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OF

JOHN FOWLER, ESQ.

President

OF

THE INSTITUTION OF CIVIL ENGINEERS,

ON TAKING THE CHAIR, FOR THE FIRST TIME, AFTER HIS ELECTION,

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ADDRESS.

GENTLEMEN,

ON ASSUMING the chair of this Institution as its President, and undertaking for the first time its duties and responsibilities, allow me to assure you that I feel deeply the honor you have conferred upon me by electing me to this, the highest position to which the Civil Engineer can aspire; and that I feel still more deeply the weight of the duties which are inseparable from this honor. I will also venture earnestly to request you to extend to me your indulgence during my period of office, and afford me your kind co-operation in any efforts I may make for the advancement of our profession, or for increasing the usefulness of this Institution.

I ask this assistance from you with peculiar anxiety, because I cannot but feel that the present is a period of unusual importance to this Society, and that the rapidly increasing prominence of the profession demands at our hands a corresponding care for its efficiency and dignity.

The high degree of material prosperity which this country and its dependencies have now happily enjoyed for a considerable time, has naturally led to great activity in our profession; probably at no former period have the skill and enterprise of engineers been so severely taxed as during the last few years; and as civilization continues to advance, and labour to require increased assistance from mechanical contrivances, the connection of civil engineering with social progress will become more and more intimate.

I hope I may be allowed to say, however, with a deep feeling of professional pride, that hitherto the inventive genius, the patient perseverance, and indomitable energy of the members of our profession have not been found unequal to the tasks they have been called upon to perform ; and although I have full confidence in the future, I venture to suggest that the present is a fitting moment for considering the means by which our younger brethren may be best prepared for the arduous duties, and growing difficulties, which they will undoubtedly have to encounter in their professional career.

Competition by foreign engineers.

It is not merely that works of magnitude and novelty are increasing, and will continue to increase, but it is becoming apparent that we shall have to meet the competition of foreign engineers in many parts of the world, and that great efforts are now being made, not only by careful scholastic education, but by more attention to practice on works, to render the civil engineers of France, Germany, and America, formidable rivals to the engineers of this country.

Here it has always been found that friendly and honourable rivalry among members of the profession has been on the whole beneficial to science and to engineering progress, and we cannot doubt that the same result will follow the more extended rivalry which we shall have now to meet from the engineers of every nation. At the same time this consideration renders it our especial duty to take care, that the distinguished and leading position which has been so well maintained by our great predecessors, shall not be lowered by those who come after them.

Former addresses.

My predecessors in this chair have addressed you chiefly upon the interesting topics and works of their own time, and with so large a field demanding their attention, it was natural that they should devote themselves mainly to describe the past, and to indicate in outline the features of greatest interest in the present.

My immediate predecessor, Mr. McClean, gave to the Institution a description of the remarkable results which had been produced by the general introduction of railways into England in combination with steam power, and clearly pointed out their influence on the increase of its material prosperities and national wealth.

Mr. Hawkshaw pointed out the rapidly increasing importance of wrought-iron for engineering works, with the promise of new applications of steel ; and the fact and consequences of the increasing speed of railways and steam boats.

Mr. Bidder, after defining the object and scope of the profession of the civil engineer to be ' to take up the results discovered by the abstract mathematician, the chemist, and the geologist, and to apply them practically for the commercial advantage of the world at large,' illustrated his views by selecting the examples of hydrodynamical science and hydraulic engineering, for the purpose of pointing out the serious mistakes which might result from the neglect of a proper knowledge of true mathematical principles.

Mr. Robert Stephenson described the modern railway system in England up to the period of his address, commenting upon its extent, and justly appreciating its value; and he reviewed, in a large and philosophical spirit, its system of management, and the commercial economy which it had produced.

Mr. Locke in like manner selected for his subject a description of the French railway system and its management, in the introduction of which he had himself been so actively engaged.

Another of my predecessors, Sir John Rennie, seems to have been determined that no single topic of professional interest should remain to any future President which he had not himself exhaustively discussed; for he not only presented a complete panorama of all past engineering works, but he gave a descriptive analysis, so full and complete as to make his address at once a history of engineers, and a manual of engineering science.

THE FUTURE OF THE PROFESSION.

