

These are the forces tearing at the road surface. In some cases they are more than the road can stand. The horse's calk acts somewhat like a chisel. It will pry out the binding material between the stones as well as the latter themselves when the bond is weakened. The driving wheels of motor vehicles push or suck any material thus loosened out of place. The binder loses weight as it parts with moisture; besides this, without moisture it also loses, not only its property of recementing itself under pressure, but to a great extent, its binding power as well. The real work of transmitting the stresses due to traffic must be borne by the stone. These are merely held in place by the binder. The latter is gouged out by the horse, drawn or pushed out by the automobile tire, blown away by the wind, or washed off by the rain, and a loosening of the upper stone results.

Even on a well consolidated road climate stresses impose a heavy duty. If, however, there be voids the risk of failure increases. Voids may be due to deficient rolling or to the rise of too much clay in the earthy binder. Lumps of this material will bridge the space between stones even under hard rolling. The bridge will break down eventually either from pressure or moisture or a combination of them. A void forms where the bridge was and continues rising until near the surface, when ravelling results. The same may be true in the cases of too light rolling.

When bituminous material is used as binder it is liable to disintegration from weathering, from overheating, or from admixture of earthy materials.

An ordinary water-bound macadam may lose material by wear up to a thickness of about a half an inch a year without being overloaded. The thickness that can thus be lost will vary with conditions, one of which probably is the ratio of the maximum wheel load to the total tonnage borne by the road.

Whatever the rate of waste, it must be replaced if the road is to be maintained.

To summarize the foregoing:—

Roads ravel from:

1. Improper construction.
2. Overload.
3. Neglect.

In all cases these affect the binder.

Poor workmanship in construction can only be cured by remedying the original defects. These generally show themselves by small local depressions in the surface from which ravelling spreads, in certain cases at an almost incredible speed. In bituminous surface faulty material and thin spots generally show up clearly. In both cases the only remedy is to rebuild the work properly, if necessary, from the sub-base up. This is not strictly repair work.

In considering the effect of overloading and neglect it must be borne in mind that any given type of construction may be so maintained as to vastly increase its carrying capacity. The problem is largely one of economics and administration. As an illustration, assume in two cases the same foundation—let one road have a water-bound macadam surface dressed with a heavy bitumen forming a sheet about $\frac{1}{2}$ in. in thickness and the other a bituminous concrete (mixed method) surface of, say, two inches. The former will cost about 40 cents for stone and 15 cents for dressing, or 55 cents per square yard, and the latter about \$1.00 (both exclusive of the foundation). With proper care the lighter surface will last about three years under fairly heavy traffic, the heavier one an unknown period, but let us assume twelve

years. The total yearly charges against the two may then be stated about as follows:—

Dressed Macadam:

	Cents.
Interest on cost, 55 cents at 4 per cent...	2.2
Depreciation, 1-3 of 15 cents.....	5.
Labor (patrol system)	1.9
Materials—Stone, $\frac{3}{8}$ cu. ft. at 9 cents...	3.4
Bitumen, $\frac{1}{8}$ gallon at 12 cents	1.5
Total	14

Bituminous Concrete:

Interest on cost, \$1.00 at 4 per cent.....	4.
Depreciation, \$1.00/12	8.3
Labor9
Material8
Total	14

The fixed charges are 7.2 cents against 12.3 cents.

The operating charges, 6.8 cents against 1.7 cents.

I do not claim that these figures are more than illustrations of the principle involved. They show a great saving in operating charges, those that show up in the yearly tax bill. The fixed charges, however, are just as real, and must be met at some date.

For a road with 9,500 square yards per mile the costs as shown in yearly tax charges, where depreciation and interest are not visible, would in this case be,

For the dressed macadam, per mile.... \$636.50

For the bituminous concrete 161.50

yet as shown above the real cost of the two roads is the same. This case affects our subject, because the treatment of a raveller road surface must depend on the system of maintenance.

In most communities the great consideration is the next yearly tax bill. If that can be kept down for a period the ultimate economy of such a policy receives but slight attention. It is generally easier to get money for a new road than for repairs. A road requiring a large yearly repair charge is condemned without a hearing. The road calling for heavy interest and depreciation charges may be an equally or even more expensive solution; but the interest charge is not so apparent, and the depreciation charge is not made. This is simply putting off the day of reckoning, which is sure to come. However, the troubles of those in charge ten years hence are usually lightly borne by the officials of to-day.

If we consider the structure of the road surface we can easily see that the 40 per cent. of voids in the macadam stone will be filled somewhat as follows:—

	Per cent.
Surface stone, passing 1-inch ring and caught on $\frac{1}{2}$ -inch ring.....	15 to 20
Screenings, passing $\frac{1}{2}$ -inch ring....	15 to 10

The other 10 per cent. should be composed of sand and clay.

When dry, the clay is driven off to a greater or less extent as dust, washed away or splashed off as mud. Its place is supplied to some extent by detritus, the result of the wear of the larger and heavier materials. These also blow or wash away and the road loses its bond. If our road is not overloaded we can retain its usefulness by making good its losses, with proper materials in their needed proportion. It is here that the trained road man is most needed. Nothing can replace his experienced judgment.