locks. There was now no detention, whereas formerly, there were frequently fifteen, or twenty boats waiting their turn.

In the case of a very small lift, such as could be overcome by one lock, the advantage would doubtless be in favour of pumping, since the expense of raising water was almost in the proportion of the height to which it required to be pumped; whilst in the case of an inclined plane, the expense of construction was the same for a small as for a great height, with the exception of the diminished length of the rails and ropes, and the working expenses were proportionably much greater on a short incline than on a long one.

January 31, 1854.

JAMES SIMPSON, President,
in the Chair.

No. 903.—“On Macadamised Roads, for the Streets of Towns.”¹
By JOHN PIGOTT SMITH, Assoc. Inst. C.E.

THERE is a very prevalent and natural feeling, against the employment of broken stone, for the surface of streets, because, under the usual construction and management, much inconvenience arises from the dirt and dust thus occasioned, and also because the maintenance and repairs are expensive, and the draught of vehicles is, comparatively, very heavy.

It may, however, be shown, from long-continued and extensive experience, that these conditions are not, necessarily, entailed by the use of such roads, and that the inconveniences may be economically and almost completely avoided.

The Author having had, for many years, under his immediate charge, 150 miles of street-roads, and also the general superintendence of 50 miles of turnpike roads, has naturally devoted much time to the consideration of the subject, and the result of this extensive and continued experience has confirmed the opinion, that broken stone, or macadamised roads, if properly constructed and managed,—by which is meant, having them

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¹ The discussion on this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

watered in dry weather for the purpose of cleansing, so as to convert the dust into slop, in order to sweep it up, and keeping them well water-cleansed in clammy, or dusty weather,—are better adapted for streets of large towns, than any description of paving yet tried.

In discussing this question, the interests of two parties must be considered :—the owners and employers of horses and vehicles, who principally use the roads ; and the ratepayers, who would be injured and annoyed if the system of road-making were unduly expensive, or unnecessarily dirty, dusty, and noisy.

It is a very palpable, though a common error, to consider that road the cheapest which costs the least, in direct expenditure merely. But if this, so called, cheapest road, causes waste of horse power, undue wear and tear of horses and vehicles, loss of time from being unfit for rapid transit, and also occasions inconvenience and injury to the inhabitants, by filling their dwellings and goods with dust, and covering their clothes with dirt, it is evident, that such a road, however apparently cheap, is really very dear.

There seems, at first sight, to be a diversity of interest between those who use, and those who pay, for public ways, as the principal loss from bad roads falls directly upon those who keep, or employ horses and vehicles, whilst the expense of repairing the roads falls upon the inhabitants generally ; a little consideration, however, will show, that this diversity of interest is much more apparent, than real, for it is the interest of all, that there should be easy, safe, and cheap means of transit through the public streets, and any increase in the cost of transit is a source of indirect expense, even to those who have no horses of their own, as it must add to the cost of everything carried through the streets, of all hired vehicles, and of all the numerous conveniences which accompany residence in a large town.

It must also be remembered, that it is very wasteful to allow a road to become degraded, for want of timely repair, since it is less costly to maintain a road in a good state, than to restore it to its primitive condition. In no instance is the truth of the old adage of “ a stitch in time,” &c., more apparent.

It is evident, that a roadway is in the best order for the owner, or user of a horse, or vehicle, when it can be travelled over most easily, safely, quickly, and cheaply, and that ease,

safety, speed, and economy in use, are to be obtained, by having the road firm, even, and smooth, (without being slippery,) and free from mud, or dust, or any kind of loose materials on its surface. It is also evident, that the same qualities will free the roadway from noise, mud, and dust, the three great causes of annoyance and injury to the inhabitants of all ordinary streets.

The only question, then, remaining to be considered, is whether the advantages of good roads are such as to induce the inhabitants to incur the inevitable cost. If the question had to be decided in accordance with the interest of the users and owners of horses merely, no doubt whatever would be entertained upon the subject.

