TEMPORARY WORK ON THE CANADIAN PACIFIC RAILWAY.

By Mr J. Grant MacGregor (Member).

SEE PLATE II.

Held as read, 18th December, 1900.

GENERAL REMARKS.

The history of the construction of the Canadian Pacific Railway has been so ably recorded by its pioneers, in various papers to kindred societies, that a review of all the characteristics of its earlier development will be unnecessary within the scope of this paper. The following notes will therefore be confined principally to a description of the temporary work employed during construction, and its relation to the more recent permanent work, with the view of illustrating as far as possible the conditions affecting the construction, and the operations peculiar to the maintenance, of what may be termed a pioneer railway.

The term "Pioneer," as sometimes applied to American railways, implies that the railway has been projected with the view of opening up a new territory for colonisation purposes, and that in its construction all due regard has been had to economy in first cost, so that the expenditure made may be justified by the prospects of the country being speedily settled and a revenue made available to the promoters from the development of its natural resources.

The maintenance, however, of a railway built on this principle, in order to meet the requirements of increasing traffic and modern equipment, must necessarily form an important factor in its future development.

Unlike the conditions existing in countries that are fully settled, the demands of a partially settled country like Canada, necessitate the adoption of the principle of economy in first cost, a principle that proved so beneficial in the earlier days of pioneer railways in the United States, where similar conditions prevailed.

Nevertheless, it would be folly to conclude from this that the American practice of building cheap railways, where timber as a natural product is so largely introduced into their construction, could be adopted with economy in all new and undeveloped countries. So much depends on the deteriorating effects of climate, cost of transportation of material and the adaptability of the natural products available, that it is only from a careful study of these conditions—with the rate of future development and cost of maintenance in view—that the most advantageous plan can be adopted.

North America is, of course, specially favourable to the construction of cheap railways on account of the great quantity of fine timber available, which is extensively employed in the building of trestles and other temporary works. In hilly country where extensive bridging is necessary, timber, as a rule, is plentiful and the cost of haulage low. On the prairies, where timber is more difficult to procure, it is not so much required on account of the favourable nature of the ground. Natural facilities such as these, together with the large proportion of line traversing flat country, go far towards reducing the average cost of pioneer railways in North America.

The greater number, however, of the more important works carried out during the construction of the Canadian Pacific Railway, were of a more permanent character than what is usually adopted on American railways. Where circumstances were favourable it was always deemed necessary, in the interests of future economy, to build the permanent structures at the outset, and this was done in the form of many fine examples of masonry and steel bridges.

A great part of the original permanent work in British Columbia was carried out by the Government, and, as experience has since proved, much unnecessary expenditure was made on these structures where economy in design and arrangement of space were not carefully studied. This fact is admirably illustrated by Mr P. A. Peterson, chief engineer, in his presidential address before the Canadian Society of Civil Engineers at the close of session 1894-95.

During construction timber was chiefly employed in the building of temporary trestles, with the view of avoiding heavy embankments, where suitable filling could not be procured at a convenient distance. The saving thus effected was considerable—the cost of trestlework being frequently as much as from 30 to 40 per cent. less than an embankment, and at the same time the construction of a costly permanent structure, where an opening or waterway was required, was avoided. Indeed in many cases it was considered unadvisable to construct permanent openings and embankments, as changes in location are sometimes found necessary after the lapse of time, when a bettter knowledge of the topography of the surrounding country is obtained. As the forests get hewn down, and fire performs the finishing touches by sweeping away the underbrush, many errors in the original location might be detected.

