

No. 1,635. "Wood as a Paving Material under Heavy Traffic."¹
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THE long-standing problem which presents itself to those in whose province it lies, to provide and maintain in the principal centres of trade a roadway structure fulfilling the various requirements of modern street traffic, is one which often seems to be in effect scarcely less complex than any which the general practice of engineering has to deal with. There is certainly no other in which at the present time technical authority is so widely claimed in consequence of its importance to every separate local administration. The task of disentangling experiences from opinions, of verifying facts, and of purifying these from the bias of prejudice or interest, is too often sufficient to compromise the broad lines of general principle which can usually be established in such an inquiry. With due care, however, to discard all matters not relevant to the purely practical question, it is not difficult to show that the pith of it is comprehended in a very few facts. It is, indeed, this freedom of the problem from special technicality, and its consequent cosmopolitan handling, which still tend to apparent complexity, and to the perpetuation of the so-called "Battle of the Pavements."

The primary point into which these conflicting details can usually be resolved is simply this: That the conditions of road-surface demanded by the two main elements of street traffic, viz., the power and the load, are almost essentially opposed. That is, that the nature of surface most favourable to the intermittent tractive action of horses is not that which is best adapted to the transmission of rolling load. To reconcile these conditions, so far as to render them in the least degree obstructive to each other, is the practical aim of road paving.

It is of course assumed that the description of traffic to which the following remarks apply is that resulting from the concentrated activity of large commercial centres; and to meet which the costs of maintenance and of renewal have commenced to bear an important relation to the resources applicable to them.

It is to be noted in the first place, that the effects of wear and

¹ The discussion upon this Paper was taken together with that upon the one preceding.

tear on a roadway are developed in a variety of forms—pressure, percussion, abrasion, and external physical conditions—the relative proportions of which can scarcely be assigned with anything like distinctive accuracy in any case. But it is, notwithstanding, important in forming a correct conception of roadway wear and tear, to avoid giving undue prominence to any one of these destructive agencies. It is often observed, and with much reason, that the value of traffic observations, as regards paving, is qualified by the fact that no two streets in the world present identical conditions, and hence the futility of laying down a law as to pavement.

The series of observations, however, collected by the Author during the past three years, tend to show that against all the discrepancies which render comparisons of street traffic doubtful, opposite conditions are found to arise by which they are compensated in the long run; and that on the whole, the effect of such minor irregularities is, as might be expected, largely controlled by the element of weight. It is often assumed, on the one hand, that a generally low speed consequent on heavy loads is less destructive to a roadway than a light, rapid, and percussive traffic; and, as a point of opinion, the reverse is sometimes maintained. In this respect, however, compensation is proved to exist in actual crushing pressure and increased weight and effort of horses, as against more frequent and sudden pounding or tearing wear. Again, the central portions of a roadway are naturally considered to sustain the brunt of traffic as compared with that which passes to the sides; yet in five streets out of ten actually observed, this is fully compensated: first, by the fact that the sides of a roadway are subjected to the greater, though less continuous, wear of vehicles drawing up and pulling off again; and, secondly, by the fact that in all streets where the traffic is numerically such as to entail the preservation of an up and down line, a limited central section of such street is more or less protected, and subject to less wear and tear than the central portions of the two halves. And, lastly, it is claimed that, even assuming equivalents in weight, its direct effect is concerned in a much greater degree in a slow (because confined) traffic than in a free, fast, and, what may be called a jumping traffic. The answer to this objection is, that it rests upon the assumption of a bad road surface, and can therefore only apply in a constantly reduced degree as repairs and renewals tend to set it aside. The jumping action, which in a faster traffic takes the place of steady pressure, is due to inequality and obstructions of surface; whereas the moment a proper condition is restored, the conversion

of rolling pressure into a series of blows is not incidental to light more than to heavy traffic within any ordinary limits.

