

be free from clay, loam, or earthy material, and should contain about thirty per cent sand. As there is apt to be some uncertainty as to the quality of the gravel, and the uniformity with which sand is intermixed with it, a greater proportion of cement is required than with a carefully adjusted mixture of cement, sand and broken stone.

The sand used in mixing broken stone concrete should be clean, sharp, and of varying sized grain. One of the objects to be aimed at in mixing concrete is to have fine and coarse materials in such proportion to one another that the percentage of voids in the consolidated mass will be reduced to a minimum.

For the surface coat the proportion of one of cement to two of sand is customary, except at street crossings, where one part of cement to one and one-half of sand is commonly employed.

Broken Stone.

Broken stone, when of a suitable quality and properly applied, is a more durable surfacing material for roads and streets than gravel. Owing to the greater cost, it is used by those townships only which have not a supply of gravel. As ordinarily used, broken stone gives less satisfaction than gravel, because the latter binds quickly under traffic owing to the presence of sand and clay. To get the best service from broken stone a road roller should be used to consolidate it; otherwise the stones roll loosely for a considerable length of time. The feeling of councils with regard to its use is that it makes a passable road for a short time in fall and spring, but that a good dirt road for summer use is spoiled. Townships which have only broken stone for road metal, will receive decided benefit from the use of a steam or horse road roller, which will at once consolidate the stone and make a thoroughly good and smooth road for all seasons of the year.

The different kinds of stones for macadam roads cannot be completely approached from the standpoint of names. Granite, limestone, sandstone, are rocks common in this Province, but to say that granite is better than limestone, or that limestone is better than sandstone, while true of the best qualities of each, may be quite incorrect as regards particular varieties, since a good sandstone may be preferable to a poor limestone or granite. The best stone for a macadam road is that which is hard and tough, not easily affected by the atmosphere, moisture, or the varying conditions of climate. The choice will generally lie between a cheaper and less durable stone near at hand, and a more costly but better stone from a distance.

A great proportion of the macadam roads in Ontario will be constructed of limestone, since this rock is the most common, quarries being within easy access of almost any part of the Province. In

quality it ranges from that which is useless to that which is almost equal to trap. Limestone, if it is tough and close grained, is an excellent material for roads on which the weight of traffic is not excessive. Some dolomitic limestones, while hard, appear to lack in toughness. Other limestones, of a slaty texture, have not good wearing qualities, are rapidly disintegrated on exposure to the atmosphere, and should be avoided. Some limestones of an open porous nature, yield readily in this climate to the effects of moisture and frost, merely turning into mud. The excellent binding qualities of limestone make up largely for a lack of hardness, a weak cement being formed by the dust, which adds very much to its durability.

All things considered, hardness and toughness to resist wear, and atmospheric action, the relative desirability of rocks is ordinarily in the following order: (1) trap, (2) syenite, (3) granite, (4) schist, (5) gneiss, (6) limestone, (7) quartzite, (8) sandstone, (9) slate, (10) mica schist, (11) marble. Of these, the last five, sandstone, slate, mica schist and marble, are of little value in roadmaking, except for the lower courses, when they are surfaced with a durable stone that will resist wear.

In determining the best quality of stone for road purposes, there are four prominent destructive agencies which have to be considered: (1) The crushing of loads; (2) the grinding action of the wheels; (3) the blows from the shoes of horses; (4) climatic influences of air, water and frost.

With respect to the first three, a stone may have great hardness and splendid crushing strength, but at the same time be brittle, yielding readily to the grinding effect of wheels, and the blows administered by the hoofs of horses. On the other hand, a stone may be able to resist, in a measure, the second two wearing agencies, those of "abrasion" and "impact," and yet be so soft as to crush readily.

The fourth agency, the decomposing effect of the atmosphere, is one of very great importance. The denser stones, those which absorb the least water, are usually best able to resist the injurious action of frost and moisture. The weight, or specific gravity of a stone, is an indication of durability in this respect, the lighter stones usually being those which are most porous and in consequence are subject to atmospheric decay.

Another feature which a good rock for road-making should possess is that, when crushed, it should break into a compact form. A stone that, in breaking, takes thin, flaky shapes, will not wear so long as one that breaks into cubical pieces, nor will it consolidate so readily in a roadbed, for a wheel, in passing over the side of a flat stone, will throw it out of place and loosen the stones adjoining.

The tests usually applied in determining the qualities of stone are those which indicate crushing strength; the power to resist impact and abrasion; the density,

determined by the weight of the stone; the amount of water absorbed. While elaborate trials may be made, a practical man can judge of the qualities of a stone by applying simple tests; by breaking the stone with the hammer; wearing it on a grindstone; crushing it in a blacksmith's vice; scratching with an iron nail; breaking small pieces with the fingers. By such simple means, a general idea of the stone can readily be formed, but no test is so conclusive as actual wear on the road.

Broken stone produced from boulders has been objected to as road metal on various grounds. The rounded sides do not permit consolidation with the minimum of vacuum. If they have been exposed to the atmosphere the boulders are apt to be decomposed, are soft and will crumble readily. The mixture of different kinds of rock on the road surface some hard, some soft, permits unequal wear, and produces a rough surface.

While these are defects which certainly are not to be overlooked in the choice of a road metal, boulders, nevertheless, constitute a very valuable material for the construction of a road, particularly in localities where they are plentiful and gravel or bed rock not readily obtainable.

In selecting field boulders, care should be taken to discard all rock which shows signs of having "weathered," or having been decomposed by the action of the atmosphere. Sandstones and granites are peculiarly subject to this disintegration, while soft limestones are very common. Rocks which should be condemned from this cause are those which crumble readily under successive blows of a hammer, or which show iron stains when broken. A little experience will quickly teach a judicious roadman to detect the stone which is unfit for road purposes.

Railway companies have shown a desire to assist in the building of roads, especially those leading the traffic to their own lines, and in some instances have delivered the material free, in others not charging more than half freight rates. When they are permitted to carry the material at slack seasons, they have expressed a willingness to do the work at actual cost of hauling, which would place some municipalities in a position to procure first-class material at even less cost than can others where material is considered plentiful. In this way, too, many towns and cities now using gravel of an inferior quality would be enabled to use a first-class quality of durable material.

The state legislature of Pennsylvania has made an appropriation of \$6,500,000 for highway improvement. Two-thirds of the cost of construction is paid by the state, and one-third by the county or township. Of the amount appropriated, \$500,000 is available this year, the same sum next year, \$1,250,000 the third year, and \$1,500,000 for the remaining two years.