In some cases it was actually found more expedient to build temporary trestlework, and fill in immediately afterwards. In such cases the filling was done from a train of flat cars, with plough and cable attached to the engine, and not infrequently the material had to be taken from some distant point ahead of the side to be filled, the trestle in the meantime serving as a temporary bridge. This method was adopted more particularly where the line crossed a swamp, or shallow water along the lake shores, and where the country was flooded during the season at which operations had to be carried on. In the case of a swamp the piling gave additional stability to the embankment, and enabled it to settle gradually as the timber decayed; and although this was perhaps not always the object sought, it avoided much loss of time and disappointment afterwards,

Another advantage derived from the uses of open trestlework is, the longer time afforded for carefully ascertaining the class of structure most suitable, and the size of opening required for a permanent structure, with the necessary protection against flood and ice.

The climate of Canada renders precautions of this kind necessary especially in a territory practically unexplored. In deciding on the structure best adapted to the situation, and the size of opening required, a good deal depends on the information available regarding the flood season, for what at one season of the year seems a peaceful valley or ravine, with a small rivulet trickling down its bed, may at flood season develop into a raging torrent several hundred feet wide, carrying ice and timber in large quantities in its course, The volume of flood water during spring does not altogether depend on the amount of snow or rainfall, but is influenced more or less by the peculiar nature of the Canadian winter. The flood season following an open winter is, as a rule, the most disastrous. This is evidently brought about by a series of thaws occurring during the earlier part of spring, removing and depositing large quantities of ice along the water courses and enabling more ice to form—finally blocking up the channels, and causing abnormal ice shores.

Observations necessary for obtaining data relative to volume of water at the flood season will consequently extend over a period of years, in the absence of information gleaned from old inhabitants or traces left by previous floods. In order that this information may be available when the question of building a permanent structure arises, the section foremen are instructed to note the highest water each year by a permanent mark on all bridges on their respective sections.

Pile trestles of the class shown Figs. 20-22, Plate II, have been known to resist the ravages of flood and ice much better than more costly structures consisting of framed bents, or even crib piers with cut-waters. The pile trestle, however, can only be adopted with advantage where the bottom is of a suitable nature for piling. Where the cost of substituting a permanent structure for this class is great, on account of the foundations, the temporary structure is maintained at a comparatively small cost for many years. New piles are driven midway between the old bents, and the superstructure replaced without any serious interruption to traffic. It is only practicable, however, to employ this class of structure where the height does not exceed 25 or 30 feet, on account of the greater length of pile required. Where the height exceeds this limit, and the bottom is of a soft nature, it is customary to arrange the piles to be cut about two feet above the ground, and capped to form a sill for a framed bent of the class shown, Figs. 15 to 17.

Much controversy seems to prevail sometimes as to the best method of carrying railways across "muskegs" or swamps, where a high embankment is required. Of course the pile trestle has always been resorted to as a ready method, but it can only be regarded as a temporary expedient and it is costly to maintain. It is not the intention of the author, however, to go into this question exhaustively in the present paper, but from observations of the several methods usually employed, it would appear that a great deal depends on a previous knowledge of the nature and composition of the underlying material. For example, in the case of a peat bog, where there are ample means of draining the water off, it appears that the method that has proved most satisfactory is that by which the crust or natural surface is preserved, and the superincumbent weight equally distributed over the largest possible area during the filling. This is frequently effected by what is known as "cross-logging," or forming a mattress of cedar logs over the entire area to be covered by the embankment. In doing this care must be taken in placing the logs so that the ends shall not all butt in line. The author observed an instance of where two lengths of logs were placed in position with the ends all butting in line at the centre of the embankment. This had the effect of breaking the crust at the centre, and tilting the logs up to form a V-shape. The side ditches are usually placed as near the foot of slope as possible, it being found that when they are placed at a greater distance than 8 or 10 feet away the crust will not yield uniformly with the weight of the embankment.

Where the situation is of a less favourable nature, and the material to be dealt with is composed of mud or quicksand of great depth, nothing has proved more effective than trestle work or rock filling; but the latter being expensive work it has not been adopted except where the rock had to be excavated from a cut or tunnel in the immediate vicinity.