Upon such considerations it becomes evident, that the formula of direct weight per unit of roadway width is that which must afford the least erroneous datum for reducing large series of traffic observations taken under fixed rules respecting the conditions to be noted. The system adopted by the Author with this view furnishes the results shown in the Traffic Table A (page 48); and although the immediate source of these figures is a set of observations extending only over the month of November 1878, they represent, by correction with similar notes from other seasons and former years, a comparative scale which has not varied to any considerable extent within the six or seven years during which the resuscitation of wood pavements has become active. Indeed the figures of the appended Table B (indicating the general proportions of certain specific classes of London traffic) are of remarkable constancy, so far as any general comparison can be reached. The method adopted in taking them was aimed at obtaining reliable averages, by means of short and definite observations properly distributed, rather than from continuous counts over an isolated series of hours. The observations were therefore collected by half hours only, at fixed periods throughout the day of sixteen hours, from 7 A.M. to 11 P.M. in every case; such half hours being respectively observed again on different days at the same points and in different conditions of weather. The remaining night hours (11 P.M. to 7 A.M.) affording a traffic small in proportion, and at the same time subject to great irregularity with variable circumstances, were excluded as vitiating the averages required. The system of short observations, while undoubtedly leading to a highly corrected comparative figure, was also found to facilitate greatly the notes respecting weight, which were of necessity collected simultaneously with them. The traffic was divided under seven heads; for the most numerous and important of which the empty weights could be ascertained with precision, and the ordinary description of load estimated without any serious or cumulative error. Such as these averages are, they suffice to show how very widely the actual wear and tear upon any given roadway may be misconceived in the light of a merely general or numerical estimate. An instance of this is afforded by the figures of Table A, derived from twelve of the principal thoroughfares of the metropolis; amongst which the line of the Strand and Fleet Street, with the high traffic return of sixteen thousand two hundred and eight vehicles per day, yields a gross weight nearly the same as that of Gracechurch Street with

[1878-79. N.S.]

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twelve thousand one hundred and forty-eight vehicles, the comparative weights per vehicle being as 0·8 ton against 1·1 ton; and the weights per wheel 0·25 ton against 0·37 ton. These results, again, are seen to be entirely modified by the factor of width; where Gracechurch Street stands far in excess, at 422·1 tons per foot; while Piccadilly and Leadenhall Street, with respectively ten thousand seven hundred and seventy-six vehicles against six thousand one hundred and twenty-eight, are identical at 253 tons of weight per foot. A difference, therefore, in actual wear of paved surface, which would scarcely be estimated at first sight, is thus made prominent; and it may be suggested that an established system of occasional short observations, combined of course with a careful record of maintenance costs, would supply by inexpensive means a statistical register, increasing in accuracy and value with every successive item. In such a record, also, due consideration might be given to exceptional loads of 5 tons and upwards, which have been purposely excluded from the table above referred to, on account of their comparative scarcity within a short period. It is probable that an addition of 10 per cent. all round to the weights there indicated would give a better approximation to actual facts.

Before any attempt can be made at a really comparative treatise on roadway wear under town traffics, the following points must clearly be conceded: (1) That no substantial evidence as to the actual economic work of pavements can possibly be acquired until some uniform system of recording experience has been adopted and generally adhered to; and (2) That such a system must include a record of cost based upon some equally uniform and accepted scale. The nature of street traffic, though admittedly in some respects much complicated, is not such as to render a record of this kind impracticable; and the question now being undoubtedly of sufficient importance to justify it, the result would be both to define the capabilities of any system of paving by the unit of ascertained wear, and at the same time to limit the controversial aspect of the subject.

In considering the circumstances which affect the durability of a road pavement (apart from traffic), these are found to be partly external to it, and partly dependent only upon material and construction. The former may be most briefly examined; and among them the variations of moisture are in all respects the foremost. Between the constant soakage of long-continued rains, or the retention of such water on the surface by the medium of mud, and the summer temperatures, when, on the other hand, the evaporative power is computed by hundreds of gallons per acre

per hour, a vast range of expansion, absorption, and other changes takes effect on the structure of a paved surface of large area. As to the manner in which these changes should be provided against in construction and material, opinion at the present time shows the widest possible divergence. Whether, on the one hand, the superstructure of a pavement should be such as to give exit to the water between itself and the foundation, or whether the entire mass should afford free drainage into the natural strata beneath; whether the material itself should retain a more or less variable proportion of the moisture, so as to be less susceptible of violent contraction and expansion, or whether, according to an opposite view, the whole water should be resisted by an absolutely impervious surface—all these are points constituting what is still a moot question. A minor effect, but an entirely distinct one (external to the pavement), is that of frost: and these two being the main external sources of injury, it is now a point of interest to inquire into their action upon fabrics of wood, as at present in use. According to the view of the Author, an indispensable feature of a weight-carrying pavement must be the absolute exclusion of water at the surface, as nearly as it can be ensured; and in this one respect it cannot be questioned that a surface like asphalt has no equal, the absorption being so gradual as to be inappreciable during any possible continuance of moisture. From this point the character of absorptiveness is presented in varying degrees by different materials and constructions down to the ordinary description of macadam paving, in which water becomes an essential ingredient of the roadway. A road of stone sets is of course impervious in material, but not often in structure; and intermediate between these are the semi-absorptive qualities of wood. The capacity of the common kinds of wood for absorbing water is exceedingly variable; and, as a rule, is much over-estimated, especially with reference to the amount of extraneous matter, soluble or otherwise, which can be conveyed into its fibres by the action of water.¹ Absorption, it must be remembered, takes place mainly by capillary action, and therefore only at such points as the fibre may be of capillary nature and easily separable—as in the lighter non-bituminous descriptions of wood, and the external, or unsound portions of its growth. And it is particularly worthy of note, that water is absorbed with far greater readiness in contact with a fibrous substance longitudinally, than by resting upon a transverse section of the same. In the one case every portion of fibre succes-