The whole field of discussion and description of the past has thus been so completely and so ably occupied by my predecessors in this chair, that I shall not attempt to travel over the same ground; but I propose to deal almost exclusively with the future, and endeavour, although I possess no peculiar personal fitness for the task, to suggest some of the means by which the younger members and the rising generation may best prepare themselves for the duties which that future will bring with it.

THE ENGINEERING PROBLEMS OF THE PRESENT TIME.

I may first briefly notice, and for the purpose of illustration and introduction, a few of the great engineering problems of remarkable boldness and novelty which are now presenting themselves for the supply of the future wants and convenience of mankind: amongst them may be enumerated the Suez Canal; the tunnel through, and the railway over, Mont Cenis; railway bridges over and under great rivers and estuaries; new ferry works of unusual magnitude; vast warehouses and river approaches for commercial cities like Liverpool; railways under, over, and through great cities; long lines of land and ocean telegraphs; and comprehensive schemes of water supply, drainage, and sewerage.

All these works present problems of great interest; and it will require cultivated intelligence, patient investigation, and enlarged experience, to accomplish the task of their satisfactory solution.

For the Suez Canal we must be content to wait a few years before the work be so far advanced as to enable us to judge of the effects of the physical and moral obstacles which to some experienced minds have appeared all but insuperable.

The Mont Cenis Tunnel, and the temporary railway being constructed over its summit, will continue to be watched with interest by all engineers, and it may yet be a question how far the mode of traction which has been adopted for the temporary railway will prove to be the best. The modified locomotive with the aid of a central rail has no doubt succeeded in surmounting gradients which have hitherto been considered to be more severe than compatible with the economical use of the locomotive engine; but further experience is still required, and the results of the trial will be watched with great interest, because it cannot be doubted that conditions will continue to present themselves to which the ordinary locomotive engine cannot conveniently be applied.

In many of the proposed and future designs of bridges over or under great rivers and estuaries, no novelty in the principles of construction may probably be required, but in other cases the mere magnitude alone will demand new arrangements and combinations; and may possibly also suggest the use of steel for parts or the whole of the structure.

The docks and warehouses of our great commercial cities are rapidly advancing in importance, and are constantly demanding increased facilities to entitle them to meet the exigencies of trade; and for this purpose every possible resource of steam machinery, and hydraulic and pneumatic mechanism, will have to be taxed, to obtain convenient and adequate power and expedition.

The new scheme of river approaches at Liverpool is one of the most remarkable proposals of modern times for its boldness in grappling with the difficulties and necessities of a pressing want, and the complete solution of a difficult problem. It is understood that the engineer of the Mersey Board, who has designed this great work, is preparing a model on a large scale, which I have no doubt will be brought before the Institution.

The railways under, over, and through great cities are amongst the most striking results engendered by the necessities of rapidly increasing and closely crowded population, and may be regarded as one of the most useful economical developments which engineering has supplied to satisfy the requirements of modern civilisation. The engineering problems they present are infinite in their number, and interestingly intricate in their character.

Ocean telegraphy is yet in its infancy, but enough has been done by the numerous lines already laid, and by demonstration before this Institution, to prove that further experience alone is wanting to enable deep or shallow sea cables to be successfully laid and maintained wherever they may be required; and probably in no branch of our profession is the future of greater interest than in the coming telegraphic connection of every part of the world by sea and land, and in the political, commercial, and social results which must follow such a remarkable increase in the facility of general intercommunication.

The rapid growth of communities, to which I have already alluded, has also developed the necessity of provision being made for a more abundant supply of pure water, and for a more complete system of sewerage than is now generally possessed by our towns and cities. Some of these works are already being carried out, or seriously contemplated, on a scale of almost startling, but not unnecessary, magnitude.

It is plain, therefore, that in every department of civil engineering the wants of commerce and society are pressing more and more urgently upon the resources of our profession. We have ship canals, but the Suez Canal throws them all into the shade. We have long tunnels through our English mountains, but we have now to penetrate the Alps. We have large bridges, but larger are required. We have noble ports, but they are choked with trade, and new accommodation of an improved kind is called for. We have steam ferries across rivers, estuaries, and straits, and rapid ocean steamers, but higher speed and better accommodation are demanded. We have large warehouses with convenient mechanical appliances, but larger warehouses and better mechanical appliances have become a necessity. We have many thousands of miles of telegraphic communication, but nothing short of its universal extension will suffice.