An attempt was made some time ago to fill in a trestle 1800 feet long, in a bay at the south end of Lake Memphremagog, with ordinary material consisting of loamy sand and clay. The bottom of the lake consisted of a depth of 20 feet of mud, the surface of which was 18 feet below water level. The work was carried out successfully, except that the quantity of filling was greatly in excess of the estimated quantity. Much of the material was evidently lost in floating away and combining with the yielding mass of mud. Had the material selected for the filling been of a less absorbent nature, such as pure sand and gravel, the work could no doubt have been done more satisfactorily and at less cost. The form which the embankment assumed when completed is shown by the cross section, Fig. 1*a*, which was prepared from soundings taken at various stages of the work, and borings made after completion.

From the author's observations of the progress of reconstruction and maintenance during the past eight years, not a few problems have arisen as to the effect of location on the future economical working of railways of this class. The questions usually left to the decision of the maintenance engineer are innumerable. Certainly a great many of the difficulties presented were, in the first place, unavoidable, but, unfortunately, not a few were due to bad location. This, however, was not always the fault of the engineer in charge of location, for frequently it would seem that too little time was afforded for this important part of the work, and during the hurry and excitement with which the work of construction was pushed forward, in the eagerness of the promoters to have the line opened for traffic, many of the more important problems of reconstruction were overlooked. It is evident, however, that no amount of time saved in the original work of locating a railway can compensate

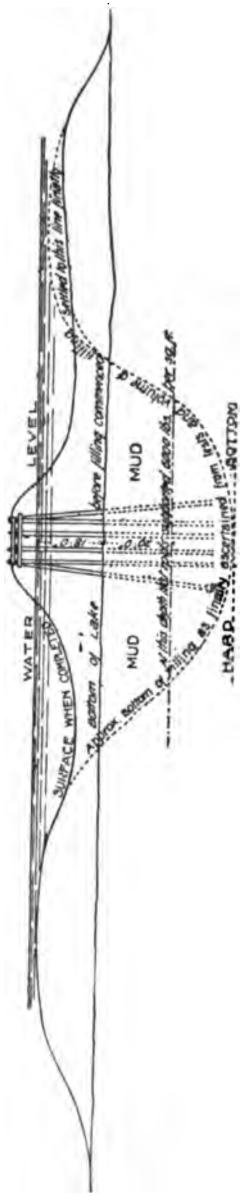
WATER
LEVEL
MUD
MUD
SURFACE WHEN COMPLETED
bottom of Lake
before filling commenced
Settled to this line finally
HARD BOTTOM

Fig. 1a.

for errors that may have a deteriorating effect on its future reconstruction and maintenance.

The Canadian Pacific Railway, stretching as it does from the Atlantic to the Pacific, traverses a territory of a nature so diversified that in its construction nearly every imaginable obstacle was encountered, thus affording a wide field for the ingenuity and skill of its engineers. Notwithstanding the rapidity with which the work of construction was carried on, it is remarkable how few errors were made in dealing with the various obstacles encountered and in providing for the future development of this great project. The experience attained by its engineers has been prolific of much useful data for the benefit of the profession, and has no doubt established certain rules to be adhered to in the work of location, peculiar to existing climatic conditions, and applicable to the variable nature of the ground traversed.

For example, in flat country or "table land," it is important that the formation level or subgrade, as it is called, should be kept as high as possible above the average level of the adjoining land, to provide for drainage, and guard against inundations which invariably occur in spring, from the melting of snow on the surface of the hard frozen ground. As the land taken for right of way is usually of a uniform width of 99 feet or 6 rods, sufficient material for a single track railway is procured from the side ditches, but failing this the additional filling required is taken from "borrow pits" at convenient points along the line. This class of work is usually termed "cut and cover," a cross section of which is shown Fig. 1 *b*.