¹ *Vide Minutes of Proceedings Inst. C.E., vol. lvi., p. 300.*

sively is free to displace itself in the act of expansion, and thus make way for the capillary action to extend inwards; while in the other, the whole area of fibre exposed end-wise must be more or less simultaneously expanded before absorption can proceed to any depth—a fact bearing directly on the conditions of wood in a pavement, and very commonly overlooked. Hence, in the particular instance of wood as usually disposed, with the fibre vertical under the action of traffic, absorption at the exposed end is in a great measure arrested, and should be intentionally arrested, by the choking of the fibres with foreign matter. If, in the first instance, the matter so becoming inlaid consists (as it should) of a clean, sharp, and hard grit, an important protection to the wood is gained by the exclusion of putrescent or other objectionable substances. This, as a question of structure, leads to the consideration of those conditions affecting the wear of a pavement which are referable to its own nature and qualities.

As observed before, the quality of absolute permeability to water is in almost every case open to serious objection, and, in that of a town roadway, inadmissible in the long run. No clearer evidence of this is afforded than the rapid formation of the large hollows and ridges occurring in a macadam road under high traffics; this being really due to the plastic condition in which the underlying material is constantly maintained. The substance of a macadam road is a conglomerate of broken stone and indurated clay—the latter formed by the infiltration of water and the detritus of the stone, which have previously been thoroughly worked up by the traffic. Even in a thickness of 12 or 15 inches, this conglomerate is not inelastic; and the formation of hollows having been immediately commenced by the movability of the fragments among themselves, it is further favoured (after they have become bound and consolidated) by the pliancy of the foundation. The Author is not aware whether the experiment has ever been made of laying a 12-inch macadam paving upon a concrete or other unyielding foundation—not, that is to say, a 12-inch thickness laid down *en masse*, and steam-rolled, so as to be instantly penetrable to pure water and frost, but formed by successive layers, consolidated under that regular action of traffic which cannot be imitated. Such a trial might probably be made to illustrate the facts of the case by two opposite results. Assuming, in the first case, that the surface were protected from the full effects of weather, and only watered sufficiently to preserve the best consistency, a far more durable roadway would in all likelihood be found to result from the support afforded by the foundation; whereas if, on the other

hand, the usual rainfall were allowed to act, the destruction of the road (as compared with the ordinary process) would be greatly hastened by the inability of the water to escape downwards, and the consequent effect of its remaining to soften, and, so to speak, dilute, the macadam.

Such being the theory of a road-surface, which, after the manner of macadam, is allowed to build itself, it is natural to inquire how the same effects are met by the systems on which roads are designedly built at the outset—a question comprising all the usual forms of paving for active traffic.

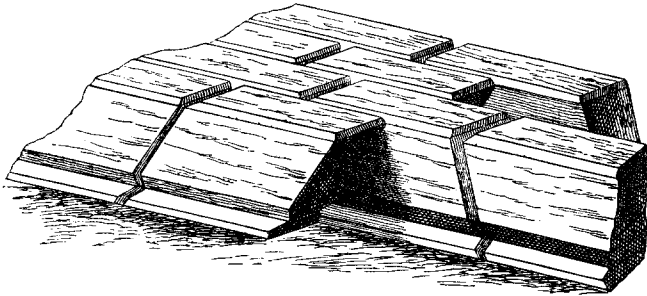
As regards built roads, much is generally said upon the question of elasticity, and it is one which is commonly misapprehended. Distinction is not made between two widely different theories, viz.:—Is road-elasticity requisite as it affects the traffic, or is it desirable as concerns the road itself? The answer is that, within limits, it is as advantageous to one as it is detrimental to the other. Elasticity of road is for the benefit of the traffic exclusively, and not for that of the road itself; and the inference is that, if any, it should be immediately at the surface, and there only. A totally inelastic road, whether absolutely smooth or designedly uneven, is open to objections, practically, on other grounds; and herein lies the chief characteristic which has brought wood into favour. Concurrently with a reasonable degree of durability, which admits of being used to the utmost advantage, it presents always, and uniformly, a slight degree of surface elasticity, to the immeasurable saving of vehicles passing over it.

