INSTITUTION

OF

ENGINEERS IN SCOTLAND.

SESSION 1862-63.

THE FIRST MEETING of the Session was held in the Philosophical Society's Hall, Andersonian Buildings, George Street, Glasgow, on Wednesday, 29th October, 1862—WILLIAM JOHNSTONE, Esq., President, in the Chair.

Four new members and two graduates were proposed.

Mr. JOHN M'ANDREW, Glasgow, was duly elected a member of the Institution.

The SECRETARY announced that the following Donations had been received during the recess; and the thanks of the Institution were voted for them:—

"Results of Experimental Inquiry into the Comparative Tensile Strength and other Properties of various kinds of Wrought-iron and Steel." By Mr. David Kirkaldy. From the Author.

"Proceedings of the Scottish Shipbuilders' Association," 30th May, 1862. Also, copy of Mr. Kirkaldy's Treatise noted above. From the Association.

"Proceedings of the Institution of Mechanical Engineers," 30th January and 24th April, 1862. From the Institution.

"Ueber die Anwendung des Satzes von der Acquivalenz der Verwandlungen auf die innere Arbeit." By R. Clausius. From the Author.

"Notices sur les Modèles, Cartes, et Dessins relatifs aux Travaux Publics, exposés à Londres en 1862." From the French Department of Agriculture, Commerce, and Public Works.

"Memorias da Academia Real das Sciencias de Lisboa," 7 vols. 4to. From the Academy.

The President delivered the following Introductory Address:—

GENTLEMEN,—As is usual at the opening of the session, I shall very briefly address to you a few remarks; and, in the first place, I would simply refer to the many important and valuable papers that were read

last Session, and the discussions which followed thereon. The whole treated upon subjects of the most useful and practical description, and much important information was elicited by them, the volume forming one of the most complete we have yet had since the commencement of the Institution. Some of the subjects were in continuation of papers read during the previous Session, to which I made reference when I formerly addressed you. As, however, the papers are to be specially considered by the members of the Institution, with the view of giving an expression of opinion on their merits, I will refrain from entering into detail upon them. I may here remark that I regret that our civil engineers should contribute so few papers to the Institution. The immense variety of constructions which are constantly going forward connected with railways, harbours, and canals, at home and abroad, furnish an ample supply of subjects for description and illustration; and I trust that in this and in future Sessions, these, and the various points connected with the efficient and economical working and maintenance of such undertakings, may be brought forward more frequently and more prominently than they hitherto have been.

I purpose on the present occasion to give a short outline of, and make reference to some engineering works that have come under my observation since last I had the pleasure of addressing you, and put you in possession of some details connected therewith, which were kindly furnished me by the engineer in charge of the works. The first of these I shall notice is the Charing Cross Bridge, now in course of construction. It is intended to carry the South Eastern Railway across the Thames to their west end terminus at Hungerford Market, and is to occupy the site of the present suspension bridge, which no doubt most of you have seen and admired as one of the late Mr. Brunel's early works.

The Thames at this particular place is about 1340 ft. wide, and was crossed by Mr. Brunel in three spans, the centre opening being 646 ft. This foot bridge is now being removed and a more substantial structure substituted, to meet the requirements of the railway.

Mr. Hawkshaw, the engineer of the new bridge, divides the openings (on the Surrey side) of Brunel's bridge into spans of 154 ft. each, by means of cylinders placed in pairs at three intervals; the two masonry piers of the suspension bridge, each 34 ft. wide, being allowed to remain to form a portion of the new structure. Future generations may be somewhat perplexed to account for these "breaks," and naturally say, Why were not cylinders used there also? This simple reflection, however, would not have justified the expense of their removal; and, at all events, knowing the circumstances, we may safely exonerate the engineer from what might otherwise have appeared to be a piece of engineering eccentricity.

The principle of construction of the main girders of this bridge, though

not absolutely new, has never, that I am aware of, been applied on such a large scale. I believe the same engineer is constructing one very similar at Londonderry, combining a carriage way on the top, which will shortly be opened for traffic.

I am aware it is not usual in an address of this kind to enter minutely into the details of any engineering work, however important; my duty being simply in a general way to notice such things, and express a hope that papers on similar works might come before the Institution in the usual and more convenient way. However, as we cannot always get English engineers to give us papers on their works when we wish it, I am tempted in this case to depart from the usual rule, and beg the attention of the meeting to a general description of this work.