In locating over undulating grounds, the material being of a clayey or sliding nature, deep cuttings are avoided as much as possible. Not unfrequently has the removal of a small quantity of material of this peculiar nature caused the general movement of a large area of the adjoining lands. To prevent the cuttings closing in, piling at the foot of slopes had to be resorted to in many cases. In situations of this nature provision is made for

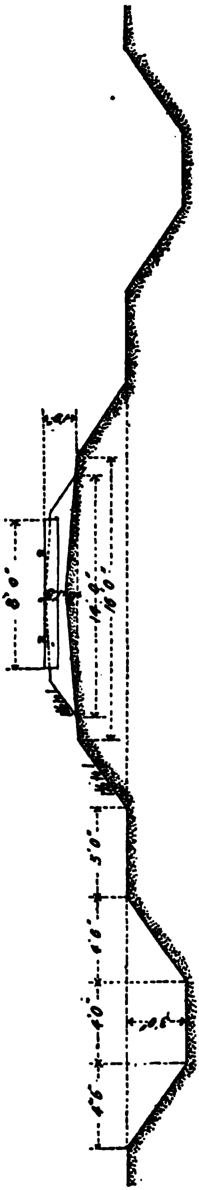

Fig. 1b.

draining the roadbed to prevent the track "heaving" while the frost is leaving the ground in spring.

The necessity for a properly drained roadbed in this climate is becoming more apparent now than ever to those interested in the maintenance of permanent way. Many of the recent failures in rails, that have only been in use a short time, can be traced to an uneven, badly drained, and poorly ballasted roadbed.

The location through the mountains was, on account of grade and general contour of the country, confined to a small area, which left little or no means of avoiding places exposed to land slides, snow slides, and wash-outs in spring. The snow sheds, which are an interesting feature of the construcrion through the mountains, have proved of great benefit in protecting the line from avalanches. Cribwork and masonry retaining walls were also constructed at the foot of slopes as a protection against land slides and erosion by floods.

TEMPORARY STRUCTURES.

In preparing the drawings of these structures attention was given to detail as much as possible in order to avoid a lengthy description, and make the work serviceable for reference. The figures illustrate the various structures composed of timber, whether regarded as temporary structures or otherwise. Of course, on a great many American railways timber structures are in many cases considered permanent work, and are renewed from time to time in timber. Indeed, if the durability of such timber as cedar be considered in the construction of box culverts, solid timber open culverts and cattle guards, in favourable situations, it would seem almost unnecessary to employ a more expensive class of structure. In many cases, where cedar had been used on some of the older railways, it was found perfectly sound after thirty years' service. In the case of fence posts and telegraph poles it is invaluable as an exceedingly durable timber, and can be procured at a comparatively small cost. Cedar sleepers or track ties are also used where they are easily procured; but on account of their lightness, and small amount of adhesion to spiking, they have not proved as efficient as those made from tamarac. Cedar is also largely used for piling and substructural work, both above and below water, and no doubt figures prominently in the small cost of maintaining the various structures in question.

CATTLE GUARDS.

Surface cattle guards of various kinds have been introduced indiscriminately, on account of their simplicity and comparative small cost, but so far as the writer is aware they have not proved as efficient as the open timber cattle guard, Figs. 1, 2, and 3, This structure, in some cases, serves also as an open culvert, where the water from the side ditches is intercepted and carried along the public highway. The span is invariably 6 feet and the minimum depth 3 feet. The drawings show the manner in which the structure can be adapted to either cutting or embankment. The sills and side walls are usually made from full squared cedar or tamarac. Cedar sawn on three faces is sometimes used for side walls, with the rough face towards the embankment, and placed on "flatted" cedar sills similar to those shown for box culverts, Figs. 4 and 5. The stringers, ties, and tie cleats are usually of pine.

BOX CULVERTS.

The cedar box culverts, Figs. 4 and 5, are constructed of 12-inch by 12-inch cedar drift-bolted together, and braced at intervals of about 5 feet with 8-inch by 8-inch cleats bolted to the outside of the side walls. The sills are of "platted" cedar, 8 inches thick, spaced 5 feet apart, and paved between with rough stone, hand laid. The covers are of 12-inch by 12-inch cedar, checked 1-inch over the side walls, and drift-bolted to the same.

