speed, the horizontal force becomes very high and tears out the stone and destroys the bond of the surface. In the case of a steam roller, the vertical force is much more apparent and therefore the roller is employed to rebuild the surface which the horizontal force destroys.

It is out of the question to restrict the speed of automobile to a point where they will not be harmful. The only solution is to offer to the pneumatic tire the solid surface with not only the necessary hardness but also the necessary weight and tensile strength.

The larger the stones composing the surface, the better the contact with adjoining stones and the more the macadam will be compact and massive. The means mentioned above for reducing the proportion of small stones, will help considerably towards the desired result. The limit as to the size of stone which will permit a sufficiently smooth surface for present vehicles is approximately 2½ ins.

Use of Limestone Dust

Another method of lengthening the life of macadam and at the same time diminishing the up-keep cost of field stone macadam, is to use limestone dust as a binder.

There is in the Parish of St. Jean-Chrysostome, in Chateauguay County, a road built in 1913 with field stone and a limestone dust binder. This road has carried continually very heavy traffic, and in addition carries the transportation of stone for the construction of surrounding roads. In 1918, after five years of continuous service, there were no apparent ruts and no loose stones, although the crown of the road has almost entirely disappeared through wear.

The value of a limestone binder in connection with field stone is pretty generally recognized, but fear is often expressed that the advantage to be obtained will not be proportional to the extra expense due to the purchase and transportation, often for long distances by rail, of this limestone dust, which cannot be obtained outside of quarries. If we take it that the quantity necessary for good results is equivalent to a layer ¾ in. thick, the necessary quantity for one mile of 12 ft. road would be 146.6 cubic yards, and as we may reasonably suppose an average cost of $3 a yard, the cost of the road would be enhanced by $440 a mile, which is an increase of 6.3% in the cost of a road costing $7,000 per mile.

If we now take it that by the use of this process we succeed in lengthening by 20% the life of the macadam, it will be economical to use this dust. We see in this way that the reduction in up-keep cost would more than cover the interest on the additional capital used up in the construction.

Limestone quarries are unable to furnish in large quantities this binder, which consists of particles varying from ½-in. to the finest dust. In some parts of the province this dust may be obtained in its natural state. The binder which was used on the above-mentioned road in St. Jean-Chrysostome, was found right in the parish and so close to the road itself as to be quite economical.

Common Errors in Construction

It is often found in practice that a number of mistakes and omissions occur in the detail of construction as written in various specifications generally used at the present time. We must recognize that specifications, however elaborate, offer always sufficient leeway that the contractor may use his personal views and methods. I think it advisable to enumerate here certain methods frequently found which seem really bad, and the suppression of which would bring us nearer to the methods in use in European countries, which possess at the present time the finest roads in the world.

Certain foremen and contractors have the habit of considering in every case crusher dust as a binder. This error is due to a false idea of what takes place in the interior of the macadam during rolling. Under the pressure of the roller, the stones mesh themselves as to produce strong friction between the surfaces in contact. This friction produces a very fine dust which is the best possible binder when the stone possesses binding qualities. This binder will be very efficient if sprinkling takes place at the same time.

Stone which will not bind without previously filling the voids will not bind any better with its own dust. In filling the voids with dust before rolling, one may obtain a macadam with an opparently compact and even surface but which will disintegrate in a few dry days. However small the proportion of binder in the stone, the macadam must be watered and rolled, but never rolled dry until the macadam is very compact and the voids reduced to a minimum. This is the time to spread crusher dust to fill what voids may remain, and thus render the surface still more compact and sufficiently impervious to water.

Must Apply Small Quantities

We must, however, make one exception. This is when limestone dust is used as a binder. Limestone must be applied in successive very small amounts as soon as the rolling begins in order to enable the limestone dust to penetrate gradually between the stones. This operation must be watched in order to prevent the application of an excessive dust at the beginning of the rolling.

We witnessed some years ago a typical case showing the undesirability of an excessive dust in the macadam. A contractor in perfectly good faith had gotten the habit of placing all the crusher dust, including the small fragments up to ¾-in., in the last layer of stone. In order better to obtain this result, the dust was spread before any rolling over the stone, which was entirely covered. Be it noted that the stone was of good quality and contained sufficient binder to give results. Nevertheless, it was only after prolonged rolling, renewed at intervals after several weeks, that he was able to obtain a satisfactory bond. One could, however, see at the same place a piece of macadam built the previous year in the same fashion, which showed a rough and uneven structure which could not be charged to wear, age or heavy traffic.

One might claim to upset this principle by showing a new macadam built after this style and sufficiently bonded. This would merely show that the stone employed was very easily bonded, and in any case the argument would only last for the time necessary for traffic and wind to destroy the layer of dust with which the surface of the macadam is camouflaged.

Cannot Interrupt Sprinkling

Another very common error in construction consists of carrying sprinkling water a considerable distance in the sprinkler itself. This means that sprinkling is interrupted for considerable intervals, during which the rolling continues under unfavorable conditions. We must not forget that the water is one of the principal materials in the construction of macadam, and although it may be true that certain limestones bind fairly well when dry, it is also true that this bond will be much more effective if treated with water at the proper time and in sufficient quantities.

It has often been noticed that in clay regions the surface of a macadam road is deteriorated for 200 or 300 ft. at each end by the clay which the wheels of vehicles spread on it. This defect which everybody sees and which is considered almost inevitable, could be much diminished by proper precautions and principally by ending the macadam with special care. Last year there was to be seen in the Parish of St. Malachie, in Dorchester County, a macadam two years old which had kept its shape and surface without any deterioration up to the point where it joined a clay road. The contractor who built this road was an artist in road construction. Would that he might have many disciples!

The up-keep of macadam roads in Quebec began two years ago, when the first signs of deterioration and of wear appeared in the roads constructed in 1912 and 1913. Two years are very short to study a problem which can only be solved through experience. It is not easy to obtain at the present time a general rule which will apply to the special conditions in our province. There are, however, certain causes of deterioration of macadam which leave no doubt as to the best measures to retard and nullify their effects.