The varieties of detail in the methods of constructing a roadway of wood have been exceedingly numerous; and to many of those of earlier date it is difficult to assign any purpose or principle except that of variety. The hexagonal and other sectional forms of block introduced into the first designs for wood paving are not less difficult to account for, from a practical point of view, than the still more elaborate varieties of conical, rhomboidal, or prismatic patterns which followed them, and the mere cost of shaping which, would, at the present time, entirely exclude them from employment on a large scale.

A type is shown in Fig. 1 of the class of block in which almost any form was aimed at except the rectangular, and the theory of which may be summed up in the fact, that the blocks were designed to withstand an assumed test which experience has shown to be mythical. The hexagonal block seems to have been employed so as to effect a close joint, with chamfered edges to afford foothold; but for what reason the chamfered edge of a rectangular block,

cross-cut from an ordinary deal, would not answer a similar purpose, does not appear. The rhomboid form has sometimes been supported on the ground that an inclined position of the grain is more favourable to wear than a directly vertical one; but such a theory is entirely untenable.

FIG. 1.



Scale $\frac{1}{12}$ th full size.

Another totally groundless opinion, as regards wood blocks, was that which insisted on the necessity of something of the nature of a down-fastening. But the friction between the blocks, or the inserted material of the joint, and their natural hold upon each other and on their foundation, need never fall short of what is requisite to preserve the whole mass sufficiently immovable under any kind of traffic.

Much attention, again, has been devoted to the theory of a paved roadway being greatly enhanced in carrying-strength and stability by its being conceived to act as an arch. The Author has no hesitation in saying that the system of forces which constitutes a true arch-action could never be really brought into play in any roadway unless a material portion of the substratum were actually removed. The pressure caused by a loaded pair of wheels, or any number of wheels, on an ordinary paved street would, if carefully traced, be found to expend itself ultimately upon the underlying stratum of material only, and not, as in the case of an active arch, laterally upon the points which sustain it. The only conceivable instance in which such a principle could really apply (without an actual failure and breakage of the road) would be that of a narrow street in which the substance of the pavement was altogether without support from below. Moreover, in admitting the theory of arch-action, it must clearly be allowed that a rigid strength in the abutments—that is to say, in the kerb and foot-pavement which usually represent them—is as absolutely

indispensable as in the curve of the arch itself. As cases are well known to have occurred in which the expansion of the roadway, without any load, has sufficed to shift these from their position, it is scarcely necessary to go further to prove such a view to be fallacious.

Among the more recent types of construction, Figs. 2 to 4, one of the last to be modified as regards elasticity was that in which,

FIG. 2.

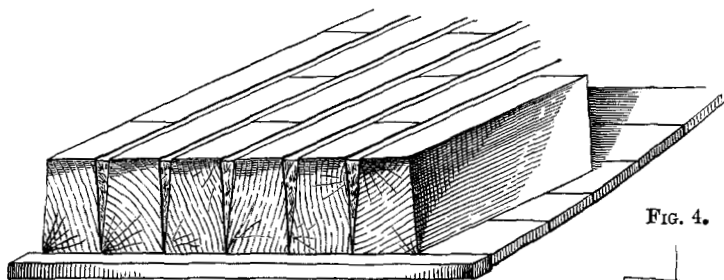


FIG. 4.

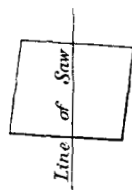
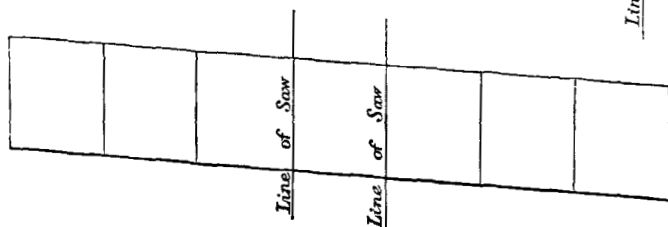


FIG. 3.

Clark's Wood Pavement. Scale $\frac{1}{2}$ th full size.

as already observed, the necessary distinction failed to exist between the elasticity of the surface and the elasticity of the foundation. The system formerly adopted by the Improved Wood Paving Company (Fig. 5), was laid with a bearing of cross 1-inch battens (generally creosoted), either in single or double layer, under the blocks, without further foundation beyond the even contouring of the natural bed: but this has now given place to the use of concrete, with or without modification as regards the planking. The courses are spaced by a fillet of wood secured with brads, and the interval filled in with a composition of either bituminous or cement grouting.

In other systems, the interspace has been maintained either by wooden tenons and pegs, by iron stud-nails, by sheet iron, or merely by the filling itself. According to the principle of

FIG. 5.