The pair of cylinders forming the intermediate pier are distant from each other 49 ft. and are somewhat bottle-shaped in appearance. The portion of each sunk below the bed of the river is 14 ft. in diameter, cast in seven segments in lengths of 9 ft., the flanges meeting and bolted together inside. The portion from the shoulder to the bottom of the main girder is 10 ft. in diameter, cast in seven segments in 9 ft. lengths, the flanges being also bolted inside; the thickness of the metal throughout being about $1\frac{1}{8}$ in. In most cases these cylinders have been sunk 40 ft. into the bed of the river, to prevent the possibility of any lateral motion, or of their bottoms being disturbed by any subsequent deepening of the river.

When completed, the lower portion up to the shoulder is filled with concrete, made with cement. Brickwork, set in Lias lime, is then used, the whole being surmounted by two semicircular blocks of granite 2 ft. 6 in. thick, cut to fit the cylinders, and when bedded projecting an inch or two above it, so as to keep the bottom of the malleable iron girder from resting on the casting. Both cylinders are joined together at the top by a cross girder, so as to guard against the barest possibility of any swinging taking place. Each cylinder is tested to the extent of 450 tons.

As already stated these cylinders are 49 ft. apart, and as the main girders rest directly upon them, it follows that that width represents the distance from centre to centre of each girder, and affords space for four lines of way. These main girders each weigh 190 tons, and when tested to 400 tons, showed a deflection of $1\frac{1}{8}$ in.

The ends of the girders resting on the cylinders are composed of plates formed into rigid rectangular columns the same height as the girder, viz., 14 ft., 5 ft. on the face and 3 ft. broad. The boxes or troughs forming the top and bottom of the girder are of that breadth, and of course spring from those ends. The upper one being inverted, its bottom forms the top of the girder, and, unlike the bottom of the lower trough, projects beyond the sides some 6 in., and being in compression requires more metal in it; in

the middle it consists of six plates, 5 of them $\frac{5}{8}$ in. thick and one $\frac{11}{16}$ in. thick, breaking joint and gradually diminishing towards the ends to two—one $\frac{11}{16}$ in., the other $\frac{5}{8}$ in. thick. The bottom of the lower trough is flush with the sides, and has five $\frac{5}{8}$ in. plates in the centre and two $\frac{5}{8}$ in. plates at the ends. The staging was made to admit of the simultaneous construction of these troughs; they are with the above exception precisely the same, each being 2 ft. deep inside and 3 ft. broad; each side is composed of 2 plates $\frac{5}{8}$ in. thick, with 2 covering plates at pin holes, each 1 in. thick; these pin holes occur at intervals of 11 ft., and number 15 in each span; four of the diagonals meet inside the troughs at those places; and 2 webs of the same thickness as the sides fastened to the bottom by angle irons $6 \times 6 \times 1$, give additional bearing to the pins, and prevent the diagonals from sliding on them. The diameters of the pins vary with the strain, from 9 in. at the ends to $5\frac{1}{2}$ in. in the middle of the girder.

The diagonals at the ends are about 15 ft. 6 in. by 12 in., and 3 in. thick; in the middle the breadth and thickness is about 6 in. and 2 in. respectively. Those in compression are forged to the required thickness, and strongly stiffened; those in tension are made up of two or three pieces of an inch in thickness, according to strain, like the links of a suspension bridges. The cross lattice girders carrying the four lines of way, and projecting beyond the main girders, support a foot-way 7 ft. wide on either side, and are suspended to the main girders by four strong angle irons immediately under each pin, and consequently occurring at 11 ft. intervals. There is nothing very special in their construction to require further notice. The weight of each, I understand, is about 9 tons.

The bridge, when completed, will consist of six spans of 154 ft. each, and three in the Middlesex side of 100 ft. each; and the bridge is to be widened on that side to 171 ft., so as to admit of seven lines of rails and platforms into the station. The radiating outside girders over these three openings remain the same in appearance as those of the rest of the bridge, to afford a continuous sky line; they have, however, very little work to do, and are consequently much more slender in construction; they rest on cylinders 8 ft. in diameter. The railway is no longer carried on cross girders, longitudinal ones placed on cylinders 6 ft. diameter, sunk at short intervals between the 8 ft. outside ones, being substituted. These girders are single-web, and strongly made, their depth being limited to 5 ft. for 100 ft. span, to afford 25 ft. headway above Trinity high-water mark, and are all under the level of the planking, so as not to interfere with the points and crossings of the lines of way to the platforms. The depth of the Thames at the site of the bridge, at low water of spring-tide, is 11 ft.

Rise of tide, ...	17 ft. 6 in.
Level of rails above Trinity high-water, . .	31 ft. 0 in.

The work is now more than three parts finished, and is perhaps the finest piece of work of the kind in the world. It is difficult to ascertain the cost of such a work. I believe, however, that £26 a ton for the wrought, and £16 10s. a ton for the cast-iron, will not be far from the mark; 30s. a foot might also be taken as a pretty near approximation for sinking the cylinders.