The double 4 feet by 4 feet box culvert, Figs. 6 and 7, is usually constructed where a large waterway is required through an embankment. The number of chambers can be increased to four or six if required. This class of structure is well adapted to situations where the bottom is very soft, as for instance the bay of a shallow lake, or the channel of a slough, where the water level is subject to sudden fluctuations.

SOLID TIMBER OPEN CULVERTS.

The construction of these culverts, Figs. 8 and 9, is somewhat similar to those already described—that is solid timber side walls drift-bolted together, and braced with 8-inch by 8-inch cleats on the outside. These structures seldom exceed 5 feet in height, and serve also as cattle passes. Where greater height is required a framed culvert, Figs. 10 and 11 is, as a rule, adopted. A planked floor and sheet piling are sometimes necessary.

FRAMED CULVERT.

Figs. 10 and 11 represent what is termed a framed culvert. The framework is constructed of 12-inch by 12-inch squared timber, tenoned at sills and caps, and drift-bolted. The sheathing and flooring consists of 3-inch planking. This structure is adapted to situations where the water-course has a well-defined deep channel with gravelly bottom.

PILE CULVERT.

Where the situation is unfavourable for the class of structure shown in Figs. 8 and 9, a pile culvert of the class, Figs. 12 and 13, is substituted. The piles are driven to a solid bearing, and capped as shown, and sheathed behind with 3-inch planks.

The superstructure shown in Fig. 14, is common to each class of open timber culvert.

PILE TRESTLE BRIDGES.

The pile trestle bridge, Figs. 20, 21, and 22, already referred to on account of its adaptability to difficult or uncertain situations, consists of a series of 4 pile bents with their centres placed 15 feet apart. The inner piles are driven to a batter of 1 in 12, and where the height above ground will permit, the outer piles are driven to the same batter, and "sprung" to 1 in 6 at the top. The transverse bracing and longitudinal walings are of 3-inch by 10-inch timber, bolted to caps and sills and spiked to piles. The superstructure is similar to Fig. 18 prescribed for framed trestles.

FRAMED TRESTLES.

The design for framed trestles, Figs. 15, 16, and 17, was selected after a careful study of the various designs from which structures were built from time to time over the entire system. One feature of this design, which is no doubt a commendable one, is the absence of the usual elaborate system of longitudinal bracing, and the additional stiffness obtained from the arrangement of the horizontal longitudinal girts. There is nothing remarkable about the transverse bracing or arrangement of posts, except, perhaps, that the same system can be applied to any desired height by simply inserting an additional post between the two inner pairs, those with batters 1 in 5 and 1 in 24, when the space between becomes too great, as would occur had Fig. 17 been carried down another storey. Fig. 19 shows the minimum height for framed bents.

The floor system, Fig. 18, deserves mention on account of the fact, that by arranging the stringers in this manner, the load is distributed over a larger area at the point of application. It was found necessary to provide for the load due to increased weight of engines in this way without materially increasing the weight of trestle floor. It will be observed that the outside or jack stringers usually placed directly under the ends of ties, can be omitted by this arrangement and brought into action to better advantage nearer the point of application of the load. The stringers, ties, and guard rail are usually made from clear white or red pine, or Douglas fir. The remainder of the work from "merchantable" timber of various kinds.

CRIB PIERS AND ABUTMENTS.

Fig. 23 illustrates the manner in which crib piers and abutments for Howe truss, pony truss, and wooden lattice spans are constructed. The courses are dovetailed at all intersections, and drift-bolted together with drift bolts long enough to penetrate 2½ courses of timber. Oak trenails are used at all other points except where the timbers intersect. All intersections at cutwaters are dovetailed at the proper angle, and drift-bolted in the same manner. The nosing of cutwaters is protected as a rule with a covering of sheet iron. The timber used is cedar, pine or tamarac.