Of whatever nature the surface of the road is to be, it is essential, that its foundation should be of firm material, well consolidated, and perfectly drained; if not, the crust is soon loosened and destroyed, the road becomes rough and uneven, and rapidly wears into holes and ruts. Having obtained a good foundation, the next point is to cover it with a hard compact crust, impervious to water, and laid in a proper form, in cross-section. The stones must be broken to one regular size, well raked in and fixed by a binding, composed of the grit, collected in wet weather by the sweeping machines, and preserved expressly for this purpose. This binding must be laid on uniformly, and watered, (if the weather is dry,) until the new material is firmly set, which, in great thoroughfares, will be effected in a few hours, with the regularity of a well-laid pavement; the sharp angles of the stones are thus preserved, whilst a great saving of material is insured, and a firmer crust is formed, than by the common method, of leaving the material to work into its place, without the use of binding. In the latter case the angles of the stones are worn off, and are reduced to powder, so that at least one-third of the material is wasted, in forming a binding, in which the stone may fix itself; whilst by the improved method, the binding is formed of material which would otherwise be useless.

Many road-makers object to the use of binding, alleging that the road is rendered rotten by it, and that, when the road is set, the binding has to be carted away again. This certainly does occur, under bad management, and when ordinary soil is used, the fine particles of which work into mud, and prevent the metalling from setting firmly, but the coarse grit obtained from

the roads by the use of Whitworth's sweeping-machines, is the very same material as is produced by wearing away the angles of the stones, and when judiciously applied to a new coating, it will speedily become as well consolidated and as firm as an old road. A practical illustration of the principle is evidenced in the following case. It was found necessary, during the summer, to metal the street leading from the London and North Western Railway Station, in Birmingham, into the centre of the town, a line subject to more wear and tear, than any other in the borough: the material was laid down on the 28th of August, and on the 29th the binding was put on; on the 1st September it was well washed, and then cleansed by the sweeping-machine, when it presented a thoroughly well-consolidated, firm, and level surface; thus accomplishing in five days, what, under the old method, would have required three months.

In the common method, not only is there great waste of material, but the loose stones occasion additional resistance to traction, great fatigue to the horses, and danger to their feet, whilst the noise produced by their grinding together is annoying to the inhabitants. By the improved method, the inconveniences of road repair are infinitely less than those of pavement, as both the re-coating and the repairs may be made, without stopping the traffic, and at any period of the year, which is a most important consideration; for under the old system it is the practice to put on the material only during the winter months, at which time the roads are required to be in the most perfect state.

Under no circumstances should a road be permitted to be so worn down as to lose its regular section, before it is mended, as it then becomes necessary to repair, simultaneously, long lines of thoroughfare; it is, on the contrary, imperative, that the cross section should be maintained in a perfect state, so as to render the work of cleansing, easy and inexpensive. If a hollow is not immediately repaired, it very quickly extends over the surface. All loose stones should be carefully picked off, as every loose stone, passed over by heavily-laden carriages, if it is not ground to powder, breaks the crust of the road; and if water is permitted to lodge on the surface, it will cause great mischief. The neglect of these essential precautions has led to the belief, that macadamised roads are expensive; as, indeed, they are, if they are neglected, but not if they are well attended to. On a well-

made road, heavy showers are beneficial, as they wash the surface like artificial watering, which does good, if plenty of water is used, and if the road is clean, or is swept quickly after it is watered. A road, when it is perfectly dry, loses its tenacity, and the surface is ground into dust; hence the economy of judicious watering in hot weather, as the road is preserved, whilst the annoyance of dust is prevented. The practice, so common in London, and elsewhere, of copiously watering a dirty road, without cleansing it, and thereby converting the dust into mud, is very injurious to the road, and merely converts one nuisance into another.

It is evident, that allowing a road to become dirty, must be a great source of waste, both to those who use and those who repair a road. The draught upon a dirty road is twice as heavy as on a clean one;—that is, a horse must exert double the force to draw the load with the same speed. The cost, however, of employing double the force is so great, that the expedient of diminishing the speed is generally adopted, as a horse can exert greater tractive force at a slower pace, less power being required to carry the weight of his own body. It often happens, that the extra resistance, occasioned by dirt, diminishes the speed as much as one-fifth, or one-fourth. The effect of the dust, therefore, is to increase the labour 20, or 25 per cent., and it will be readily believed, that such a waste far exceeds the cost of the most perfect cleansing.

