Discussion.

The PRESIDENT, in moving a vote of thanks to the Author for his Papers, regretted that he was unable to be present that evening, being in China. The President.

Mr. WM. MARRIOTT remarked that he was disappointed with the Paper on reinforced concrete. It described methods known many years ago, which engineers had now abandoned. Reinforced concrete was a highly scientific system of construction, and material could be put exactly where it was required ; for that reason he deprecated strongly the use of concentrated reinforcement, and he thought most engineers would probably agree. He imagined that the Paper had been written some years ago, but, at any rate, he hoped that no engineers in England would attempt to follow the Author's recommendations. He suggested that the Chinese authorities should visit France if they desired to study reinforced concrete in its most modern form. It had to be admitted that engineers in England were not so up-to-date in concrete construction, although he hoped before long to see them foremost in connection with reinforced concrete as in other things. They had been rather hampered in the past, but reinforced concrete was now regarded in quite a different light. On the Paris, Lyons and Mediterranean Railway, which had more than 6,000 miles of track, there was now a regulation that every possible structure should be carried out in concrete. That railway was practically eliminating steel girder bridges because of their excessive maintenance-cost. The major part of all the reinforced concrete in France was done on the Considère system, and he had been much helped by seeing the wonderful work carried out there. It might be necessary in a new country to use old rails as reinforcement, but in England work should be carried out on more correct lines. Makeshifts were not economical in the long run. Things could be done much better, and generally at much less cost, by proceeding on scientific lines. Mr. Marriott.

Mr. F. J. WARING considered that the Paper on railway economics showed evidence of the care and research which the Author had devoted to the subject. As regarded axle-loads (p. 266), an 8-ton axle-load was suitable for a 45-lb. rail, but was very excessive for a 35-lb. rail. Referring to the Table at the foot of p. 266, the Eastern Bengal Railway appeared to hold a comparatively unfavourable position in regard to both cost per ton-mile and freight per train. The other Mr. Waring.

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Mr. Waring four railways mentioned were, he believed, wholly on the 5-foot 6-inch gauge, whereas the Eastern Bengal Railway was constructed on both the 5-foot 6-inch and metre-gauges. It would be interesting to know whether in the Railway Report for 1916, from which the figures had been taken, the statistics for both the gauges were combined, because, if so, that might acccount for the unfavourable position that railway held. He would like to suggest that rail-weight was about the last item on which to economize *unduly*, as that was sometimes the only item in which appreciable economy in construction could be effected. In the discussion on Sir Frederick Upcott's Paper he had cited[1] the Ceylon Northern Railway, which was built on the 5-foot 6-inch gauge. The curves and gradients were favourable, and the works were very light. It was considered essential by the Government of Ceylon to effect every possible economy, and the principal item in which any appreciable economy could be effected was the permanent way. Instead of adopting the usual 72-lb. or 80-lb. rail, he considered that, as the traffic at the outset was likely to be very light, he might safely adopt a lighter permanent way, and, therefore, as chief engineer of the railway, he recommended the adoption of a 46¼-lb. rail, as he felt that, if the traffic developed and if heavier rails were required, the change could readily be made without interfering with any other item of the work. Even then the cost of the permanent way per mile amounted to 24,336 rupees, or about 45 per cent. of the total cost per mile of the line, which was 54,269 rupees. It was needless to say that, had he adopted a rail-weight of 72 or 80 lbs., the cost would have been much higher. In the Appendixes there were one or two items which either were incorrect or required some qualification. In Appendix B (p. 290), the Federated Malay States Railways were stated to be built to a 3-foot 6-inch gauge, whereas they were actually of metre gauge. It was the case that the railways in Perak and Selangor were originally laid with 46¼-lb. rails, but, when those States were united to form the Federated Malay States in 1903, 60-lb. rails were adopted as the standard and that still existed. In Johore and in the island of Singapore 80-lb. rails were used. In Appendix G the Author referred to the Shire Highlands Railway in Nyasaland. That railway, from Port Herald to Blantyre, was built with 41¼-lb. rails—that was a matter in which his firm, who acted as Government engineers for the line, had no say. But in his opinion, in view of the steep gradients on that line, those rails were much too light. On the other railways in Nyasaland, the line from Port Herald to Zambezi, 60-lb. rails

[1] Minutes of Proceedings Inst. C.E., vol. clxiv, p. 220.