CRIB RETAINING WALLS.

Crib retaining walls are frequently introduced as a protection at the foot of slopes running out into water where there is danger of erosion from currents, also at various points where otherwise masonry retaining walls would be necessary. They are constructed from rough logs, laid in the manner indicated by Fig. 24, The timbers are notched at all intersections and drift bolted together. The timber used is chiefly cedar, spruce, and tamarac.

APPROXIMATE COST OF STRUCTURES.

The cost of the various structures referred to varies so much over so vast a territory that it is scarcely possible to give more than approximate figures. The following prices, however, may be considered a fair average, when timber can be procured at a reasonable figure, and the work done by experienced workmen, under the superintendence of men familiar with this class of work.

CATTLE GUARDS AND OPEN CULVERTS.

Timber in place per 1000 ft. B.M.	$20
Superstructure, stringers, ties, etc., ...	$30
Piling per lin. ft. left in work, ...	30 cents.

Wrought and cast iron included in above prices.

BOX CULVERTS.

Box culverts,	2 ft. by 2 ft. per lin. ft.	$2.5
Do.	3 ft. by 3 ft. ,, ,, ...	$3.0
Do.	4 ft. by 4 ft. ,, ,, ...	$4.0

FRAMED TRESTLE WORK

Framed trestle work in place per 1000 ft. B.M.,		$22
Stringers, ties, guard rails	,, ,, ,,	$30
Piling per lin. ft. left in work,	... ...	30 cents.

Ironwork included in price of framing above. Trestle work about 20 feet in height costs about $6 25 cents. or say 25 shillings per lineal foot.

Crib piers and abutments cost per cub. yard, including stone filling complete $3 50 cents. Open cribwork for retaining walls with stone filling costs per cubic yard $2.

The author had in view the idea of introducing in the present paper a few examples of the permanent work by which the temporary work is being rapidly replaced. There are many features of the construction of masonry arch culverts, piers and abutments, on Canadian railways which might be of interest by way of comparison, but in order to attain this purpose it will be necessary to deal with this division of the work apart from the present paper.

The principal object the writer had in view in preparing this paper, was to deal with the subject in a manner to be of interest to the younger members of the profession who, perchance, may have to engage in similar work. Exchange of ideas, not necessarily new, in the arrangement and performance of works of this description may frequently be productive of much benefit. Though much remains to be accomplished by the engineer in converting the desert and the tropical swamp into a habitation for civilised races, yet public attention has also been directed to the vast wealth lying for ages underneath the perpetual snows of our northern latitudes. To this region in future, no doubt, will the attention of the engineer be directed in solving the problems by which these regions may be made habitable and brought within the easy reach of man.

In conclusion, the writer desires to express his indebtedness to Mr P. A. Paterson, chief engineer, and other members of the engineering staff, for opportunities by which he was enabled to

collect material for this paper, also his appreciation of the interest evinced on all occasions by these gentlemen in matters that tend to promote a more universal desire for interchange of ideas and closer fellowship between kindred societies, as well as between individual members of the same society.

Discussion.

The discussion on this paper took place on 23rd April, 1901.