It is not possible to keep a road in good repair, when the cleansing is performed by scrapers, as by their use, the stones are dragged from their places and are ground to pieces, whilst the adhesive dirt is not effectually taken away. Sweeping is the only mode of cleansing that should be allowed, either in streets, or on turnpike roads. Mechanical cleansing, by means of Whitworth's machine, appears to be preferable to all other systems yet tried. The wide brooms of this machine sweep longitudinally, with a pressure that can be adjusted according to circumstances; they extend across a considerable breadth at one time, pressing most upon the ridges and least upon the hollows, and thus reducing the former and filling up the latter; whilst the operations of sweeping and of picking up the mud are performed simultaneously, by which means, the usual mud-heaps are entirely avoided.

[1853-54.]

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When the mud is stiff, and adheres firmly to the stones, the surface should first be well watered, to enable the dirt to be completely removed by the machine, without disturbing the crust, leaving the surface firm and compact. The use of water for this purpose has been objected to, and it has been alleged, that it removes the useful grit: long experience has, however, demonstrated, that by the use of the sweeping-machines, with the proper employment of water, a saving of full one-third of the material required for the repair of the roads, has been effected in one particular district in the Borough of Birmingham. The average quantity of metalling used in that district, during a period of seven years, preceding the introduction of the machines, was 20,000 tons; whilst in the four years subsequent to their first being used, only 13,000 tons were required.

The following is the result of an experiment, to ascertain whether useful grit was, or was not removed by water and machine-sweeping. On the 22nd of March, 1849, the Quadrant, Regent Street, (London,) was covered with a thick layer of adhesive mud, which was causing great annoyance, as well as considerable injury to the road, but could not be taken up by scraping, without removing also much of the new stone to which it adhered; it was determined to sweep one half of it whilst dry, and the other half after proper watering. This was done, and the sweepings were washed, to separate the refuse from the stony matter mixed with it; when it was found, that one-third of that which was taken up dry, consisted of coarse grit, which would have been useful on the road; whilst one-twelfth part only of that which was removed in the form of liquid mud was stony matter, and that was so completely pulverized, as to be of scarcely any use. After the two portions of the road had been cleansed, the difference between them was very striking; that which was swept whilst dry, was still covered with adhesive mud, which, together with the stones to which it adhered, was lifted by the wheels, the whole road being rough and uneven, whilst the portion which had been swept, after watering, was perfectly smooth and even. On the 24th both portions were again swept, but only one quarter as much dirt was taken from that which had been water-swept, as from that which, being in a sticky state, had been swept without the aid of water. On the 26th some rain fell, and three times as much slop was taken off the

part of the road which had not been swept on the 22nd. The preservative effect of water-sweeping by mechanical means, was demonstrated by the decidedly better condition of that portion of the road so cleansed.

The great objection urged against macadamised roads for streets, is the annoyance of dust and dirt which they are said to occasion, and many persons prefer, therefore, submitting to the deafening noise of pavement; but this would not be the case, if machine-cleansing was adopted, combined with the copious use of water at proper periods, and the expense would soon be saved, by the diminished cost of repairs.

It has also been objected, that the draught upon macadamised roads is heavier than upon pavement. If all carriages were exactly similar, this objection would be valid, and especially so, if all the vehicles travelled slowly; but it must be remembered, that the proportion of the draught is only one of the circumstances, by which the labour of the horse is to be estimated; another very important consideration, is the surface which affords the safest footing for the horse, and the 'foot-hold,' on pavement, is so much less secure than upon a good broken stone road, that upon pavement full advantage cannot be taken of the smaller draught.

Again, carriages, especially when travelling quickly, are exposed to much more violent concussions, upon pavement, than upon a smooth macadamised road, consequently, not only must the carriages be stronger and, therefore, heavier, but the increased frequency and violence of the concussions consume a large portion of power, which goes far to counterbalance the diminished rolling friction. It has been ascertained, from practical experience, that the wear and tear of both horses and vehicles is much greater upon pavement, than upon macadamised roads; and as in reckoning the real cost of a road, all the expenses attending its use should be calculated, if these points are taken into consideration, pavement will be perceived to be exceedingly expensive; whilst carriages roll so smoothly over a well-maintained macadamised road, and horses are comparatively so little injured, either by falls, or by strains, that the wear and tear upon the former, and the chances of injury to the latter must be less than on pavement.