I shall now proceed to lay before you some particulars of the Middle Level deluge—which caused so much excitement in the early part of this year—and the means resorted to by the engineers to stop it. Unless one has travelled in those districts of England known as the Fens, and forming large patches in the counties of Lincoln, Norfolk, Cambridge, and Huntingdon, he can scarcely realize the fact that thousands of families live and move, and quietly follow their farming operations, on a level only some two or three feet above low-water mark. Every ploughman becomes an engineer deeply skilled in wattling, puddling, and embanking; and farmers show wonderful skill in the arrangement of their drains, which cut up and interlace their farms, until the water reaches the main drain at a convenient place, to be there pumped up and pounded, until the ebbing tide in the river, often many miles distant, allows it to pass to the sea. The early Dutch engineers, brought over by James I. of England, divided those immense tracts into levels or confederations, each getting peculiar privileges granted them by parliament, with power to levy rates on the acreage benefited by their main drains and outfalls, for their construction and maintenance.

The Middle Level is one of those, consisting of 140,000 acres, extending nearly to Peterborough, and cut from off the sea-board by a belt of intermediate fens eight miles wide, under separate commissions, each maintaining, by their own taxation, independent drains and outfalls. The only thing common to all is the river Ouse, into which they all in that quarter drain, each commission subscribing to a general purse for the maintenance of its banks. This river rises in Bedfordshire, pursues a north-easterly and very tortuous course, receiving contributions from the Cam and other rivers as it passes through Cambridgeshire, and reaches the sea through the Norfolk estuary, a few miles below Lynn.

It is tidal for many miles into the interior, which during floods hinders the free passage of the water to the sea, and often prevents the gates of the inland main drains being opened for several days together.

The original outfall of the Middle Level waters into this river was, on account of the intermediate fens already mentioned, placed some fifteen miles from the sea, and was particularly subject to irregularity of action. The commissioners consulted the late Mr. James Walker, an engineer who was eminent for his skill in hydraulic works. [Since the preparation of

the present remarks the rather sudden death of Mr. James Walker has been announced. This event must be deeply regretted by the entire profession on account of Mr. Walker's very high standing as a civil engineer; but it must be the more felt amongst us on account of his long connection with this locality, and from his being an honorary member of this Institution.] Mr. Walker advised the entire removal of the outfall sluice nine miles further down the river, and that parliamentary powers should be sought to make a main drain across the intermediate fens to it. This accordingly done, and, after encountering a severe parliamentary contest, the act was obtained.

The sluice consisted of three 20 ft. openings, the sills being 6 ft. below low water of spring tide; strong pointed gates opening outwards prevented the ingress of the tide so soon as the level of the water in the river exceeded that in the drain. The drain, which is perfectly straight, is on an average 130 ft. wide; and its bottom, for the eight miles across this district, is 7 ft. below low water. The level of the adjoining lands being only 3 ft. 6 in. above low-water for a length of six miles out of the eight, really gave good grounds for objecting to such a dangerous element being carried out on such a large scale through their very midst. But what they most dreaded was an accumulation of upland or fresh water in the drain during floods, more than could be discharged in the interval of low water, the pressure of which on banks, however carefully constructed originally, might, by negligence in maintenance, become unfit to meet all exigencies. On that ground they opposed the bill, and obtained protective clauses; but it does not seem to have occurred to them that any failure could ever take place in the outfall sluice, and it will be for the courts of law to decide whether those clauses do not altogether exclude the sufferers from any compensation whatever for the damage done by the sea. This is mentioned for two reasons—first, to point out that the land inundated was not the Middle Level at all, but the intermediate districts; and secondly, to be excused from giving, directly or otherwise, any opinion as to the sufficiency or insufficiency of the works which for eighteen years stood well, and almost convinced the most timid opponents that their former fears were groundless. Everybody admitted the drain and outfall sluices, from their magnitude and apparent efficiency, taken as a whole, to be a masterly piece of engineering.

To the Middle Level the boon was incalculable, and far more than realized the most sanguine expectations of its immense population. Pumping engines in many districts were abandoned, and land which was worthless during the old state of drainage soon brought upwards of £50 an acre.

On the 4th May this year Mr. Walker's grand sluice, without much

previous symptom of decay, fell in pieces, as if rent by an earthquake; and the tidal waters of the Ouse rushed with indescribable fury up to the drain, until at the end of the eight miles they were checked by the barrier sluice on the frontier of the Middle Level district. The drain for this distance became a sort of creek; and had its banks been strong enough to have resisted until a dam could have been made across the mouth, no inundation to the adjoining country would have taken place. This state of things lasted for a week, several minor breaches in the banks being successfully stopped at every tide, until at last the west bank gave way at a point situate four miles up, and a tide 14 ft. higher than the land rushed over the devoted country, then beaming with most luxuriant crops. The land being all of the same level, was not for a few tides covered to any depth, consequently the farmers were able to escape with their lives and also to secure their cattle. All attempts to stop the breach were perfectly futile, owing to the rush of water back to the drain again during low water. This altered state of things had also a wonderful effect on the dam the farmers were trying to put across the mouth. The twenty-four barges, varying in size from 30 to 80 tons each, which had been loaded and sunk in the yawning chasm to form a base for some thousands sacks of clay to be built on at low water, were speedily separated and turned over; and nothing that could be sunk or thrown into the torrent would for a moment remain.