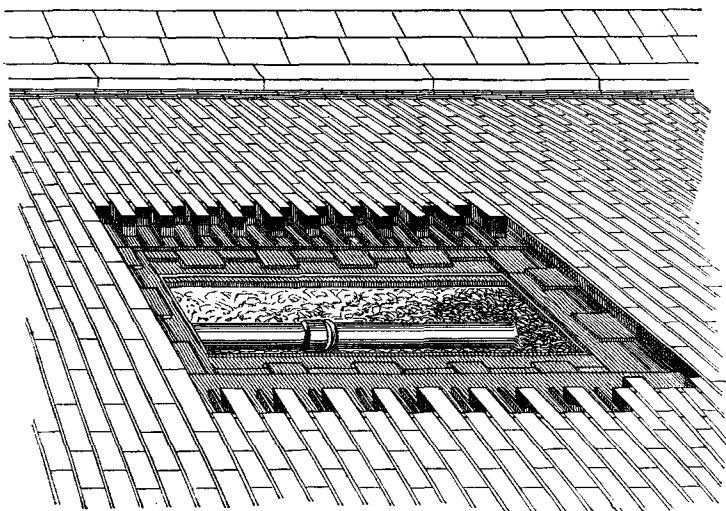
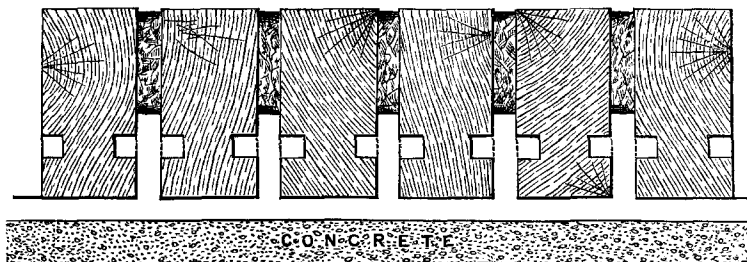


Fig. 6, the whole superstructure is designed to be keyed down by the use of a channel-groove or auger-holes in the sides of the blocks, such channel, as well as the interspace, being filled with

FIG. 6.



Method of uniting the blocks to the asphalt by auger-holes. Scale $\frac{1}{4}$ th full size.

a material homogeneous with that upon which the blocks rest—whether bituminous or cement composition. This is brought to within a short distance of the surface, and the remaining depth is filled with the final surface-dressing of small ballast. The width of joint has been varied from 1 inch to $\frac{1}{4}$ inch or less, with

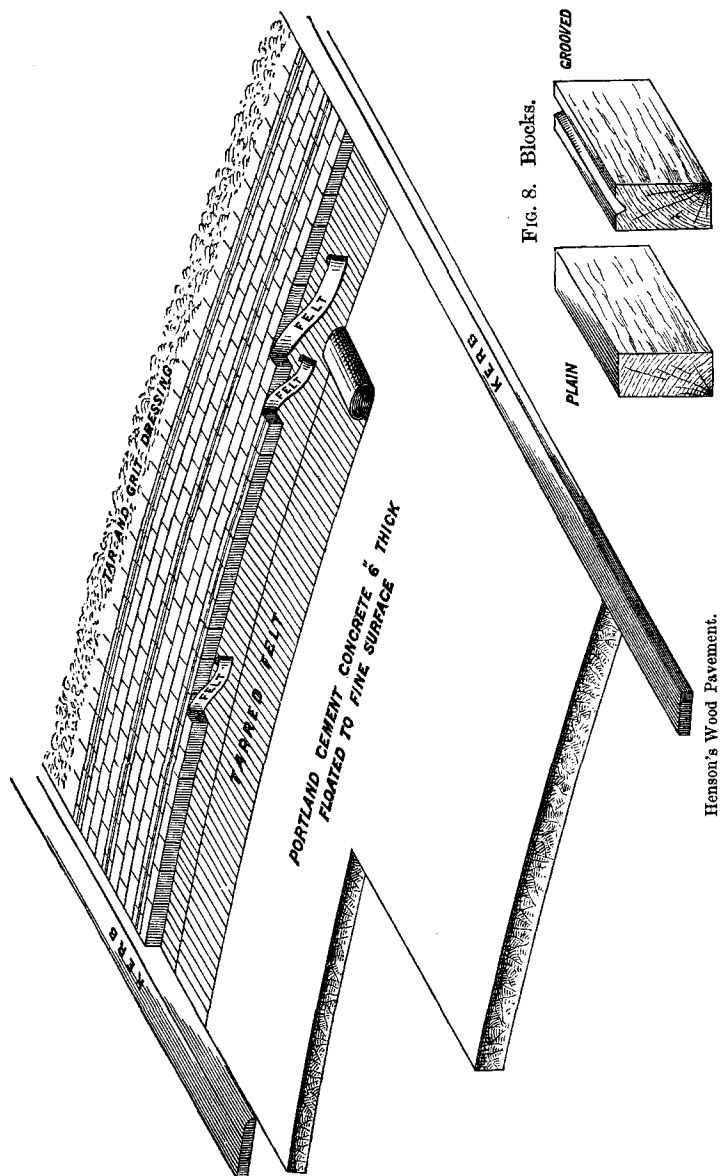
the result that the closer the joint the greater is the freedom of the pavement from mud; and the less permeable the interspace, the less is the amount of imported mud retained. The actual formation of mud upon a wood pavement, when once cleared of the residue of top-dressing first added, should be absolutely *nil*, as the detritus of the wood itself is too gradually formed to be appreciable. The removal of imported mud or dust, and the dressing with sand during frost, should comprise all the tending required. But in every instance of an open-jointed pavement, however varying in detail, the same results are to be noticed: (1) as to the wear of the blocks at the corners, and consequent opening of the fibres; and (2) the action of the interspace (whatever be the filling material) in eventually forming a superficial reservoir by which more or less mud and moisture are retained. If the filling of the interspace be not an impervious one, water and mud are retained between the blocks, in contact with the length of the fibre; and, if upon a solid foundation, without escape below. If the filling be of an impervious and rigid material, the courses of blocks are isolated from each other as regards expansive action; and on this account again, impermeability to water cannot be fully secured. The various experience afforded by these trials points to the conclusion, that the true theoretical condition under which wood should be used, is that of a continuous and uninterrupted surface. If a whole street could be conceived to be paved with a single slab or section of fir timber, the surface well inlaid with clean grit or large sand, such road would (apart from expansive action) present, without comparison, the fairest test of the durable qualities of this material.