In the solution of these problems, thus rapidly indicated, and in others which could be easily adduced, we may rest perfectly satisfied that the difficulties they present are not to be overcome by a stroke of genius or by a sudden happy thought, but they must be worked out patiently by the combination of true engineering principles, ripe experience, and sound judgment.

Definition of a Civil Engineer.

Having thus called your attention to the peculiar position of our profession in consequence of its rapid growth, and pointed out some of the problems which await an early solution, I shall now attempt to describe the nature of the functions of the modern Civil Engineer; and consider how the coming generation can be best prepared for its inevitable work, and to what extent this Institution can be made ancillary to that purpose.

Although we know from history that men have existed from the earliest times who have been distinguished by great mechanical capacity, remarkable skill in working materials, profound science, and constructive knowledge, yet it is only during the present century that civil engineering can be considered to have become a distinct and recognized profession. Now, however, it has assumed the position of an *art* of the highest order. Perhaps we may without arrogance be entitled to claim for it the title of a true *science*.

Many attempts have been made to define and describe a civil engineer in a few general words, but all such attempts have been more or less unsatisfactory. Still, though it is difficult, if not impossible, to describe an engineer by a short definition, it is not so difficult to enumerate and describe the nature of the works he is required to design and execute, and the professional duties he is called upon to perform.

CLASSIFICATION OF THE WORKS ENTRUSTED TO A CIVIL ENGINEER.

He has to design and prepare drawings, specifications, and estimates, and to superintend the carrying out of works which may be thus enumerated :—

1. Railways, roads, canals, rivers, and all modes of inland communication.

2. Water supply, gas-works, sewerage, and all other works relating to the health and convenience of towns and cities.

3. The reclamation, drainage, and irrigation of large tracts of country.

4. Harbours of refuge and of commerce, docks, piers, and other branches of hydraulic engineering.

5. Works connected with large mines, quarries, ironworks, and other branches of mineral engineering.

6. Works on a large scale connected with steam-engines, with machinery, shipbuilding, and mechanical engineering.

This list, which might be almost indefinitely extended, involves a vast variety of work, and must appear almost appalling to a young engineer. Yet it greatly concerns his future success that he should as far as possible be prepared to undertake any or all of the works embraced in the list.

I believe the personal history of most of us would show that circumstances have led us in a widely different direction, in the exercise of our profession, from that which we originally contemplated, and that the success of many men may be distinctly traced to their ability to avail themselves of unforeseen opportunities to advance in some new direction.

Study of objects, and their value.

The civil engineer must therefore be prepared for the various classes of constructive works thus enumerated; but in addition to this professional preparation, it is of the first importance, as affecting his true position, and the confidence which ought to be reposed in him, that he should also have a correct appreciation of the objects of each work contemplated, as well as their true value, so that sound advice may be given as to the best means of attaining them; and he must be prepared, if necessary, to advise his employers that the objects which are sought are not commercially worth the cost of the means which would secure them. It is not the business of an engineer to build a fine bridge or to construct a magnificent engineering work for the purpose of displaying his professional attainments, but, whatever the temptation may be, his duty is to accomplish the end and aim of his employers by such works and such means as are, on the whole, the best and most economically adapted for the purpose.

Choice of materials.

The first question which will present itself to an engineer with respect to any proposed work, will be the selection of his material; and as this question is so vital to the accomplishment of a satisfactory result, I propose to treat it in a preliminary and special manner. I wish to impress upon every young engineer a due sense of its importance, because probably a greater number of mistakes have been made by the use of a wrong material, than from any other cause.

Stone.

In the case of stone work, it is essential that the mode of construction shall have reference to the character of the stone; and this requires much of the knowledge of the geologist, the stonemason, and the quarryman, so that the engineer may know how best to work and set the stone, and what are the pecularities of the quarry as to its sound or unsound beds, and, in addition he should have sufficient chemical knowledge to detect any unfitness in the conditions of use to which he proposes to subject the stone.

Let us always bear in mind, in connection with this subject, the example of Sir Christopher Wren, engineer as well as architect, who himself selected the quarries, and sometimes even the blocks of which his structures were composed.