By the late Mr. Walker's recommendation, Mr. Hawkshaw visited the scene of disaster to see what could be done; and he at once gave orders to give up all attempts to stop the breach in the bank of the drain, which by this time was about 100 yards wide, because, if successful, the chances were that the opposite bank would give way, and do still greater damage to the lands on the other side. He also abandoned the idea of constructing the dam at the mouth, most of which had now been carried to sea, as, in addition to the sacks of clay and other make-shift material which were being thrown in, he wished to drive a few piles; so, taking advantage of a timber bridge of three openings across the drain near the mouth, he had all the pile engines that could be found in the neighbourhood placed on it, and set to work; nothing was to be put in until the piles were driven on either side of the bridge, and strongly braced together; the planking was then to be taken up, and the prepared material dashed in. Matters were so arranged that much progress was made in the course of two days with the driving of the piles; but during the progress of this work, up turns one of the huge 80-ton barges (which was supposed to have followed its companions out to sea), and dashing against the row of newly-driven piles, snapped them right through, and carried away the entire bridge as well as the piling engines and necessary appliances—the men only escaping

with their lives. Two other occupation bridges shared a similar fate, but a bridge carrying a turnpike road resisted sufficiently to afford time to secure it. This was a most unfortunate accident, as great difficulty was experienced in getting a supply of pile engines in the neighbourhood.

Now was the time for the Dutch engineer, who, with Mr. Hawkshaw's consent, had been sent down to try what could be done by sinking cradles, for such was the excitement generally throughout the country, and the imminent peril of the surrounding district, that Mr. Hawkshaw, seeing the time which must necessarily elapse before the destroyed plant could be replaced, and a dam such as he deemed necessary could be constructed, felt he would not be justified in offering any opposition; but, on the contrary, he heartily supported him. In the meantime, a few tidal and other observations established some facts that set all minds at ease, and went a great way in discountenancing the Dutch mode of procedure. *First*, The land inundated extended six miles along the west side of the drain, and was two miles broad at the widest place. On an average the water was 5 feet deep over all, being luckily confined to that area and depth by the existence of two roads which stood about 1 ft. 6 in. above that level, and surrounded it for many miles; and *Second*, The tidal observations showed that the tide affected the level of the vast lake to an extent of only 6 inches; so long, therefore, as the level of the roads held good, no further damage could arise by the free admission of the tide. The Dutchman, failing in the first attempt, was preparing a second cradle, when it became a very serious question whether he would not, by pounding up a certain quantity of water every successive layer of cradles he sunk (for to stop it in a few tides was not to be hoped for) gradually, but undoubtedly, raise the level of the water from 9 ft., at which it stood until, in the course of time, it would approach the height of 18 ft., which was the mark the same tide made at the dam. Where then would be the 1 ft. 6 in. we had to come and go on? His operation was, therefore, after due deliberation, stopped.

The difference of level of the water in the fen from that in the Ouse arose from the tidal current having to pass four miles through the drain before entering the inundated land; and from the extent of area inundated being no less than twelve square miles, it only affected the height of the water in the fen to the extent of 6 in., as afterwards explained.

Before giving a description of Mr. Hawkshaw's dam, I may state some of the difficulties he had to contend with—Firstly, The high water in the inundated fen, as compared to the same water in the Ouse, was as 9 ft. to 18 ft., and the tide rose and fell in the fen 6 in. Nothing approaching low water in the river could ever therefore be obtained in the drain. The only interval of repose, or what might be called slack water, was

when the tide outside attained the height of 8 ft. 6 in. or level of the low water in the fen. Ten minutes time was sufficient to send a gentle current inwards, which increased in velocity every minute afterwards until high water; but the high water in the river being 9 ft. higher than in the fen, no still water was again obtained until the tide had receded in the river to that level; it then rushed out like a mill stream until the tide rose to 8 ft. 6 in. again. Secondly, The bed of the drain being 7 ft. below low water mark, it followed that, at the time of slack water, when any work could be done at all, the depth of water in the drain was 15 ft. 6 in.; this was increased some 2 ft. more, notwithstanding all efforts to maintain the bottom. The drain a short distance inside the site of the dam was ultimately deepened to 17 ft. for a distance of 20 chains. Great caution was, therefore, necessary in any attempt to contract the sectional area.

