us in road building, we cannot follow here the methods currently used in France and England. Even among American and Canadian engineers we find quite a diversity of opinion on this subject. This is quite natural, as we cannot suppose that speaking from personal experience the New York engineer will have the same ideas as the man who has been building roads around Lake St. John. This is due, of course, to sub-soil conditions. The autumn rains and the intense colds following thereafter, place the Province of Quebec in an unique position which cannot even be compared with that of the states of Vermont and New York close by.

Quebec Problems Different

Quebec roads must be studied, free from all theories obtaining in other countries. We know that the provincial department of roads has always given its full support to the experiments of their engineers. The special conditions found in our province are: Firstly, the heavy winter frosts which penetrate several feet into the earth and cause heaving. Secondly, the nature of the materials to be found locally and which must be used to the best advantage. We cannot here go extensively into these two subjects. Let us remark, however, that water-bound macadam, having relatively little elasticity and small resistance to shearing stresses, suffers considerably from the disturbances caused by frosts. The only way to obviate, to a certain extent, this disintegration is to keep away from the roads the water resulting from the autumn rains.

Drainage, therefore, plays a very important part in this work and neglect of ditches and curbs will entail much more serious consequences than is generally known. However, in a good many cases the drainage is not sufficient to prevent infiltration, and in these cases means must be taken to catch the water before it penetrates under the road.

Water penetrates through the shoulders from ditches when their grade is poor, and even sometimes from the surrounding land, especially in cuts.

The construction of a longitudinal drain below the foundation will intercept the water and maintain the road in a sufficiently dry state, and so nullify the action of frost. The cost of these drains put down after the method adopted by the Department of Roads of Quebec is approximately 25c. per lineal foot, and increases the cost of construction of macadam roads approximately 10 or 15% for a drain on one side only. This relatively high cost is probably the reason that drainage has not been more extensively adopted in municipal road work. It is, however, recognized that under the very unfavorable circumstances, drainage must be used to avoid the necessity of reconstructing the macadam surface every spring.

Field Stone and Limestone

Field stone is most usually employed in the construction of water-bound macadam in Quebec. Quarries are not usually sufficiently scattered, and the cost of transportation is, as a result, too high to permit the use of quarry stone on road construction in all parts of the province. Besides, nearly all our quarries produce limestone, for example, the quarries of Montreal, Quebec, Deschambault and Joliette. These limestones are homogeneous and free from defects and mesh very well, but experience seems to show that they are not sufficiently hard for the necessary resistance to wear for heavy traffic. However, for roads of purely local importance, which are exactly the ones that should be built with water-bound macadam, these limestones should be used wherever their cost is comparable to that of field stone.

Despite the advantage of limestone, it can be foreseen that field stone will be mostly used in macadam roads. It can be found anywhere, and the use of it for road work enables the farmers to get rid of the rock heaps often to be found in their fields, which interfere with ploughing and harvesting. Field stone, as a result, is a mixture of different crystalized blocks, with granite and gneiss predominating. It is usually hard but somewhat brittle, and almost entirely lacking in the mesh qualities which characterize limestone and schist.

It would be difficult to make a careful choice of the various kinds of field stones scattered in small heaps in various farms, and in order to lower the cost of transportation, the best procedure is to use stone close to the road. Stone which is evidently of an inferior quality can be discarded before crushing. The discard will usually be small and comprise only stone too soft to be used for the wearing surface.

It is to be hoped that the installation in the various municipalities of permanent up-keep gangs and foremen will enable this selection of stone to be made in the winter.

Macadam, as invented and practiced by the originators of this system of road building, was meant to have a smooth, hard surface, and the union of the stone should be sufficiently effective to render the wearing surface almost as hard as concrete. European nations have come close to this idea, and the French people especially find it quite natural that a water-bound macadam road should give them 15 or 20 years of hard service without the necessity of resurfacing.

European Methods Not Applicable

Let it be well understood, however, that the European procedure cannot in every case be applied to Canadian roads. In France the abundance and low cost of labor enable the crushing to be done by hand, at least for the surface course. They attain in this manner carefully selected stone, practically cubical in shape, and varying in size only from 1½ ins. to 2½ ins. This is quite different from the product of crushers which often give flattened stone with sharp angles easily broken up under the roller, which enlarges the proportion of small pieces. It must not be said, however, that these defects of jaw crushers necessitate a revolution in our system of road building. This country is young, labor is scarce and consequently to be spared whenever possible. We must therefore substitute machines. Even with the high salaries latterly paid, the cost of crushing has hardly exceeded 50c. per cubic yard.

We must calculate therefore on the principle that we must make the best of the situation as we find it, as the aim is to better the crushing and so to grade and crush stone as to introduce here, as much as they may be applicable under our conditions, the processes which experience has proven to be most efficient in other countries.

The three principal points to be carefully watched in crushing are the speed of the machines, the renewing of worn-out jaws, and a proper arrangement of screens for grading. It is easily seen that speeding up the crushers means that stone crushed to the proper size in the upper end of the jaw will be crushed once again before getting out of the bottom, and this will result in too many small fragments. It is therefore necessary to choose a crushing speed which will prevent this, and will at the same time be sufficiently fast to give an economical output. The high price of jaw blades, which has become exhorbitant in the last year, has resulted in the use of worn jaws (by some contractors and foremen) until the jaws are perfectly smooth. Flat stones can therefore pass through the crusher and make their way to the screen in sizes which cannot be used.

It is therefore essential that jaw blades be carefully inspected, and a good foreman will not await orders of the engineers to replace these when they are worn out.

Small Stones Undesirable

Careful attention to the first two points will practically eliminate the third. It can easily be seen that by diminishing the proportion of small pieces, narrower limits as to size can be set down, and we would thus use for the wearing surface nothing but stones from 1½ to 2½ ins. This can only be done provided that there is not too much reject and that the small stones from ¾ to 1½ ins. will prevail only in sufficient quantity to be used up as filling material in the foundation courses.

The undesirability of small stones is very apparent when one knows how difficult it is to maintain a good bond on roads macadamized with field stone. It is easily seen that the force exerted on macadam surfaces by passing vehicles is the resultant of two forces, one (vertical) being the weight of the load, the second (horizontal) being the tractive effort of the vehicle. These two forces are very variable. In the case of an automobile travelling at high