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were used, and rails of that weight were proposed for the projected extension of the Nyasaland railways from Luchonza to Lake Nyasa. Mr. Waring.

Mr. W. W. Grierson remarked that the two Papers were of especial interest to those who were engaged in foreign and Colonial practice, but questions affecting the economical construction and working of railways were of general importance. The Author had endeavoured to show how the solution of problems connected with railway promotion might be assisted by the application of formulas and by the use of rules; but he did not think that in practice questions such as the location of a railway-route, or even the weight of rail, or the width of rail, or the gauge, were ever likely to be settled by what might be called mathematical refinements; they would be determined by the large amount of practical experience and information which was now at the disposal of railway engineers. He quite agreed as to the advisability of adopting a rail fully equal to the load it had to bear; a rail that was likely to become distorted or which was lacking in rigidity impaired the smoothness of running, added to the cost of maintenance, and reduced the life of the track. It was true, as the Author pointed out, that the supports of the rail could be increased by the addition of sleepers, but there was a limit to the extent to which that could be done, a limit prescribed by practical considerations, namely, the necessity of maintaining sufficient space between the sleepers to enable maintenance and ballasting operations to be performed efficiently. In Great Britain the weight of rails ranged from about 70 to 100 lbs., and in recent years there had been a tendency to adopt two standards, 80–90 lbs., and 90–100 lbs., say 85 and 95 lbs. The 85-lb. rail would carry any type of British locomotive, but it would not carry a locomotive for so long or so economically where the traffic was dense as would the heavier 95-lb. rail. It was fully equal to all the requirements of lighter traffic, and enabled the line to be efficiently maintained, and consequently the life of the track to be fully secured. The Author stated that in a mountainous district it was justifiable to construct very steep gradients, even involving banking-engines, presumably on the ground that the increased cost of working would be more than compensated by the saving effected in the first cost of construction. Before the war the cost of a locomotive in this country was generally thought to be about £1,500 to £2,000 a year, and at the present time from £3,000 to £4,000 a year. If this annual expenditure was commuted it would give a sum of about £60,000 or £80,000. It had to be remembered, moreover, that one locomotive could not work continuously, and for a day and night service an additional engine was required; and if the traffic required several Mr. Grierson.

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Mr. Grierson. engines, the commuted sum would be very large indeed. The Author might possibly be correct where the trains were few in number, but Mr. Grierson felt sure that a railway company with capital at its command would generally find it economical to avoid very steep gradients wherever possible. The limiting curves for locomotives no doubt were correct, but he thought they must apply to narrow-gauge lines. In England the limiting permissible radius was generally regarded as 330 feet, and was avoided wherever possible, because it tended to strain the frame of the locomotive and also to cause the line to be knocked about. The Author pointed out that the standard number of sleepers on the Indian railways did not appear to be dependent on the density of traffic or the width of the gauge, but Mr. Grierson thought it would be quite improper to draw the deduction from that remark that the axle-loads, density of traffic, and number of trains did not exercise a very considerable effect on the number of sleepers required. He was not at all sure that in considering the number of sleepers a comparison on a numerical basis was sound. The Author gave the size of sleepers for the 4-foot $8\frac{1}{2}$-inch and the metre-gauge. While he did not think that the Table was intended to apply to the Indian railways, it showed that both the breadth and the length of the sleepers for the 4-foot $8\frac{1}{2}$-inch gauge were greater than in the case of the metre-gauge. If the base of the rail was 5 inches wide, the resultant bearing-area on a sleeper 8 inches broad would be 40 square inches. It was quite certain that, if soft wood was used, as was generally the case, and if the axle-loads were heavy, it was only a question of time until the flange of the rail cut into the sleeper and destroyed it. In England for many years the area of the base of the chair had been gradually increased until now it was about 110–115 square inches, and consequently it was very seldom that a sleeper was removed from a line on account of mechanical destruction: they were nearly always taken out on account of natural decay. The sleepers also were creosoted, and the life ranged from 16 to 25 years. Having regard to the comparatively short life of sleepers given in the Table on p. 279, it was possible that the sleeper had to be removed on account of natural decay before mechanical destruction took place. If, however, at any time in the future it became a practice to treat sleepers and consequently to get a longer life, he thought the question of a larger bearing-area would have to be considered. The use of old rails and old telegraph wires, galvanized iron, and so on, for reinforcement was considered a novel procedure in England. He would have liked to have known whether old scrap could be adopted in England voluntarily with advantage, and he gathered from Mr.