The first thing to be done was to construct across the drain a strong stage 30 ft. wide, resting on screw timber piling, which was projected into the current—the capstans on the piles being turned by ropes from the shore. Close piling on each side of this staging was then commenced, and continued from each shore until a clear space of 90 ft. in the centre remained, it being considered imprudent to carry it further. This space was divided into twelve openings, by driving twin piles on each side of the stage opposite to each other, at 7 ft. 6 in. intervals. Great care was necessary in pitching those piles, and it could only be done during the short time of slack water. Each pile was 14 in. square, and separated from its fellow by the first one having a thin piece fixed to its outer face, against which the second was driven, thus forming two grooves, 8½ in. wide, for the panels, which were intended to be dropped into the openings, to slide in. Strong waling pieces of whole timber inside and out of each row at top, and as low as the water would admit of at the bottom, kept the whole in gauge, and the transverse timbers and iron bracings communicated any outward pressure through the dam from one row to the other, the outside of the dam being staid to the side of the drain by double timbers, 60 ft. long, the ends abutting against piles backed by a mass of concrete. These struts were placed against the waling pieces at top and bottom, and stiffened by cross diagonals like a girder. The staging was left open at the top, to admit of material being tipped from the two lines of way, laid across the dam, and communicating with the prepared heaps of puddle and other material at convenient places up and down the drain on both sides. Two outside stages, one on either side of the dam, and supported by cantilevers from the twin piles, admitted of almost any quantity of tipping from barrows, to make good any scour which the soundings taken at every slack might indicate. The rush of water through the dam thus far completed, was, both on the flood and ebb tide truly alarming; the simple

introduction of those piles and bottom walings causing a difference of head level of nearly 5 feet. In the midst of this roaring cataract, this framework and the dam stood without the slightest vibration being felt. It was daily visited by thousands who, though reserving to themselves the right of grumbling at what they did not understand, could not but admit it to be the only way of meeting the difficulty.

The greatest and most anxious care was now necessary to preserve the bottom of the drain from the scouring action of such a weight of water passing over it at the rate of 10 ft. a second. Tons of broken stone were tipped from the outer stages and thrown overboard from barges, to form aprons on either side. But, except as a last resource, no stone was to be thrown into the centre of the dam, lest it should prevent it afterwards from being made perfectly water-tight. The long panels composed of timber 8 in. thick, not framed, but merely built one above the other, and held together by three long bolts and heavy iron straps, made them quite rigid, and no difficulty was experienced in driving them. They were made with a sharp edge, and dollied down until their top was level with the bottom of the drain, or nearly so, and backed well outside with stone. Great quantities of puddle were tipped into the dam at every slack water; not with any hope of its remaining, but simply to feed the cancer—if I may so express it—and thereby allow less time for the dreadful current to act on the bottom. This was all the more necessary, for the piles on an average could only be driven 14 ft. into the ground. All attempts to exceed that depth resulted in fracture. No doubt a bed of gravel existed at that depth, totally different in character from the coarse silt and alluvial deposit resting on it, and now so anxiously maintained.

The first attempt at closing the dam resulted in failure from the fracture of two of the twin or gauge piles, which doubtless were injured in the vain attempt to get them deeper into the bottom. No blowing, however, occurred, and the panels when liberated were carried off. The greatest apprehension existed until the return of slack water, when the divers reported no damage, the lower panel, driven into the ground, preventing any cutting of the bottom. In consequence of the failure all the other panels down to low water were drawn, to allow free access to the tide, until the piles could be replaced. This was accordingly done, and a week elapsed in making good the damage and otherwise preparing to meet other contingencies, of which experience was daily pointing out the possibility. All was now ready; the panels were again swung in the gallows frames, ready to be dropped at slack water on the ebb. They were all lowered into their places in twenty minutes, material was then tipped in with great rapidity by the waggons, and the outsides

weighted from the barrow stages. All was most successful; a little blowing took place where the stumps of the fractured piles interfered with the proper fitting of the panels in those places. However, by throwing a great quantity of hay, and piling a great quantity of clay bags on each side, it was checked until sufficient puddle was tipped into the centre. This was accomplished in twenty-four hours, and set so completely that not a drop escaped through. The tides no more went up the drain, but ebbed and flowed outside with a stillness which, when compared with the previous day, partook of that oppressive character experienced near a mill, or in the midst of going machinery suddenly stopped. Syphons 3 ft. 6 in. in diameter were then placed over the dam to relieve the Middle Level from the surplus water that would not find its way to the Ouse, through the old outfall, which for the present was again resorted to. Many thought they would not act. No good reason, however, could be urged against them, and all admitted that it was proper to make the experiment. These syphons have been finished and recently opened, and all found to do their work very well indeed. Their bottom level where they pass over the dam is 18 ft. above low water, and the bottom of the mouths 6 ft. under low water. In spring tides, high water rises 20 ft. These operations have succeeded in relieving the Middle Level of water, and it will be a great boon to the whole of that district.