Upon the basis of these principles the system of paving with wood known as Henson's (Figs. 7 and 8), was introduced in 1875, having for its object the testing of the previous theory, that artificial structural foothold is indispensable to afford a fulcrum for tractive power, as well as showing the value of real continuity of surface, by providing the nearest possible approach to an uninterrupted area of wood only.

It being sufficiently established by experiment, that the vertical position of the fibre was the only one in which wood could be employed so as to afford a durability comparing reasonably with that of stone, the simple and practicable form of blocks, cross cut to 5 or 6 inches depth from deals of the ordinary commercial dimensions, was not departed from; the most conveniently available being 3 inches by 8 or 9 inches. The aim of the experiment was primarily to lay the blocks "heart to heart," upon a sound weight-

bearing foundation, so as to present a continuous and uniform

FIG. 7.



surface of wood on end. To such a construction the only foreseen

obstacle was the variable expansion and contraction inseparable from that material under varying atmospheric conditions; and this, when accumulated over a large area, would doubtless have been of sufficient extent to become detrimental to the efficiency of a road pavement. With a view to meet this, it was borne in mind that the action of capillary expansion in wood is one which must be regarded as exercised slowly, through the minutest distances; but accumulated in proportion to the area of material subject to it. The compensation of such an expansion could therefore only be uniformly effected over a large area, by providing for the absorption of minute portions of it at the smallest possible intervals, establishing a series of minute compensations throughout the entire structure. Thus the accumulated horizontal expansion could only be taken up (without disturbing the whole mass) by an equivalent compensative elasticity distributed throughout it.

The substance which was found in practice to be most available for this purpose was the ordinary description of roofing-felt, from $\frac{1}{16}$ to $\frac{1}{8}$ inch thick; a strip of which, cut to the same width as the depth of the blocks, is interposed between each course, and thus forms a perfectly close and yet slightly elastic joint. In laying this pavement the system is adopted of driving up the blocks, as every eight or ten courses are laid, by means of heavy mallets and a plank laid along the face of the work, attention being given to the even range of the courses as this proceeds. The joint is thus closed as completely as possible, leaving only the actual fabric of the felt to take up the expansion, and, by the mutual support of the blocks, saving them from the rapidly destructive action of fraying down at the edges. The protection of the wood is farther enhanced by a continuous layer of similar or somewhat stouter felt over the whole surface of the concrete foundation, upon which the superstructure of wood is cushioned.

Results have tended to show, that the several functions of this simple construction were correctly anticipated. The endurance of the wood, consequent upon its relief from vertical jarring and the mutual support of the edges of the blocks, is increased by probably not less than one-half or two-thirds. Since the first experimental length upon this system was subjected to the traffic of Oxford Street, in the autumn of 1875, it has presented, without intermission, the appearance of a uniform and homogeneous surface, almost entirely free from detritus, and resembling that of asphalt.