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Marriott's remarks that it could not. There was nothing in the Paper to show whether that was so. The conclusion was drawn from the figures given in Table VI that the reinforced slab was cheaper than steel, but there did not appear to be anything in the Paper which showed whether it was or not. Three spans were given in that Table—12, 20, and 30 feet. He did not know whether it was to be inferred that concrete slabs had been built to carry railway traffic with spans as long as 30 feet. Abroad, many reinforced-concrete beams were used for railway traffic with spans ranging from 10 to 20 feet, but very few beyond. If it was the practice in China to use reinforced concrete for railway underbridges up to spans of 30 feet, it would be useful to know the facts. Mr. Grierson.

Sir BRODIE HENDERSON, K.C.M.G., agreed with Mr. Grierson that to try to fix rail-weight by definite formulas was, as all engineers would probably agree, an impossibility. If a definite formula for rail-weight was required, the formula (p. 266) adopted by the Government of India was as good as could be obtained. Many volumes could be written about the question of gauge. It was usually fixed by circumstances over which the engineer had not very much control, namely, finance, the nature of the country, the amount of traffic, and similar factors. There was no doubt that a narrow gauge restricted speed and capacity, and he could not help thinking, in spite of the opinion expressed in the Paper, that it had a very considerable effect on the cost of working. The narrow gauge was generally more expensive to work than a broader gauge directly it had to carry a heavy traffic. In countries outside Europe one could not lay down any rule for the number of sleepers. Most of such lines, perhaps almost all of them, had a flat-bottom rail, spiked or fastened in some way to the sleepers. The number of sleepers per mile depended on the weight and the quantity of the traffic, and on the nature of the ballast, drainage, etc., and therefore it could not be taken generally that 2,000 sleepers was good practice on all lines; in some cases even more sleepers were required in bad sections. The economy resulting from the adoption of steel sleepers was said to be the saving in the cost of ballast, which could be replaced by earth. Most engineers who had had experience of lines laid with steel sleepers packed with earth did not consider that material by any means ideal. The 4,000 miles of track in the Argentine referred to in the Paper were not laid with steel sleepers because they were considered to be better than timber: it was simply a question of supply and demand. Steel sleepers were not preferred to the excellent timber sleeper obtainable in the Argentine, but, at one time of heavy construction, timber sleepers could not be obtained in sufficient Sir Brodie Henderson.

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Sir Brodie Henderson quantities. In that country for many hundreds of miles nothing but earth was available for use as ballast, but it could not be considered, under any circumstances, to be satisfactory ballast if anything better could be obtained. The Author gave various construction-widths, and it was interesting to compare those with the standards adopted in the Argentine :—

Gauge	5 ft. 6 in.	4 ft. 8½ in.	Metre.
Construction width :—			
India	9 ft. 6 in.	..	8 ft. 6 in.
China	..	10 ft. 2 in.	..
Argentine—			
Fixed structures	13 ft. 9¼ in.	13 ft. 1½ in.	11 ft 6 in.
Rolling-stock widths	12 ft. 9½ in.	12 ft. 1⅝ in.	10 ft. 6 in.

The maximum widths mentioned in the Paper could be considerably exceeded with safety. The Author stated that a fairly detailed survey should be made in a sparsely-populated country. He would like the Author to omit the word "fairly." His own experience was that a thoroughly good detailed survey was an economy.