I trust that, while some of the members may consider the description and details of these important works uninteresting, others will be benefited by them, and be led thereby to see the necessity of perseverance, so as to overcome unforeseen difficulties that may be expected to arise during the progress of such works.

I have already referred to the desirability of more papers on civil engineering being brought before the Institution. It may be that the members who carry out the works which would form the subject of such papers, have not time for their preparation. But the younger members may take up any great work either in progress, or which has been completed, but not yet publicly described; and in doing so they need not limit themselves to works in this country. The rapid extension of railways on the Continent and in India is constantly giving rise to the necessity of constructing works of great magnitude; there are mountain ridges to be cut through, and ravines and rivers to be crossed of much greater magnitude than anything with us. In executing such works, the engineers in charge of them have the benefit of our experience. Few of us have an opportunity of inspecting these works in detail, either when in progress or by going over their plans. But I have no doubt that some of our members have the means of giving a professional account of many of these works which, if brought before this Institution, would be most instructive

and interesting. For instance, there are the Victoria bridge at Montreal, the various railway bridges over the Rhine at Cologne, Mayence, and Strasbourg, as well as others of similar construction across Indian rivers—all works of great difficulty and magnitude, and involving many novelties in construction which would each furnish a valuable subject for a paper. All these works are of wrought-iron, with arches of great span across wide and navigable rivers subject to great variations of level; and both in the general design and construction, they offer important lessons to the engineer. The Victoria bridge is a tubular one, and all the others are lattice bridges. Should the details of such works be brought before us, I would suggest that a careful comparison of the advantages, the difficulties, and the cost of the two systems of construction should be made, which I have little doubt would show that the lattice bridge is by far the better and the cheaper of the two. In these lattice bridges over the Rhine we have examples of the largest description of swing bridges yet constructed; and altogether, for elegance of design, excellence of workmanship, and economy in cost, I believe them to be unrivalled among recent railway structures. Those at Strasbourg and Cologne are completed, and the one at Mayence is now in progress. The first consists of three central arches, each 184 ft. span, and of two side swinging arches 85 ft. span. The central piers are finished with handsome and effective Gothic spires, and the general appearance of the whole is most satisfactory. Its total cost was about £280,000. The bridge at Cologne is much larger, and embraces a railway and roadway alongside of each other, the cost being, I believe, somewhere about £500,000.

In carrying out the Swiss system of railways, ample opportunity has been afforded for the exercise of great engineering skill and ingenuity, of which full advantage has been taken. These must strike the eye of the professional tourist, even during the hasty run which is now taken by many among the Alps in summer; and there are two lines now in progress, which, when completed, will present works of a much more striking character than anything now in operation: these are the lines from Geneva to Turin by Mont Cenis, and from Martigny to Milan by the Simplon Pass. The first is now certain to be carried out, and its great and important feature will be the tunnel through Mont Cenis, which will be about eight miles long, and above 6000 ft. beneath the crest of the mountain. Of course, at such a depth intermediate shafts cannot be resorted to, so that the whole excavation must be carried on from either end. This very greatly increases the difficulties of the work; and these difficulties, coupled with the constructive skill necessary to be displayed in overcoming them, are such that the completion of the tunnel will be regarded as an epoch in rock excavation. The cost will be somewhat

enormous, and would have been insurmountable had it not been for the assistance given by the French and Italian governments.

The other line over the Simplon will have a higher summit level than that across Mont Cenis. Many points connected with its construction have not yet been determined, such as the level and length of tunnelling at the summit. When completed, it must embrace many works of striking magnitude and novelty, which will completely eclipse those of Napoleon's famous road, so long the admiration of Europe.

These railways will be of immense value to the countries they connect, more especially to Italy, which has suffered so much and so long from its commercial isolation from the rest of Europe; and I need not point out how valuable it will be to the profession, to have full and exact details of the most novel and striking of these works. In obtaining these, any one of our members can easily have the advantage of personal inspection of the works, should he find this necessary for an accurate description. Not so, however, with respect to those great works in India or America. At the same time many of these are made with English capital and by English engineers; and where this is the case there will be no difficulty in obtaining access to the plans. Some of the iron bridges have indeed been made in this country, and these now form the largest and most interesting of recent railway structures; so that the difficulty of obtaining the necessary details is not so great as may at first be supposed.

