fine, though sharp, sand. Materials containing clay are barred as its presence tends to cause disruption of the surface through the emulsifying properties of clay and water on bitumens.

The cost of these surface treatments vary with freights and localities, but the contract prices in Maryland, showing a total cost of between 6 and 7 cents per yard, give a good idea of the cost of doing work carried out on a large scale with power trucks in the best possible manner using stone chips for cover.

The point where it becomes desirable from an economic and engineering standpoint to build a bituminous macadam instead of a plain macadam with a surface treatment is not easy of determination. Theoretically, the decision should rest on the ability of the road to resist internal wear. The surface coatings, if kept intact, preserve the road from wear from the top but they do not prevent wear within the road itself. This internal wear has long been understood in England but has been given little study in this country.

If the loads on a macadam road increase beyond the ability of the structural strength of the road to bear them, the stone move on each other and internal disintegration takes place. With soft stone and heavy loads, a road will quickly wear out from within even though the surface is protected by treatment.

Any approach to the point where this wear becomes a serious menace to the life of the road would indicate the advisability of introducing a bitumen into the structure of the road to prevent interstitial wear.

The bitumen may be introduced either by the mixing method or by the penetration method. The less expense of the penetration method, the ease of handling the bitumen, especially if refined tar is used, the less skilled workmen required, and its peculiar adaptability to state highway conditions would warrant its wider adoption. Theoretically, the method is not perfect; practically, under ordinary conditions, it meets every requirement.

The difficulties which engineers have had with the penetration method have arisen less through the faults of the bitumens applied than through neglect of some of the fundamental tenets of macadam road construction. That is the reason that the greatest success of the penetration work has been achieved in New England and especially in Massachusetts where macadam road work has been practised in an understanding way for a generation. Some credit should also be given to a knowledge of tars in road work for the New England tar and gravel sidewalk has made the use of tar for road purposes familiar to every New England road man.

Bituminous macadam roads require, even more than plain macadam, strict attention to drainage both underground and surface. It is folly to construct a bituminous macadam without strict attention to drainage.

The base course will vary with soil and load conditions from four to eight or even ten inches. The deeper bases must be laid in layers as it is difficult to roll more than 4 inches of loose stone and consolidate it. The base course should be built like a one-course macadam rolled dry and then filled with stone screenings or gravel. The filler has the double purpose of making the base more solid and of preventing the bitumen from draining away from the top course where it belongs into the base where it is not needed.

The stone for the bituminous course, which is usually 2½ inches rolled, must be carefully selected to get clean stone, in fact much of the success of the pavement depends on the cleanliness of the stone, its proper sizing, and its proper rolling.

The size of the stone and the method of putting the top together depend much on the softness of the stone, its form of fracture, and its action under the roller. As a general rule, a soft stone should be of larger size, even up to 3 inches, than hard trap rocks. With the hard rocks, it is often necessary to add smaller sizes of clean stone in order to form a proper surface for the reception of the bitumen.

The course must be rolled enough to key the stone together and obtain structural strength, but extreme care must be exercised, especially with soft stone, not to roll it so much that the surface is closed against the entrance of bitumen. Work with asphalts and work in cold weather require a more open top than work in hot weather. In fact, care must be taken in extremely hot weather not to let the bitumen run through to the top of the base course, leaving the top course deficient in bitumen at the surface.

The amount of bitumen is, roughly, one gallon for each inch in depth of rolled stone but this quantity should include the seal coat. Usually, one and one-half to one and three-quarter gallons are used in the first coat and one-half to three-quarters of a gallon in the seal coat, for a 2½-inch top.

The bitumen is applied best by pressure apparatus of some kind. A very simple one adaptable to refined tars delivered in tank cars has been devised, using steam pressure from a road roller on the refined tar in a tank wagon and forcing it out under pressure through a single spraying nozzle. The success of the method depends on the man at the nozzle but it is not difficult to train a man to do good work, and a little extra bonus usually keeps him on the job.

After the first coat of bitumen, clean three-quarter-inch stone are cast over the surface to chink the voids. The road is then thoroughly rolled and any excess of chinking stone removed by sweeping with push brooms.

The seal coat is applied in the same way and then clean peastone cast over the surface and rolled in.

If the stone is soft, the road is finished with clean peastone. If it is hard stone, especially on light traffic roads, it is best to follow the clean peastone with stone dust. The surface voids are in this way more completely filled.

The unique property of refined cold tar of sticking to cold stone makes it especially valuable in penetration work. The hot spray striking a cold surface sticks and even a slight amount of moisture does not prevent adhesion. Coupled with this, the coal tar bitumen has strong cohesion so that even though coated surfaces be disturbed, the pieces upon being brought together reunite.

These rather striking properties allow considerable latitude in penetration work and it is not impossible, if due care is used, to build good pavements even in freezing weather.

The possibility of building macadam roads with stone not previously considered available should also be kept in mind. The cementitous qualities of a rock so necessary in waterbound macadam may be neglected, and really successful roads may be built out of flint, quartzite and granite of very low cementing values.

Some soft rocks are also made available, especially where not subjected to much rainfall. Roads built of the soft adobe rock in the vicinity of San Antonio, Texas, and protected with refined tar have been markedly successful. Experiments at Phoenix, Arizona, with caliche gravel show equal promise.

The scope of road engineering is rapidly widening and the study of the possibilities of available local materials must always be a fruitful field to cultivate.