Mr. Husbands. Mr. H. W. S. Husbands doubted whether all the Author's economic arguments were based on sufficiently reliable information. The Author stated that the ton-mileage per train-mile varied in proportion to rail-weight, and that the other standards of construction, such as formation-width, sleepers, ballast, etc., did not vary so much with rail-weight or ton-miles. He thought it must be admitted that, although it was natural to increase the rail-weight as the traffic increased, banks and other earthworks were built generally to a higher standard to start with, and therefore did not vary so much. The Author mentioned the increase in the weights of some of the steel sleepers. In India, on the Nizam's line, metre-gauge, 75-lb. steel sleepers were used with a 50-lb. rail, and he believed 110-lb. sleepers for 75-lb. rails were used on the broad gauge. Those were being given up, and heavier sleepers had been adopted—he thought just over 100 lbs. for a 50-lb. rail and 150 lbs. for the broad gauge with a 75-lb. rail—but he was not sure of the actual figures. The same thing had been found with pot sleepers; the weight had been gradually increased as heavier engines had been introduced. Although the rail-weight might remain stationary, it could partly be made up for by an increase in the weight of the sleepers. The pot

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Mr. Husbands.

sleepers on the Great Indian Peninsula Railway were now very considerably heavier than formerly, and it was hoped that they would last a long time, but he did not know whether the results had proved so satisfactory as was expected. On the neck running into Bombay, where there was a quadruple track, the Company had now gone back to the best English practice and were adopting wooden sleepers and chairs. He thought it would be found that what was required for a stable road under heavy traffic was not only heavy rails but also either heavy sleepers or sleepers and chairs, so as to increase the inertia of the permanent way as a whole. He did not think it could be said that the weight and size of sleepers did not vary with the traffic. The Author also seemed to suggest that, if a heavy rail were put in, although the sleepers might be light, it would immediately reduce the working-cost per train-mile. There would not be any increased economy from the heavy rail until heavier bridge-girders, etc., had been installed, so as to permit the use of heavier rolling stock and higher speeds. There was obviously a limit to the extra weight of rail that could be put in economically. As a rule, it was not now the practice in India on new lines to adopt the minimum rail-weight. When the Nizam's metre-gauge line was built, the engineers did not adopt the minimum, but put in a 50-lb. rail; and on some of the other lines they were using up heavier second-hand rails from the broad-gauge line. It seemed to him that, when new light lines were being constructed, that was preferable to putting in new heavy rails. He had tried to discover what would be the economical time over which it would pay to put heavy rails in before they were required to be used to their full value, and he had found that to use a 75-lb. rail instead of a 60-lb. rail would not be economical unless that extra capacity was required within about 20 years, and the same would apply for the 40-lb. rail in place of a 30-lb. rail. He had not allowed for any reduction in saving on the sleepers, because the Author had not made any note of the extra cost that would have come about by increasing the girder standards, and he had put the one against the other. In a country where it was not possible to obtain a price for scrap rails, naturally the period would be slightly longer, and it would be longer also if prices were rising. On the other hand, even if prices were rising, that might be compensated for by getting, 20 years hence, rails of better value. He was afraid the Author had based his comparisons on figures from the Indian Report of one year only. It had generally been found that it was not safe to base any definite conclusions on figures for one year unless all the conditions were known. In the Table given on p. 266 the very heavy cost per ton-mile shown against the Eastern Bengal

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Mr. Husbands. Railway had already been explained, and it would be noticed that the two railways which showed the lowest cost were the Bengal-Nagpur and the East Indian. The reason for that was that those two railways both tapped the largest coal and mineral fields in the country; thus they obtained cheaper coal and also had a very heavy mineral traffic. The Bombay, Baroda and Central Indian Railway and the Great Indian Peninsula Railway had the same cost per ton-mile, although the Author showed the one as having 69-lb. rails and the other as with 100-lb. rails. In the 1912 Report, the former was stated to have 69, 82, and 90-lb. rails, and the latter 100, 82, and 69-lb. rails. He was sorry to see that in summarizing the costs for the different gauges the Author had only dealt with very level ground, and had given a maximum cost which looked very large. It was a pity he was not able to give something which was nearer to what was generally supposed would be the difference in cost. He had taken a minimum bank of 2 feet which was practically a surface line, and of course that would give the maximum cost. It would be interesting to know what the average bank was, so as to get an idea of what the average cost would be.

