOUT 1 in 20



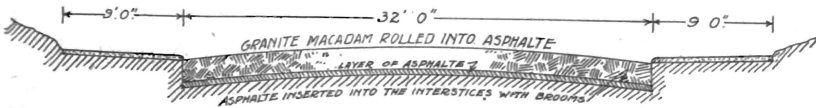
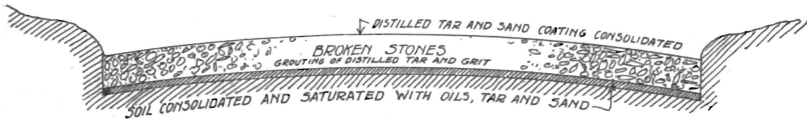
10" MACADAM
15' to 20'
MACADAM'S ROAD. 1784

CROSSFALL ABOUT 1 in 25



16 to 20'
14" MACADAM
RUBBLE FOUNDATION
TELFORD'S ROAD 1800

DISTILLED TAR AND SAND COATING CONSOLIDATED
BROKEN STONES
GROUTING OF DISTILLED TAR AND GRIT
SOIL CONSOLIDATED AND SATURATED WITH OILS, TAR AND SAND
CASSELL'S SYSTEM 1834



9' 0" 32' 0" 9' 0"
GRANITE MACADAM ROLLED INTO ASPHALTE
LAYER OF ASPHALTE
ASPHALTE INSERTED INTO THE INTERSTICES WITH BROOKS
LEOPOLD STIEBEL'S SYSTEM 1884

Fig. 1.

Telford's magnum opus was, however, the construction of the Shrewsbury and Holyhead Road, one of the finest pieces of road engineering carried out up to that time. The surface traversed consisted of rocks, bogs, ravines, and precipices. In those days road pavements were consolidated by the traffic, with all the attendant inconvenience, losses, and delays. Wherever the nature of subgrade was good and suitable, he used Macadam's method, reserving his own type for weaker or defective surfaces to effectively distribute the load over a greater area.

Since the advent of the steam road-roller the making of Macadam roads has entered a new phase. The formation is preferably made parallel to the finished surface, and instead of pitchers hand-packed, 4in. or stronger metal is now laid for a bottom or foundation course where one is required, and a top course of 2in. or 2½in. gauge metal lightly blinded and well rolled by a steam roller weighing from 10 tons to 15 tons. Under the old system it took months to consolidate a road, but nowadays they are made to-day and in use to-morrow. They may now be made any time of the year, though the autumn is the best season, instead of only in the winter as formerly, and they withstand heavier traffic. This is in brief the recognised standard system on which the best Macadam roads are now made.

The rationale of the different pavements is as follows:

The Roman pavement was made as solid as possible, partly owing to difficulty of draining foundation, and partly to insure durability and minimum of maintenance. With large flat stone foundation the top course of metal must be thick or the flat stones must be in several layers.

A thick coat of metal distributes pressure and prevents a load being concentrated on one particu-

lar part of flat stone. In those days it was not customary to prepare formation so as to make it uniformly strong, so that with a thin top course and one layer of flat stones there is a local concentration of load, and the flat stones will surely cockle and rock sooner or later, letting water into foundation and ultimately ruining the road. The Romans therefore adopted two or three courses of flat stones, sometimes cemented together, closing the voids with a strong matrix and excluding moisture.

Where a road is formed below the natural surface, or where the surface is bad, a strong foundation course is advisable; but before the advent of the steam roller the only possible way to attain this end was by laying hand-packed stones on flat with points upwards, wedged and jammed with small stone shivers tightly driven in. This prevented the soft earth working up and destroying the surface, and enabled the great thickness of the Roman road to be halved and the expense reduced; but drainage had to be carefully provided for. This was the system of Tresaguet and Telford; but Telford's was much the superior.

Wherever the natural formation is good a 10in. coat of metal broken to a 2in. gauge is sufficient to distribute the weight of a vehicle with moderate load without injury to earth foundation; and as, without a heavy roller, all dirt, etc., that is put on to such road while the metal is loose must stay there, it is preferable to use grit. Where the metal is consolidated by wheel traffic, sufficient grit will be abraded from metal without the addition of anything else, provided the surface is properly tended. This is the system of Macadam. (There were no road rollers in his day.)