Brick.

Of bricks I must be content with saying, that the power of detecting the good from the bad, the suitable from the unsuitable, must be acquired by the combined assistance of reading, experiment, and practice.

Mortar and cement.

A knowledge of lime, and the art of making the best practicable mortar from each description of building lime, is almost of equal importance to that required for selecting the stone, brick, and building materials themselves, but it is somewhat remarkable, that the art of preparing mortar in a proper manner is not so general as it deserves to be; and to secure good mortar is a matter of continual anxiety to the engineer.

Mortar for engineering works is ordinarily made from cement (chiefly Portland cement); or from hydraulic lime, such as lias; or from ordinary lime, such as grey or chalk lime.

Cement is chiefly used in combination with sand in various proportions, according to the nature of the work to be executed, and it is not only necessary to possess the requisite knowledge and experience for determining the proper proportions of cement and sand for each individual case, but it is desirable to have the means of determining by direct and repeated experiment the strength and quality of the cement which it is intended to use.

In the case of hydraulic lime, such as lias, the same general knowledge of the proper proportion of sand to be used is also requisite, but, from the great variation in the character of lias lime, and the different proportions of silica and alumina in combination with the lime itself, it is essential to obtain a careful chemical analysis, in order to avoid the great disappointment and bad consequences which may result from ignorance of the various qualities.

Of ordinary limes, it is only necessary here to say that they are of almost infinite variety as to quality and constituent parts, and must each be dealt with accordingly, and the engineer can scarcely take too much trouble to inform himself of the exact nature of each lime he has to use, and the best mode of using it.

Modern science, and the convenient manner in which steam power can now be applied, has given to the modern engineer the means of obtaining better mortar from the same materials than was possible before the general introduction of steam.

The heavy rollers and iron pan worked by steam-power are now almost universally used for grinding and mixing lime and sand for works of magnitude; they produce with properly proportioned ingredients a mortar so good in quality, and so equal in the time and power of setting, that the engineer can calculate with certainty upon the conditions under which his designs will be carried out; and when he has become thoroughly acquainted with the quality and power of good mortar, and acquired confidence in its use, he will feel himself justified in its adoption in cases where our predecessors, and even some modern engineers, would have hardly ventured to employ it in the place of the more costly Portland cement.

Iron.

When iron is intended to be used in structures, it is essential to know under what circumstances cast-iron is best for the purpose, or when wrought-iron should be employed, and also when steel must be resorted to. The profession has probably been assisted to a greater extent by the experiments and writings of its members and of distinguished men of science in the material of iron than on any other subject; but these valuable investigations and experiments must be supplemented by the practical knowledge which can only be acquired by attentively studying the peculiarities of material and manufacture.

Cast-iron or pig-iron re-melted and run into moulds is largely used by engineers for columns and other parts requiring great power of resisting compressive strains; and, as its price per ton is generally about one half of that of wrought-iron, it becomes a matter of economic importance to adopt it in all cases where it can be safely and properly used, but it is of the most varied quality and strength, and the greatest attention of the engineer is required to secure the proper kind.

Wrought-iron is perhaps less varied in its quality than cast-iron, and for many purposes of engineering it is the safer metal to adopt, from its greater power of resisting tensile strains, and has liability to sudden fractures, but it must be remembered that wrought-iron is sometimes pure and of high quality, sometimes very impure and of the commonest quality, and even with the same degree of purity it may be soft and fibrous, or hard and crystalline; therefore it is obvious that the young engineer should acquire a sound knowledge of its nature both chemically and practically, so as to enable him to obtain the quality he desires, and to know when he has secured it.

It would be easy to enlarge upon this interesting question of wrought-iron, but it may suffice to instance armour-plates, and rails, as cases where the best quality is required, but the quality, though best, must be different in kind; for armour-plates the iron can scarcely be too soft and fibrous, whilst for rails it can scarcely be too hard and crystalline, provided it is not so brittle as to be liable to fracture by use. Again, in some iron, such as the 'best Yorkshire,' the quality appears to improve with every additional operation in the manufacture, whilst the ordinary Welsh iron is almost destroyed by repeated manipulation. All these and many other matters connected with iron should therefore be known thoroughly and practically to the engineer.