Mr C. P. HOGG (Member) said the subject matter of Mr MacGregor's paper was not one which came to any great extent within the practice of engineers in this country. Nevertheless, there were several interesting points which were worthy of careful study, more especially to the younger members who might have to go abroad. On page 162 Mr MacGregor emphasised the importance of careful location, and that, of course, was common to all countries, but he would like to know the best method which had been adopted for such a great length of line where a comparatively free hand was allowed. He also noticed that on page 164 Mr MacGregor laid particular stress on the importance of keeping up the formation level. That was of very great importance in connection with drainage. The feature of the paper was the timber work in the trestle bridges. Figures 20, 21, and 22 illustrated very good examples of carpentry work, and somewhat common to the kind of work done in this country, but he noticed, particularly in Fig. 22, a point which he did not think he had ever seen in this country. Where the piles were of a sufficient height, the outer piles were driven to a batter of 1 in 12 in the ground, and then "sprung" above the ground to a batter of 1 in 6. He thought that that was a very good method for keeping the work well braced together. Good examples of carpentry work were also shown in Figs. 15, 16, and 17. At first sight, the diagonal bracing in Fig. 16 seemed to be defective, though it might not be so in practice. The longitudinal timbers might be sufficient, but, looking at it just as one sees it in the diagram, he thought it was somewhat deficient in diagonal bracing, although Mr MacGregor claimed it to be a feature in the design. "One feature of this design," he said, "which is, no doubt, a commendable one, is the absence of the usual elaborate system of longitudinal bracing and the additional stiffness obtained from the arrangement of the horizontal longitudinal girts." In regard to the prices which Mr MacGregor quoted for the timber work, he referred to a standard of 1000 feet B.M. He took it that that was the American Board measure, the standard thickness of which, he understood, was 1 inch, so that that would give about 83 cubic feet for 20 dollars, or rather under 1s per cubic foot, which was a very moderate price, and not half, probably, what one would require to pay in this country. Mr MacGregor referred to the price of trestle work 20 feet high as being 25s per lineal foot. He supposed that that meant per lineal foot of single line railway, but he would like to ask Mr MacGregor if that was so.

The PRESIDENT said he understood Mr MacGregor was in Canada, and that Mr Hogg would get an answer to his query by correspondence. He had much pleasure in moving a hearty vote of thanks to Mr MacGregor for his very interesting paper. He thought they ought to apologise to him for the fact that the discussion had been postponed as it had been. They were all aware, however, that in the particularly sad circumstances of this winter their discussions had been to a great extent upset, and perhaps more upset than they would otherwise have been on account of the very exceptional interest in one paper, the discussion on which was now under way. He did not need to say anything further on the subject, except to move a very hearty vote of thanks to Mr MacGregor for his excellent paper.

The motion was carried by acclamation.

Correspondence.

Mr MACGREGOR, in reply to Mr Hogg, stated that he was somewhat surprised to learn that a similar class of work to Figs. 20, 21, and 22, was being done at home. With regard to the efficiency—or rather apparent deficiency—of this diagonal bracing

Mr MacGregor.

in Fig. 16 referred to, he was inclined to think that the question raised by Mr Hogg was rather an important one. In theory it would seem erroneous to state that stiffness would result from any arrangement of members in a structure which did not assume a purely triangular form. The arrangement of the longitudinals in this case, however, had many advantages over many other designs, and particularly where the bents were connected by 4″ x 12″ "running boards" placed flatwise. When placed on edge, overlapped, and well drift-bolted, the resistance to longitudinal motion had been found in practice to be very considerable. In some cases the diagonals were omitted altogether where there were no embankments, and the ends of the trestle butted against the natural slope. The risk, however, of building long trestles without diagonal bracing was found to be too great, on account of their liability to collapse during erection by wind storms, as, indeed, happened in one particular case. The foot board measure referred to was the American standard, 1 inch thick, or 83⅓ cubic feet to the 1000 F.B.M. The trestlework figured at 25s per lineal foot was for single track. In conclusion, he would say that the same sad circumstances referred to by the President were more or less of a universal nature, and that, although he appreciated in no small degree the good intentions indicated, he sincerely felt that, under the circumstances, any apology for postponing the discussion on his paper was unnecessary. What he feared most was that the efforts of other members who had better claims might suffer from the same cause, and curtail the proceedings of what to his mind would otherwise have been a brilliant session. It so happened that he had chosen his subject at a time when very little was being done by the railway engineering Members, and he felt somewhat afraid that, even under the most favourable circumstances, the subject might be uninteresting. From his own experience, he might say that the efforts of members engaged in engineering works abroad were pretty much handicapped for lack of opportunity, but, nevertheless, it was gratifying to observe that communications from this wide field of engineering were generally well received.