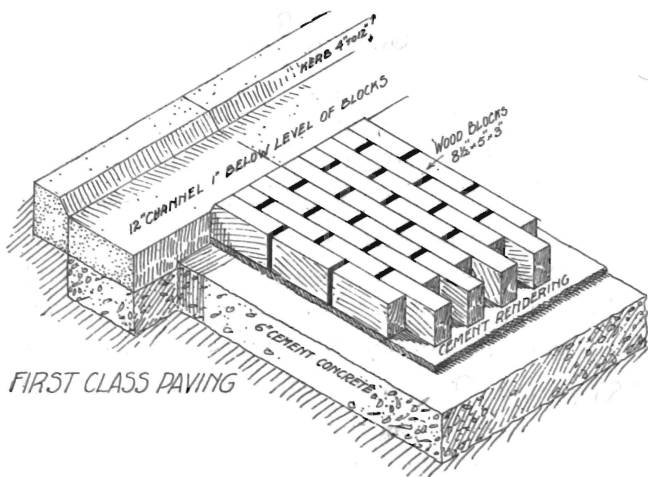
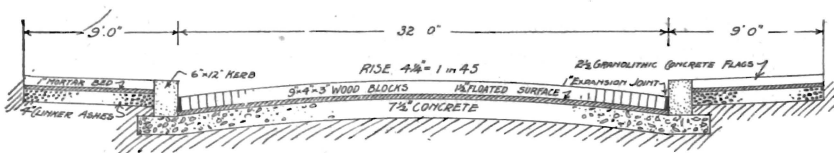
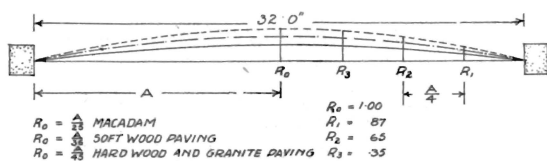
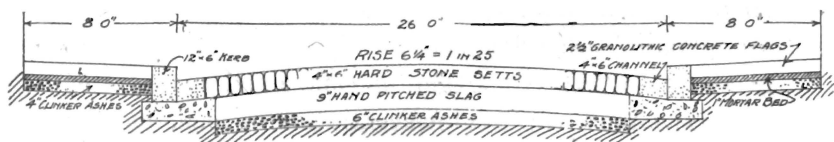


Fig. 2.

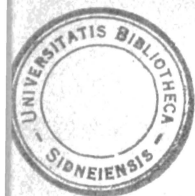
Under modern conditions and requirements, roads carrying heavy traffic would have to be made with a Telford base if a heavy roller were not available. With a heavy roller a foundation 8in. to 12in. thick of 4in. to 6in. metal can be consolidated so as to stand heavier loads than the original standard Telford foundation; for country and suburban roads this type of macadam road is quite satisfactory. The distinguishing feature of a macadam road, as now known, strictly speaking lies in the use of metal broken to a gauge whether 4in. or 2in. no matter whether consolidated in one layer or two, or three, so long as there is no hand set foundation.

In my opinion the greatest road engineer of recent times was Telford, and the greatest road engineer administrator was Macadam. Although Macadam originated the most economical system and demonstrated the soundness of his principles successfully in practice, yet Telford adapted methods to circumstances scientifically, improved on other systems, and originated methods when necessary, and produced the best roads of his day.

The use of cobblestones for the pavement of roads is naturally older than Macadam, and evidences and accounts show that they were used many centuries earlier.

The same may be said of stone block pavements. First irregular shaped blocks were used, and later regular shapes were employed, as in Belgian block pavements.

Regular sized stone setts were introduced as a standard stone pavement during last century. They were first bedded on old macadam and sand, and later on concrete and sand or tar-asphalt. They form probably the most durable pavement known, lasting under very heavy traffic for upwards of 30 years, when of best quality.



Natural rock asphalt came in about the same time, being first used in Paris. The life of this pavement under heavy traffic is remarkable. A 2-inch coat on a concrete foundation lasted in Threadneedle Street, London, for 37 years, and was only removed by reason of the corduroyed state of the concrete foundation, due to the cutting of trenches for water, gas, sewer and other services. I saw this pavement lifted and renewed in 1909 and was as much surprised at the small amount of wear on the asphalt as at the corrugations in the surface of the concrete foundation.

The history of wood block pavements is somewhat ancient, but up to half a century ago they were practically a failure. The soft timber wide joint always adopted up to about 30 years ago made this form of pavement a questionable success.

The adoption of Australian hardwoods was a decided advance in wood block pavement, and when they were dipped in tar laid with close joints they at once became established as one of the best pavements for city streets. Later when the surface of pavement was protected by distilled tar and fine gravel or metal screenings, their life was materially increased and expansion greatly reduced.

Tarmacadam has within recent years again come to the front as a pavement, replacing macadam. Its impervious surface and wearing qualities making it in every way to be preferred to macadam.