The railways in our American colonies, though invaluable to the districts through which they pass, have hitherto been unremunerative. This result has to a large extent been caused by inattention to economy in construction, and, as many believe, by disgraceful jobbing in financial matters. Notwithstanding these drawbacks, I have no doubt but the rapid progress of these colonies in material prosperity will soon furnish traffic to make the present lines profitable undertakings. By that time the colonies on the western shores will also be far advanced in commercial importance, so that we look forward at no distant date to an extension of the Grand Trunk of Canada across the Rocky Mountains to British Columbia. Such an undertaking will necessitate the construction of works of magnitude equal to, if not greater than those already completed. Its effect on the development of the resources of the vast territory which it will traverse, will be invaluable. The result, therefore, will be equally great in a professional and national point of view, and may claim the attention alike of the engineer and the statesman.

The great question of cotton supply renders the rapid extension of railway transit in India a matter of the most pressing and immediate importance. Invaluable time has already been lost in endless discussion of detail by parties who were entirely unfitted for such work; and it is

to be hoped that now when a beginning has been made, Indian railways, will be pressed on with all practicable speed. It has been a matter of bitter reproach against England by Burke, and by all who have followed him in challenging our Indian policy, that we have done so much in conquering the natives and in enriching ourselves, and so little in opening out the material resources of that magnificent country. Our greatest boast has been our advancement in the arts, in mechanics, and engineering, and more especially in all processes connected with improvements of land transit; yet during the century of our sway in India we have allowed the great works of artificial navigation made by former engineers to fall into decay, and have been contented to carry on intercourse in one of the richest and most populous countries in the world by bullock tracks like those described by Livingstone as being used by the African savages among whom he travelled.

We have now entered upon a different policy. Trunk roads and trunk railways have been traced out, and partially constructed between the capitals of the various Indian provinces. We have commenced to improve the river navigation, and to place steamers on all the larger streams. The old tanks and canals for irrigation have been repaired, improved, and greatly extended; and if this course be persevered in, we may expect to see the whole country opened up in a short time by works which will make internal transit there as cheap and efficient as it is with us, and which will form the most striking monument yet raised to the power and magnificence of Great Britain. I need not point out what a large field of engineering employment the construction of these works will open up, nor the necessity of smoothing away the difficulties which their construction will give rise to, by a full discussion of them at institutions such as this.

I alluded in my address of last year to the prospects of the Great International Exhibition, and to the part which we expected the industry of the west of Scotland to occupy, and I am glad to be able to congratulate the members that our expectations in these respects have been fully realized.

The Exhibition, almost in every respect, exceeded that of 1851 as regards number, variety, and importance of the articles brought forward; and Great Britain, on the whole, has had reason to be proud of the position she has occupied in the grand industrial tournament to which she had challenged the world. In the production of metals, chemicals, glass, and earthenware, and of all ordinary woven fabrics, we have undoubtedly distanced all competitors, with some very few exceptions.

In the case of machinery, the department more peculiarly interesting to engineers, it may be said without exaggeration that we have been first. There certainly is no comparison between our locomotives, our marine

and land engines, our spinning and weaving machinery, our sugar-mills, and our tool-making machinery and those exhibited by our rivals; and it must have given great satisfaction to all of us to see the honourable position occupied by many of our own members who are exhibitors in these classes.

Among the few exceptions I have referred to, I may mention railway carriages and their fittings, cast-steel forgings, and some of the unusual forms of rolled iron. It has long been matter of common remark, that the carriages of foreign railways were better and more comfortable than those of a similar class with us. This may be partly explained by the large proportion of old and badly-constructed stock still kept up by many companies in this country. But even allowing this, I am afraid it must be admitted that foreign stock of railways is fully superior to our own; and there can be no doubt that the best foreign carriages exhibited were fully equal, if not superior to those of English make. Many reasons have been assigned for this, but they may all be resolved into the simple fact that our foreign rivals have paid more attention than we have done to the proportions and quality of the fittings and to the excellence of the workmanship in every minute particular. It is impossible to overestimate the importance of attention to these points, not only as regards the comfort of passengers, but also as regards the question of economical working. Repairs and renewal of rolling stock form a very large portion of the working expenses of a railway; and to use stock after it becomes ripe for renewal is not only severe upon itself, but is equally injurious to the permanent way. The rail and the wheel are, in the words of Stephenson, "man and wife," and you cannot injure or depreciate the one, without doing corresponding damage to the other. This great truth is now fully recognized in railway management, and is shown by the increased attention which is being paid to the improvement of rolling stock and of the permanent way; and I hope that such attention, coupled with the natural decay of old and objectionable rolling stock and its renewal, will soon enable us to surpass all continental railways in these all-important matters.

