## TYPES OF BITUMINOUS CONSTRUCTION AND THEIR LIMITATIONS.*

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THE selection of the most economical and suitable types of bituminous road construction to meet a given set of traffic, climatic, subsoil and drainage conditions involves a clear comprehension of the limitations of the various types in use and the conditions essential to their successful employment. Certain conditions should absolutely preclude the use of certain kinds of construction regardless of possible low first cost, and disregard or lack of knowledge of the vital principles underlying different forms of construction has often resulted in the waste of large sums of public and private money.

Whatever type of construction is decided upon, it must always be borne in mind that a bituminous wearing surface is flexible and will only give good service when it is properly supported by an adequate foundation. Soft spots or weak places in the foundation will cause a settlement of the overlying wearing surface which will result in rapid deterioration. Water will collect in such low spots and rapidly destroy the bond between the bituminous binder and the mineral aggregate. The wheels of each vehicle passing over such depressions will strike a heavy blow as they drop down into them and cause displacement of the wearing surface, resulting in the formation of a ridge which still further adds to the vibration of the springs and causes successive blows to be dealt to the pavement until the spring vibration becomes normal again. This, of course, results in the formation of waves. In most heavy commercial vehicles the springs are comparatively short and stiff. The vibrations are, therefore, quick and tend to strike very heavy blows, resulting in wave formation at right angles to the line of traffic having their crests from 3 to 4 feet apart. This is plainly noticeable on roads having a bituminous wearing surface and it is still more evident on waterbound macadam roads. The poorer and less rigid the foundation the more pronounced the waves. This is quite distinct from the shearing or shoving action exerted by vehicles rounding curves at a moderately high rate of speed. The motor bus is perhaps more directly responsible for this type of wave formation than any other modern type of vehicle. In England, more especially in the neighborhood of London and other large cities, it is easy to pick out those roads which carry motor bus traffic, as they invariably show the kind of wave formation above described. On waterbound macadam roads it is no uncommon thing to find considerable stretches in which the difference in level between the wave crests and troughs amounts to 4 inches and over. This wave formation is noticeable in rock and sheet asphalt pavements laid on 9 inches of concrete as well as on country roads covered with sheet asphalt, tarred slag, bituminous concrete or bituminous macadam. Generally speaking, the wave formation in sheet or rock asphalt pavements laid on concrete foundations, while noticeable, is not excessive, whereas in bituminous surfaces on inferior macadam foundations it is one of the primary causes of disintegration. The consistency of the bituminous binder used in these English roads is on the average somewhat harder than that used in the United States and there are no long hot periods to soften them up, such as are frequent in the latter country. In their very moist climate it has been found that a harder bitumen adheres more tenaciously to the mineral aggregate and is less affected by water action. It is fair to assume, therefore, that their road surfaces are at least no more plastic than ours and personal examination showed that in the majority of them the bonding qualities of the bitumen had not been weakened by water action and that the grading of the mineral aggregate was normal. The writer believes that much of this could be avoided by having longer and more flexible springs on vehicles of this type, thus greatly lessening the road shock.

Slow-moving, heavily loaded vehicles are much more prone to cause displacement and wave formation than are the lighter type of vehicles moving at a speed of from 15 to 25 miles per hour. This was clearly shown by a 60-ft. street in one of our eastern cities which was paved with a bituminous concrete mixture containing more stone than the average Topeka mixture. The foundation was 5 inches of concrete and the average grade about 3 per cent. A trolley line in the centre of the street sharply divided the moving traffic. The traffic uphill was composed largely of slow-moving, loaded, 3 to 4-ton, horse-drawn vehicles and a few motor trucks, whereas on the down grade it was confined to light delivery wagons and empty trucks, but the number of vehicles on each side was about equal. The pavement on the uphill side very soon developed wave formation to such an extent as to require a large amount of resurfacing, whereas that on the downhill side gave satisfactory service for a long period with practically no wave formation. Both sides were laid with the same mixture and at the same time. The concrete in many places was defective and at these points the wave formation was most marked.

In the writer's opinion, wherever the traffic calls for a bituminous surface, a concrete foundation is justified and is economically sound. There is always movement in a macadam foundation, as evidenced by the rounded edges of the stone of which it is composed. This is noticeable wherever a macadam road is dug up or scarified. If the larger particles of stone are screened out from the mass and examined, their edges will be found to have become rounded by attrition. Where the traffic is very light, as on country roads which are not main arteries from or between large cities, and in some residential streets, old macadam roads have proved to be suitable foundations for bituminous surface mixtures. Far more failures than successes have resulted from their use, however, and great caution should be observed with respect to employing them. Many roads are classified as macadam roads which contain no base course of large stone and are in reality old dirt roads on which comparatively fine stone has been dumped and consolidated by traffic, no provision having been made for their proper drainage. Unless constructed on a sandy soil, such roads inevitably become quagmires in spring when the frost comes out of the ground and are totally unfit for use as a foundation. New York State has many miles of penetration roads constructed on such foundations which have utterly failed, sometimes within six months after they were laid. Before using any macadam road as a foundation its history should be investigated and more particularly its behavior in the spring of the year. The character and depth of the stone should be determined by putting down a sufficient number of test-holes and proper under and side-drainage must be provided. In most instances it will be found necessary to rebuild the road in many places. Assuming it to have been a properly constructed and drained macadam road and hence suitable for a light traffic

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