

be built with gravel or stone and should be so compacted and bonded that it forms a waterproof covering. If the traffic is to consist of heavily loaded wagons with narrow tires, with a large proportion of heavy and fast motor vehicles, a stronger foundation is necessary. Into this field enters the Telford foundation and the concrete foundation. The more frequent and faster traffic calls for a resilient surface, such as surface treatment of tar or asphalt, commonly called a carpet coat, the heavier type of bituminous surfacing, either penetration or mixing methods, being used on roads carrying heavy motor traffic.

Grades.—The grades on a highway are affected by the character of traffic. If it be mainly pleasure, the economic disadvantages of heavy grades are not as perceptible as in the case of heavy commercial traffic conditions. Also, with some kinds of traffic, a heavy grade, if established, will result in an irresistible demand for an expensive surfacing in order that the traffic conditions may be properly met.

The damaging effect of horse traffic in particular, is considerably increased by heavy grades, the digging and pounding action of the horses' feet in drawing loads up the hill being very destructive of the road surface. On macadamized roads it loosens the surface and digs out the stones, while in wet weather the surface, being soft, is pounded to a pulp and the stones rounded in such a way that the breaking up in dry weather is greatly facilitated.

Tires.—It is plain that different tires—rubber, rubber studded with steel, steel and steel with transverse bars, as on traction engines—have widely varying effects on the surface of the road. It has often been suggested that the width of tires should be proportionate to the maximum load upon and the diameter of the wheels. There appears to be considerable difference of opinion as to the relative amount of damage caused by steel and rubber-tired wheels. It cannot be disputed that rubber-tired motor trucks are most destructive to macadam roads. It is suggested that the cause of this is to be found chiefly in the high speeds and small diameter wheels employed, together with the great weights transported and the limited use of springs. It is agreed that cross-bars should not be allowed on steel tires, but that, if the grip with smooth tires is insufficient, the surface of the tires should be grooved.

Width of Road.—The width of the roadway to be provided is determined by the traffic conditions. The determination of width for all classes of roads is of the utmost importance, and should be given careful consideration. Narrow roadways encourage the concentration of traffic and the development of ruts, especially where the shoulders are properly provided with sufficient slope (usually $1\frac{1}{2}$ inches to the foot).

A committee in connection with the American Road Builders' Association recently made a recommendation that roads carrying a large proportion of fast motor traffic should have the unit width of traffic lines nine feet or ten feet, instead of seven feet or eight feet, as at present, because of the greater clearance required for safe passing of the units of such traffic.

On many of our roads vehicles are constantly forced to turn out on to the shoulders, thus causing them to wear down rapidly, and making necessary a large yearly expenditure for maintaining the shoulders.

In Britain, all main highways have been increased to a minimum width of 21 feet; also in many of the States the width of roads has been increased to 18 feet in tangent and 21 feet in curves, with 3-foot shoulders.

That the radii of curves are affected by traffic is evident when the conditions of the various classes of traffic are taken into consideration. Slow-moving horse-drawn

vehicles can readily pass around much sharper curves than can fast motor vehicles. Also, in the case of the former, not as much warning of the approach of other vehicles is needed as in the latter case. Hence the necessity for unobstructed vision for a reasonable distance at curves is not as great.

In 1913 the International Association of Roads Congresses made a recommendation that the radii of curves in roads used by fast traffic should, wherever practicable, provide the best possible and an unobstructed view, and that where this is not possible, the curve being of too short a radius, means should be provided whereby the approach thereto is in some way clearly indicated.

Maintenance.—In many cases a certain minimum of traffic is required in order that the maintenance may be most satisfactory and economical. This may seem a strange statement, but nevertheless it is true, that traffic up to a certain amount is desirable on some surfaces to keep them in good condition. For instance, unless a waterbound trap rock macadam gets a sufficient amount of hard-tired traffic to produce by abrasion sufficient fine material to offset that lost through the effects of wind and rain, the condition of the road surface will not be satisfactory, and its maintenance will be expensive. The Massachusetts Highway Commission has paid about \$50 per mile annually for the spreading of sand on the lightly travelled trap rock waterbound macadam roads in order to prevent the macadam ravelling after the blowing away of the fine material from its surface. Again, the sweeping effect of soft-tired motor traffic requires the abrasive effect of hard-tired traffic to counteract it. The dislodging effect of horses' feet needs the rolling effect of wheels to prevent the ravelling otherwise inevitable.

Destructive Factors.—There are three factors of traffic which may destroy the road, when it is assumed that the surface is ideal, and that the drainage and foundation are good in every respect: (1) The shocks of the horses' feet or of hard tires of vehicles; (2) the crushing effect of loads, a maximum per unit of width of tire; (3) the shearing action of motor car traffic.

High speed and small wheels, combined with heavy loading, is a destructive factor. Even exceptionally heavy loads on wheels of large diameter and reasonable width, travelling at a slow rate, cause very little damage to macadam roads in fair condition, except immediately after a frost, whereas fast traffic on small wheels and with much lighter loads soon causes considerable damage. It must, moreover, be borne in mind that the better and more regular the surface of the roads the smaller the damage, even with this type of traffic, and the damage increases at an alarming rate as the surface becomes worn and uneven.

Weather.—Where the atmosphere is generally humid, and there is a considerable proportion of wet days, the damaging effect will be greater on roads generally, and particularly on waterbound roads, than in the case of a drier atmosphere and with fewer wet days. It is not so much a question of comparing rainfall as the number of wet days and the general humidity.

Selection of Surface Material.—The road engineer must not only choose the type of surface over which it will be easiest to haul a load, which will prove durable under the traffic that it will carry, and which will be suitable to local conditions, but he must choose the surface that will produce these results with the minimum cost. It is not always possible to decide with facility what surface will prove the most satisfactory for the lowest total expenditure per ton carried over it. Nevertheless, this is the question to be solved in every new construction.