It must have struck every one that foreign carriage fittings in iron, more especially those from France, were also fully equal to ours. They were certainly lighter and very well made; and I was surprised at being informed that they were actually cheaper than with us, being only on an average 2½d. per lb. This is a somewhat astonishing result, if we consider that the raw material is 25 to 40 per cent. dearer in France than in Britain. We have almost all the materials for iron-making—the ore, the coal, and the lime, lying in close juxtaposition, so that with us the cost of raw material is very small indeed. But in France they are widely separated, and the extra cost of carriage, compared to what it is with us,

raises the price of pig-iron from 60s. to 90s., and of bar-iron from 130s. to 170s. per ton. It is very much to the credit of the French manufacturers that they can, in the face of this great difference against them, produce iron work of first-class quality as cheaply as in Britain.

They also produce angle iron, T-iron, and I-iron of extra sizes for smaller extra charges than those made by our makers; and they have carried the manufacture of these extra sizes and forms much farther than we have done; and I understand it is the case that many of these sizes and forms must be ordered by our Glasgow iron merchants from French and Belgian makers, and the prices are so low that I-beams, 12 in. deep, cost only £12 10s., and when 2 ft. deep, £20 per ton. There is no doubt that the advantages we possess for ordinary sizes and qualities, with proper skill and attention, ought to be carried into every branch of the manufacture. Were this done our foreign trade would be greatly extended, and the use of iron would be adopted to a larger extent in many kinds of industry.

A good deal of the uncertainty attendant on the introduction of iron-making arises from the obscurity which still surrounds many of the chemical changes that take place in its various stages. This obscurity can only be removed by accurate experiments on a large scale. These could easily be conducted by many of our members who are connected with the manufacture; and such a series of experiments, besides being of great value to the makers, would furnish the subject of many excellent papers, which I hope to see brought before the Institution.

In concluding these remarks, I have much pleasure in being able to congratulate the members on the increased and increasing prosperity of the Institution in every respect. Although, we however, had a considerable increase in the number of members last Session, we must not show any laxity in increasing the number with suitable members still more, so as to keep up our funds, which naturally will fall off, owing to the entry-money and yearly subscriptions having been recently reduced; and this is the more necessary as we will require to draw pretty heavily on these funds in the establishment of such a library as will be worthy of the Institution.

I refer with much satisfaction to the pleasant and agreeable meeting our last conversazione afforded the members and their friends; and much praise is due to our Secretary and the members of committee who were intrusted with the arrangements. I trust that the Institution may see proper to have a similar meeting at the close of the present Session, as I think such meetings have a tendency to create good feeling and harmony amongst the members of the Institution.

On the motion of Mr. R. Bruce Bell, a hearty vote of thanks was awarded to the President for his very interesting address.

Mr. Walter Macfarlane begged permission to offer a few remarks, suggested by the President's address. The members must feel deeply indebted to the President for bringing so fully before them the Railway Bridge and Terminus at Hungerford, which was to connect the railways on both sides of the Thames at Charing Cross. There was a probability of their soon seeing a scheme launched in Glasgow of a kindred sort—a general terminus in this city to connect all their railways. He could not but express his regret at the very disgraceful state in which Glasgow stood in regard to her railway termini; and it must be patent to them all that a large amount of money was unnecessarily spent from this cause. It had generally been held that the great obstacle to the success of a general terminus was its expense, which he did not think should be the case in such a city. Seeing that London, with the view of centralizing her various railway depots, had carried out such a scheme, he thought there would be no difficulty in this, the second city in the empire, following the example, and taking a position more creditable than it now occupied. The President's remarks were most suggestive, and a meeting such as the present was most valuable, as it gave a good opportunity for bringing their engineering opinions to bear upon a scheme before it was finally committed. Glasgow should look upon this matter in a broad aspect of view, and see the necessity for having railway accommodation commensurate with the increase and extent of the city. The Central Railway Terminus to which he had referred was very much akin to the Hungerford Market and Bridge scheme. Hungerford Market had only been established thirty years, and yet it was being removed at enormous expense; and if one or two railways at London could do this, he should be disappointed if Glasgow were not soon in a similar position.

The President endorsed all that Mr. Macfarlane had said. He was of opinion, that if it was found necessary to join the London railways, much more was that the case in Glasgow, for it would connect the leading lines in the west and south of Scotland with those of the north and east of Scotland. He knew a good deal about the scheme referred to, having been consulted in reference to it. He had seen Mr. Hemans the engineer, who had got ready the plans and a very fine model, which was exhibited in one of the booths at west end of Bothwell Street. He believed the chief difficulty was the want of money, but partly also the absence of co-operation on the part of the railway companies. However, he had no doubt that the scheme would come up soon, although it would not be proceeded with in the present session of parliament.