Mr. Johnson. Mr. T. R. JOHNSON said the Paper on economics gave unmistakable evidence of having been written some years ago. In 1920 three engineering conferences were held in Peking, when matters in connection with railways were standardized to a very considerable extent; many of the subjects referred to in the Paper were then dealt with, and recommendations were made to the Ministry of Communications. Although perhaps the Ministry might not have promulgated those decisions or recommendations, they were as a matter of fact being worked to very largely on the railways in China to-day.

Mr. Ricketts. Mr. D. P. RICKETTS agreed with Mr. Marriott that in many particulars the reinforced concrete work referred to was not quite in accord with present-day practice. The Paper was written towards the end of the war, when steelwork was difficult to get. A great deal of concrete was used, made of anything that could be got at a time when proper materials were not available. Steel rails were not now so used. Reinforced concrete was a matter that required very scientific and careful treatment. A great many slabs were made for bridge spans, but none exceeding 15 feet were used while he was chief engineer. He did not think sufficient knowledge had been obtained with regard to the facts of reinforced concrete to warrant the risk of working in larger spans. The weight of rail was generally regulated by conditions other than mathematics. In China the maximum weight was standardized at 85 lbs. Many railways had

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Mr. Ricketts. to use a much heavier rail than they otherwise would, chiefly owing to military traffic and the weight of main-line engines, which might have to travel over the whole country. With regard to pipes, they had been made only when cast-iron pipes could not be procured, during the war, and had been used to a certain small extent, but he did not recommend that as a practice.

The Author. The AUTHOR, in reply, dealing first with the Paper on Railway Economics, remarked that Mr. Waring's point as to rail-weight seemed to be brought out on p. 268, where it was stated that for a line to traverse anything but the easiest country the 40-lb. rail might be regarded as the minimum. With reference to the question as to the Table on p. 266, the 5-foot 6-inch and metre-gauge portions of the Eastern Bengal Railway were returned separately in the report. In reply to Mr. Grierson, the curves given for locomotives were for engines of standard or narrow gauge, with Bissell trucks, link-hung. It was not suggested that this curvature should be adopted outside station-yards in the case of the standard gauge. Decay appeared to be the determining factor in the removal of timber sleepers under a flat-footed rail, and it took place entirely at the spike-holes. The destruction was of course partly due to mechanical causes, and its extent could be judged from the fact that the hardwood sleepers of the Peking-Mukden Railway had a life of about 8 years, whereas the determining factor in the life of a bridge tie was merely its capacity in spike-holes—at most four holes. Bridge ties 8 years old examined recently were found to be quite sound. Lack of bearing-area was not, as far as his experience went, a cause of removal. In China, under a length of 60 feet of 85-lb. track, it would be customary to have at least eighteen sleepers, whereas he believed twenty-three sleepers would be used under the chair road of the London and North Western Railway. Where Oregon timber was employed in China instead of hardwood, there would be as many as thirty-two sleepers per 60 feet. With regard to Sir Brodie Henderson's remark as to construction, the Author questioned whether the speeds allowable on the Argentine Railways were as high as those in the other two countries compared. Packing and boxing with suitable earth was only advocated for lines of small traffic in the case of the steel-sleeper road. This was the practice, and was satisfactory, on the Benguella Railway (Portuguese South-West Africa) where the rainfall of 60 inches per annum all occurred in 6 months. Mr. Husbands would recognize the difficulty of reducing to a condensed statement a mass of apparently irreconcilable data. In every case heavier rails were taken to imply heavier engines and girders, and the cost of haulage per ton-mile was only expected

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The Author. to show a reduction with increased rail-weight if full loads were available. The Report on Indian Railways for 1916 was not the only one consulted.