In the earlier work, a V-shaped groove (Fig. 8) along the centre of the exposed end of the blocks was inserted at every fourth

course; but this serves very little real purpose as regards foothold, on the contrary, rather diminishes it, by becoming, like an open joint, a receptacle for mud, the true source of slipperiness. The use of the groove was therefore discontinued, except on inclines steeper than 1 in 30, or thereabouts.

A surface retaining the least possible quantity of extraneous matter is the desideratum; and only on this being attained can the true capacity of wood on end for affording a frictional foothold be duly appreciated. When this is increased by a dressing of clean sharp grit, or large sand, which at once becomes permanently inlaid into the fibre, it may be made amply sufficient to ensure the safety of all traffic under ordinary circumstances—even under the existing crude system upon which horses are shod. The Author exhibited two of the specimen blocks taken up recently from the centre of Oxford Street, where they have been subjected during three years and a half to a traffic of nearly 300 tons per foot per day. This figure, quoted from Table A, is of course not inclusive of the wear represented by the action of horses' hoofs, which, from its nature, can scarcely be estimated, but which, especially in the earlier part of the life of a pavement, bears the more important part in its wear. These blocks, originally 5 inches in depth, still show a surface inlaid with the particles of grit originally imbedded in it; and their actual vertical wear, allowing for a slight surface-compression, is almost inappreciable. From $\frac{1}{16}$ to $\frac{1}{8}$ of an inch is the utmost amount of wear shown by any blocks from the same position. It is therefore evident, that if it were possible to assume an absolutely uniform quality of wood-fibre, a wear of at least twenty-five years per inch depth of wood might be confidently expected from good ordinary deals under similar traffic.

Practically, of course, several incidental conditions arise which affect this estimated duration in a greater or less degree; the most important and unavoidable of which is irregularity of surface wear. A very slight fixed obstruction, whether external to, or part of the material itself, will originate a depression on each side of it in the direction of the traffic, such depression increasing in a rapid ratio with the hammering action which it at once sets up. The life of a pavement, then, becomes simply a question, first, of its resistance to the vertical impact of heavy weights; and ultimately, of the extent to which unevenness of surface can be tolerated. The only safeguard against this defect is careful attention to the homogeneous character of the material, whether stone, asphalt, or wood. In the case of compound structures—of which macadam

may be cited as a prominent one—the material is essentially the reverse of homogeneous; and hence their inferiority under heavy wear.

Another source of inefficiency in all pavements is that to which attention has already been called, viz., the failure of foundation stability, where the inevitable results of uneven surface have begun to take effect. To this failure was mainly due the abandonment of wood after all its earlier trials; latterly, however, its importance has been fully recognised, and a substantial bed of concrete, or an equally rigid foundation, is universally provided for large traffics, whatever may be the superstructure.

A third question of durability, to which much discussion has also been devoted, is that of internal decay, in respect of which some difficulty always seems to occur in citing sufficient verified cases to sustain any theory. The capacity of wood to remain intact for a lengthened term in the presence of putrescent matter, and variable degrees of moisture, is much contested. Probably the key to the whole question is to be found in the fact, that almost every phase of internal decomposition in wood is traceable to organic growth of some sort—of low development, no doubt, but nevertheless organic, and therefore subject to the primary condition of all organic growth, viz., freedom from mechanical disturbance. It has been held that a purely chemical change in the first instance initiates fungoid growth; but the Author inclines strongly to the opinion, that the process is *vice versâ*, and that it is organic germination which originates and promotes chemical decomposition. The manner in which unprepared timber is found to have endured, perfectly unaltered, under the vibratory action of street traffic, is, in this view, fully accountable; and if true, it points to a decided advantage in such timber for paving purposes over that which has been creosoted or otherwise protected. In the latter case organic decay is arrested, but only at the expense of favouring oxidation and subsequent chemical changes of a different order.

An even-grained well-grown deal, of medium weight and hardness, offers the best conditions, as far as experience goes; and against the contingencies above referred to, experience alone can furnish an absolute guarantee. It is scarcely necessary, however, to point out that the particular condition in which any specified portion of paving may happen to be adjudged as “worn out” is not one which is definable within a few months’ or a year’s time; and to this extent the comparative life of a pavement can only be regarded in the light of what is locally expected of it. The

standard of comparison therefore, to which street pavements are to be referred, must embody the two elements deducible from the preceding remarks, viz., the work performed (as represented by some such systematic scale as before suggested), and the sum total of direct expenditure upon it during a recognised unit of time. Applying such a test to streets of the class now under consideration, viz., those with traffics of from 200 to 400 tons per foot wide per day, it will not be unreasonable to exclude the foundation as absolutely permanent, which may be assumed to be the case if it be constructed of a sound and well-mixed Portland cement concrete of sufficient thickness to carry extreme weights. Granted, for instance, that 6 inches of a cement concrete of 5 to 1 will show no failure under a load of 3 tons per wheel, it may be reckoned as good for 100 years as for 10 years if undisturbed. An independent statistical expense of pavement over shorter periods may then be ascertained. Taking, for example, a figure somewhere about that of the present cost of wood pavements; an outlay of say 10s. per square yard first cost, and the same for entire renewal every seventh year, with 1s. per square yard per annum to cover all maintenance from the first, would show a fixed cost of 2s. 5d. per square yard per annum *in perpetuo*.