The greatest amount of wear and tear of macadamised street

surface in Birmingham, with one exception, is 4 inches per annum ; and taking the average at 2 inches, (which is a very high rate,) the cost of maintenance will be fourpence per yard, and the cost of watering and cleansing twopence per yard ; making a total annual cost of sixpence per superficial yard.

Paving will cost fifteen shillings per yard, and will require to be renewed about every fifteen years, whilst the cleansing will cost about one halfpenny per yard ; it is, therefore, evident, that in Birmingham, paving is double the cost of macadamising.

The points especially urged are :—

1st. The necessity of forming a sound, dry, and firm foundation.

2nd. The great importance of keeping the road dry by forming and maintaining a crust of broken stone, even and sufficiently rounded to prevent water from lodging on its surface.

3rd. The economy of preserving this surface perfect, and of preventing the existence of any ruts, or hollows.

4th. The expediency of binding all new coatings with grit, gathered from the road ; thereby fixing it quickly and saving the wear of the new material, whilst grinding into its place.

5th. That new coatings may be laid on at any period of the year.

6th. The saving by proper cleansing, and the expediency of sweeping rather than scraping the road, and especially the advantage of sweeping longitudinally with the broad brooms of Whitworth's machine.

7th. The necessity of using water to separate stiff mud from the surface, with proof of the saving of useful material by that practice.

8th. The real economy of a high state of street cleanliness ; and, that a macadamised or broken stone surface is the most advantageous both for vehicles and horses, in large towns.

The Paper is illustrated by a tabular comparative statement of the expenditure incurred for cleansing and maintaining the Streets and Roads in the Borough of Birmingham, during the year 1853, from which the Papers in the Appendix are compiled.

APPENDIX.

STATEMENT of the Cost of Maintaining the Streets and Roads in the Borough of Birmingham, for the year 1853, extracted from the Accountant's Return, made to the Public Works Committee, January 16th, 1854.

	£.	s.	d.
No. 1. Staff of Officers and Men	6,979	10	7
2. Keep of 63 Horses, shoeing and Veterinary expenses	3,276	0	0
3. Rag-stone and Hartshill-stone	5,949	18	6
4. Pebbles and Gravel	4,513	7	6
5. Water	771	3	8
6. Cleansing-Machines and Brooms	965	6	8
9. Team Hire	631	7	2
10. Rent	12	0	0
11. Gearing	114	6	4
12. Wheelwright	423	7	3
18. Stationery	117	17	9
22. Sundry Accounts	2,840	6	1
	£26,594	11	6

DETAIL of the Cost of Maintaining, Cleansing and Watering the Streets and Roads in the Borough of Birmingham, during the year 1853.

£. s. d.

The urban part of the Borough contains 34 lineal miles, or about 359,040 square yards, of street: the cost for material only was a fraction under fourpence per square yard.

The materials used were 20,112 tons of rag-stone and of

Hartshill-stone, at 5s. 11d. per ton 5,949 18 6

The suburban districts contain 116 lineal miles of streets and roads, or about 1,429,120 square yards: the cost for material only was three-farthings per square yard.

The materials used were 36,107 tons of pebbles and gravel,

at an average price of 2s. 6d. per ton 4,513 7 6

There are in the Borough 150 lineal miles of streets and roads; with a total area of 1,788,160 square yards.

The materials used weighed 56,219 tons, which gave an average coating of about 1½ inch in thickness for the whole area; at a cost of 10,463 6 0

The total cost of maintaining, cleansing, and watering the streets and roads in the Borough was a fraction more than threepence halfpenny per square yard, or £26,594 11 6

Mr. J. P. SMITH explained, that the sweeping-machines were drawn to the gully grates, into which the fluid portion of the material was allowed to drain off: and the grit remaining at