With regard to the Paper on Reinforced Concrete, Mr. Marriott's strictures called for the following comments. The possible field of appeal of this Paper was very clearly stated in the opening paragraph. Mr. Marriott could have had no experience of dealing with Chinese or nigger labour. As an instance of what might occur, in the autumn of 1921 the Author was responsible for the design and construction of a 250,000 gallon storage-tank, 50 feet in diameter, of concrete. The dome was reinforced with $\frac{1}{4}$-inch bars, and during its construction the blocks which separated the tension and compression reinforcement were displaced, displacing the reinforcement 4 or 5 inches. The foreman in charge had not considered it necessary to use the wooden template employed for checking the position of this. The placing of the concrete was proceeding as if all were in order, and would have continued had it not happened to be the Author's day for inspection. He was well aware of the scientific nature of reinforced-concrete construction, but in view of such conditions as these he affirmed that a heavy bar was infinitely preferable to two light bars of similar total sectional area in beams or slabs designed on the Considère or any other system. Mr. Marriott alluded to methods known many years ago. The Author's authority was Messrs. Buel and Hill's book (1906 edition) in which would be found (p. 276) bridges of the type advocated in the Paper. Had the general methods of design altered fundamentally since that date, apart from the fact that the rail-reinforced beam was out of date ? One of the difficulties which hampered engineers abroad was lack of reference books. It might surprise Mr. Marriott to know that no text-book available to the Author dealt with the design of slabs reinforced with rails or steel sections, and that the formulas given in the Paper had been chanced on in Skelton's "Handbook of Steel Sections." No experimental data could be found. A reference library for the engineers should be part of the equipment of every big railway service abroad. Finally, he thought America, rather than France, was the country in which to study the most modern applications of reinforced concrete.

On the Peking-Mukden Railway it was the practice to use bar reinforcement, where considered economical in concrete, in second floors to workshops, gantry and other columns, store-racks, storage-tanks, etc. There had been no failures. In reply to Mr. Grierson's question, the girders specified in Table VI. (p. 307) were of the usual plate type. The slab designs given there over 12 feet span were

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suggestions only. As stated by Mr. Ricketts no span exceeding 15 feet had been tried. Prolonged trial with the concrete pipes had indicated that they were an experiment not to be repeated. The Author.

Correspondence.

Mr. W. B. EDWARDS thanked the Author for compiling much useful information in a form convenient for reference. No hard and fast rules could be laid down on a question embracing all countries outside Europe. Probably no one would dispute the conclusion that rail-weight was about the last item on which to economize, but a range of weights between 40 lbs. and 100 lbs. per yard left ample margin for the exercise of discretion on the part of the engineer. He was employed as an assistant on maintenance on the Cape Government Railways 30 years ago, and they were then replacing the 40-lb. rails with the 60-lb. type. From the Tables given in the Paper, it would appear that the rail-weight had not been increased since. Most new extra-European lines were of a more or less speculative character, and a 60-lb. rail would allow of considerable increase in traffic and axle-loads. Even where no immediate market existed for old rails, many of them could always be utilized on the railway itself, apart from the track. On the Cape lines old rails were used for fence-posts, veranda-posts, beams for culverts, etc. There was no doubt that heavy gradients were economical for mountainous districts, so far as construction-charges were concerned; and, where the steep inclines were concentrated, a pusher-engine could deal efficiently with the normal traffic. It should be remembered, however, that descending trains also were delayed owing to the necessity for reducing speed to a safe limit. On the Hex River Mountain incline, which was on his district at the Cape, all down trains not fitted with a continuous brake had to stop at the summit to allow the vehicle brakes to be pinned down. The incline was about 12 miles long, the gradients ranging from 1 in 40 to 1 in 100, and in places the curves were of only 5 chains radius. Down trains literally crawled over that section. Steep gradients, even of short length, introduced into the more level portions of a line, were objectionable, as assistant and pusher-engines could not be used economically. The maximum gradient on the Cape lines was 1 in 40, and that occurred in many places, taxing severely the capacity of a single engine. Such gradients Mr Edwards.

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