Of the three alternative materials—macadam, granite or porphyry sets, and asphalt—the first is beside the question, if only on the ground of its representing under similar circumstances a fixed charge of from 3s. to 6s. per superficial yard per annum. Granite is at the present time more nearly balanced with wood—excelling it somewhat in the matter of cheapness, but outweighed by it on the score of noise and injury to vehicles owing to its rigidity—the latter two defects insuperable, excepting at a cost which is but rarely bestowed upon it.

Asphalt, labouring under an occasional deficiency insuperable at any cost—viz., absence of foothold—is nevertheless to be regarded favourably in point of cost, and will rank high so long as the definite solution of the problem of durability stands in abeyance. Meanwhile the above notable failing, together with the difficulty attending partial repairs, must detract from the value of the money-figure to be assigned to it. In view, therefore, of the few materials which can be used, and of their several qualities and defects, the following questions comprise the chief issues to be decided.

First.—Is the policy of paving for heavy traffics to aim at reduction of first cost and the retaining of certain alleged advantages attached to systems of continuous maintenance? or at the extinc-

tion of maintenance, and the acquisition of durability combined with certain alleged disadvantages accompanying great resistance to wear?

Secondly.—Can a paved surface be made to fulfil the needs of tractive power by means of the intrinsic nature of any material, independently of designed mechanical form tending to obstruct free draught of load?

And lastly.—Can the durability of any description of wood, compatible with reasonable cost, be enhanced either in construction or maintenance, so as to place it on a commercial rank with substances of greater resistance, but of less advantage in other respects?

This Paper is accompanied by several diagrams, from which the woodcuts, Figs. 1 to 8, have been prepared.

APPENDIX.

TRAFFIC TABLE A.—AVERAGE VEHICLES per 16 HOURS. *November 1878.*

Street.	Number.	Gross Weight.	Average per Vehicle.	Average Width.	Weight per Foot of Width.	Pavement.
		Tons.	Tons.	Feet.	Tons.	
Euston Road	12,132	10,658	0·878	44	242·2	Granite, 1863.
Edgware Road	8,212	8,376	1·020	43	194·8	„ 1876.
Oxford Street	16,886	17,076	1·011	57	299·5	Wood, 1875.
Regent Street	10,796	9,668	0·900	52	186·0	Macadam.
Piccadilly	10,776	9,358	0·868	37	252·9	„
Parliament Street	14,306	14,380	1·005	45	321·7	„
Victoria Street	6,040	5,780	0·957	40	144·5	„
Strand and Fleet Street	16,208	13,596	0·839	37	367·5	Wood, 1877.
Gracechurch St.	12,148	13,507	1·112	32	422·1	Asphalt.
Leadenhall St.	6,128	7,588	1·075	30	253·0	Wood, 1877.
Minories	5,246	7,542	1·438	33	228·5	„ 1877.
Whitechapel Rd.	6,348	7,768	1·224	55	133·9	„ 1877.

TABLE A1.—PER 12 MONTHS.

Street.	Width.	Weight per Yard.	Number of Wheels.	Weight per Wheel.
	Yards.	Tons.	Millions.	Ton.
Oxford Street	19	288,000	18	0·30
Piccadilly	12½	243,200	11½	0·26
Strand	12½	352,640	17	0·25
Parliament Street	15	316,880	15	0·30
Gracechurch Street	10½	405,120	11½	0·37
Minories	11	219,520	5½	0·41

TRAFFIC TABLE B.—Per 16 HOURS. *November 1878.*

Street.	Omnb.	Cwt.	Cabs.	Cwt.	Loads above 3 Tons.
	Average Empty . . . 25	Weights Full . . . 55	Average Empty . . . 8	Weights Full . . . 12	
Euston Road	910		6,572		1,040
Edgware Road	840		3,196		928
Oxford Street	2,080		8,044		792
Regent Street	952		5,968		280
Piccadilly	3,448		6,084		728
Parliament Street	3,160		6,385		434
Victoria Street	1,240		2,876		504
Strand and Fleet Street	2,170		9,636		728
Gracechurch Street	910		2,428		2,180
Leadenhall Street	952		1,336		1,260
Minories		554		1,912
Whitechapel Road	600		588		1,180

[Mr. DEACON