Concrete, though used many years ago as a pavement, was not greatly thought of till recently when it was scientifically constructed both plain and reinforced. It is now largely used in America, and has been introduced into many other countries, including Australia. More detailed reference will be made to current practice later.

Some 20 years ago, the dust nuisance came into prominence. Not that there was not dust before that, but because faster traffic such as motors (self propelled vehicles) made it so prominent that everyone seemed to notice it and demand its abatement. The means suggested to overcome the trouble were numerous and varied. Of course, this had to do with macadamised roads only. Almost all reformers have started out to so treat the macadam surface that any dust formed or grit worn off would be made self-binding and reinforce the surface like a mat or cushion. In this way the life of the road might be greatly increased and the comfort of the people equally improved by lessening the vibration, noise and dust. Others, again, have attacked the problem from another direction, and have sought to combine with the macadam some substance which will virtually produce a new kind of pavement, or substitute a new and different pavement altogether, having the desired qualities in a high degree.

Following up the latter scheme first, it will be seen that such pavements include mineral asphalte, wood blocks, and others which are too costly for the majority of the streets. Tar pavements of various kinds have been tried with more or less success for a time, but they are difficult to repair and are extremely hot—in fact the hottest pavement known. When double-distilled tar is used and the traffic is not heavy they give good results, though more costly than tar-dressed roads, and their use is chiefly indicated when the traffic is too heavy for the latter. All pavements which are of the nature of a substitution can only be adopted as existing pavements become worn out, and relatively they are costly, and, with the exception of mineral asphalte, require frequent dressings of tar and sand, estimated at 2d. to 4d. per square yard per annum according to traffic. Regarding this class of pavement

(tarmacadam) the Board of Commissioners appointed to investigate the question of pavements for Washington, United States of America, reported that "while some of the latter and better class of coal tar pavements show good service, and give a fair promise of reasonable durability, yet the general condition of this class of pavements in the city is such as to lead to their condemnation as faulty in principle and deficient in vitality."

Referring now to those inventions or methods which aim at treating the existing macadam so as to confer on it the desirable qualities of dust-prevention, coolness, pleasant travel, and freedom from glare, they are naturally divided into two distinct classes. One class of itself is dry and inert, and requires a humid atmosphere or frequent sprinkling from a watervan. Some of these processes are relatively cheap to apply, but are costly if watered. Perhaps the best of this class is calcium chloride, which, without the presence of water or moisture, itself becomes a powder and rises in dust under traffic, and in winter it tends to produce mud. The chief use of such substances is to reduce the cost in connection with streets which are regularly watered. Where water is free for city purposes, their employment would be rarely justifiable on that score alone; but the less water the less wear and rutting of surface. Where they do not increase the cost of watering their use may be justified. Where streets are swept with horse broom every day, they would have to be applied daily and would generally prove too costly.

Soluble silicate of soda and numerous other substances, which become dry and powdery when absorbed into road surface, are equally unsatisfactory.

Tar is also applied to roads, being broomed over the surface, which is sprinkled with sand or gravel before it dries. There can be no doubt that where the traffic is

light this dressing produces a very satisfactory and cheap treatment, and is entirely successful in reducing dust and noise and in pleasantness of travel, but it is extremely hot, and if double-distilled tar is used noise is not reduced very much, and the clatter of horses' hoofs becomes very marked in narrow streets. The cost varies greatly, with the price of tar. When tar costs 5d. a gallon at the site, one dressing costs from 3d. to 4d. per square yard, according to the state of surface and amount of repairs to be effected, and it is rarely less than 2d. On roads with a fairly heavy amount of traffic this coating in winter frequently works up into a black mud, which is very objectionable. Although it is serviceable on many roads, the limited supply of tar and increasing demand point in the direction of higher prices. Yet, where the cost does not exceed the average annual cost of repairs to macadam roads, its use is preferable to other substances which do not provide a wearing surface in themselves.

There has recently been placed on the market quite a number of patent lines having an oil base, and these, or some of them, seemed to offer great promise of success under almost all circumstances of traffic and weather.

It should, however, be remembered that air-borne dust is not amenable to any local treatment, no matter how effectually it may preserve the surface to which it is applied.

The following list has been selected as illustrating the importance attached at one time to this subject in England, and in fact Europe and America generally, and are from experiments made in England:—

Westrumite, a solution of petroleum and water, cost in England £8 10s. per ton, and when used in 10 per cent. solution cost $\frac{1}{2}$ d. per square yard per application. In Australia the price quoted was double, representing over 1d. per square yard per application.