road tested. This means, at this speed, a consumption of energy at wheel treads, of nearly three times as much on level poor macadam roads as on good level asphalt roads.

(10) Increasing the gross weight of the vehicle by 12 per cent., through load, was found to have no effect on tractive resistance within the observed speed limits for smooth roads in good condition; but on rough roads, a distinct increase in tractive resistance with this extra weight was observed.

(11) The presence of a layer of dust, say, 1 cm. thick, on a fair macadam road, was found to increase the equivalent grade of tractive resistance, at all tested speeds, by about 0.15 per cent.

(12) A freshly tarred and therefore very soft tar-macadam road was found to have an increased tractive resistance equivalent, at substantially all tested speeds, of about 0.5 per cent. The tires in this case sank about 0.8 in. (2 c.m.) into the road-bed, the gross car weight being 2,140 kg. (4,710 lb.).

(13) The total range of tractive resistance equivalent grade covered in the tests, was from 0.93 per cent, on the best asphalt road, at lowest speed, to 2.7 per cent. on the worst macadam road, at nearly the highest speed.

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## PARTITION OF LOAD IN RIVETED JOINTS.

IN the November issue of the Journal of the Franklin Institute an article appeared written by Cyrol M. Batho, assistant professor of applied mechanics at McGill University, in which he described the theoretical and experimental work carried on there in connection with ascertaining the load carried by each rivet in any form of riveted joint. Experiments were made upon different forms of joints, having a single line of five rivets on each side of the joint, and loaded in tension. The analyses indicated that a series of equations can be obtained giving the load carried by each rivet in any form of riveted joint in terms of a quantity K, which if the results are in shear depends upon the manner in which work is stored in the rivets; or if they act by frictional hold on the plates depends upon the work stored in the parts of the plates so held.

Only the specimen with ½-in. rivets was carried beyond the working load, but the regularity of its action showed that the partition of load obeyed the same laws at all loads up to that causing permanent deformation of the plates or rivets. In every specimen and at all loads the first and fifth rivets took by far the greater part of the total load, the actual proportion decreasing gradually as the load increased. For example, in the specimen with ½-in. rivets, the first and fifth rivets carried 83.5 per cent. of the total load at a load of 10,000 lbs., and this decreased to 70.0 per cent. at a load of 30,000 lbs. The latter load corresponds to an average stress of about 12,650 lbs. per square inch of actual rivet section, or 15,280 lbs. per square inch of nominal rivet section. This would usually be taken as the shearing stress on all the rivets, but actually the end rivets, if, as there seems little doubt, the rivets were in shear and not holding by friction, were each under an average shear stress of 22,150 lbs. per square inch, while the third rivet at the same load took only 3.2 per cent., corresponding to an average shear stress of only 2,020 lbs. per square inch. Thus in joints having several rows each containing an equal number of rivets and designed in the usual manner, i.e., allowing the average load per square inch of rivet section to be equal to the working stress in shear of the rivet material, the rivets in the end rows must carry stresses far above the allowable working stress.

The above refers to the specimens in which the cover plates were of the correct thickness; i.e., each half as thick as the middle plate. If they are thicker, the first rivet takes an even greater proportion of the load, the proportion increasing with increased thickness. In specimen B, in which the cover plates were of correct thickness, the first and fifth rivets took 88.1 per cent. of the load at a load of 16,000 lbs. In specimens D, E and F at the same load they carried 86.2 per cent., 89.7 per cent. and 78.9 per cent. of the total load respectively, but of these the first rivets carried respectively 70.7 per cent., 63.8 per cent. and 50 per cent. of the total load. Specimen F, in which the middle plate was of varying width, illustrated the action in members riveted to a gusset plate, and it was found that the varying width of plate resulted in a rather more even distribution of stress, the first and fifth rivets carrying only 69.7 per cent. of the load, as compared with 78.9 per cent. when the middle plate was cut down to uniform width.

In all the specimens tested the ratio of width of cover plate to pitch of rivets was the same, ¾. K probably varies as the width of cover plate divided by the pitch of the rivets; thus, with a smaller pitch or wider plates, K would be increased, and the effect of this would be to make the partition of the load rather more uniform. But a large variation of K only causes a comparatively small alteration in the percentage of the load carried by the end rivets. For example, in the specimen A a change of K from 0.485 to 1.3 only altered the load carried by each of these rivets from 40.7 per cent. to 35 per cent., and the alteration for a given change becomes less and less as the values of K increase. Thus the effect of change of pitch or breadth of cover is not likely to be very great, except possibly in splices containing a number of rivets in each row. However, further experiments are needed in order that a general law may be found for the value of K. When this is determined it will be possible to predetermine the exact partition of load in any proposed joint, and this will enable the joint to be designed in the most efficient manner. A very good approximation, sufficient for most purposes, may, however, be obtained from the data already given, since the general manner of partition of load is the same for all values of K.

Prof. Batho's summary and conclusions are as follow:—

1. It is shown that a riveted joint may be considered as a statically indeterminate structure, and that a series of equations may be obtained for any joint by means of Principle of Least Work, giving the loads carried by each of the rivets in terms of a quantity K, which depends upon the manner in which work is stored in, or by the action of, the rivets.

2. This theory is applied to various types of joints, and the modifying effects of non-uniform distribution of stress in the plates, unequal partition of the load between the two cover plates, and a difference in the modulus of elasticity of the middle plate and the cover plates are also considered.

3. It is shown experimentally that extensometer measurements on the outer surfaces of the cover plates of a riveted joint are sufficient for the determination of the mean stresses in the plates, and that the partition of the load among the rivets may be determined from such measurements. It is also shown that, at any rate after the first few loadings, the distribution of strain in the plates of a joint is not altered by repeated loadings.