In order to illustrate the necessity of the systematic study of the peculiarities of the metals called iron and steel, let me refer to the experiments of Mr. Eaton Hodgkinson, which first demonstrated that the average resistance of cast-iron to crushing was more than six times its tenacity, whilst the resistance of wrought-iron to crushing was only four-fifths of its tenacity, and it will be remembered that the mathematical investigations he founded upon these experiments first established on a satisfactory and reliable basis the degree and ratio of tensile and crushing force in cast and wrought-iron.

Steel. With respect to steel, it must be admitted, that before we can safely adopt it to any considerable extent for purposes of construction, it will be necessary to have a similar series of experiments and investigations specially made, but so promising a metal will amply repay all the trouble that may be bestowed upon it.

Timber. Of timber a thorough knowledge should be acquired, as no material is otherwise more likely to deceive and to disappoint the engineer. Not only is great difference found in trees of the same general description, such as the numerous varieties of the pine, but the same kind of pine is a different quality of wood in different countries, and even in different soils and climate in the same country; and again the same tree is entirely changed by being 'bled' or having its sap withdrawn. The oaks of America, England, and the Continent, are entirely different in their character, and oaks also differ in quality from each other in the same country, and so with numerous other woods used by the engineer. The strength, durability, and peculiarity of different kinds of timber, and the true value of artificially preserving them, should also be known and understood.

I have selected these examples for the purpose of illustrating this important fact, that before an engineer can even commence the designs of his works he must have previously obtained a large amount of preliminary information regarding the nature of all the materials employed upon engineering works; so as to enable him to select for his intended structures those materials which will be on the whole the most suitable; having reference to efficiency, durability, and economy.

Knowledge required by a Civil Engineer.

I will now proceed to the question of the kind and degree of knowledge which is required to enable a young engineer to proceed to the actual design of a public work of importance, such as a railway with its stone, brick, and iron structures, its earthworks, and its all-important permanent way, a railway station, a station roof, docks and their appliances, water-works, breakwaters, or a Great Eastern steam-ship.

Although it has become the practice in modern times for many civil engineers to be employed chiefly, or almost entirely, in some one branch of the profession, I desire to repeat my conviction that it is most important that the early preparation and subsequent study should be as extensive as possible, and should embrace every branch of professional practice, not only for the purpose of securing to a young engineer more numerous opportunities for his advancement, but also because sound knowledge and experience in all branches of engineering will greatly add to his efficiency and value in any special branch, in the same manner that a medical man will be more reliable in his practice on the eye and the ear if he possesses a sound practical and theoretical knowledge of every part of the human frame.

All classes of the profession, but especially the railway, the dock and harbour, and the water-works engineer, must possess a knowledge of parliamentary proceedings, so as to be able to avoid all non-compliances with the Standing Orders of Parliament. To do this, it is true, is no easy matter, as the clauses are often drawn up with so little care and practical knowledge that neither engineers nor solicitors, nor the most experienced parliamentary agents, can understand what is intended.

On the subject of parliamentary proceedings generally, it may be taken for granted that all Committees desire to do justice to the cases which are brought before them, and that if they sometimes fail in their decisions, either as regards the interests of the public, or in arranging a fair settlement between antagonistic interests, it is not unfrequently due to the imperfect and crude manner in which cases are presented to them. I would therefore impress on all young engineers the importance, both to themselves and to their clients, of laying their cases before Committees in the most perfect manner possible, accompanied by full and correct information, carefully prepared and clearly worked out.

Railway engineering.

The professional knowledge required by the *railway engineer* commences with surveying of all kinds, the use of the theodolite, the aneroid barometer, the level, the sextant, &c., and includes the surveys for preliminary and parliamentary purposes; and also working surveys of minute accuracy, on a large scale, from which engineering works may be set out with precision upon the ground.

The railway engineer must understand thoroughly the nature of earthworks of every kind, and the proper angles or slopes to be adopted for cuttings and embankments.

He must have the qualifications requisite to enable him to design bridges, viaducts, tunnels, and all other incidental works and buildings, in the best and most economical manner.

He must have a knowledge of the training of rivers, and of the effect of floods and drainage, in order that he may make accurate provision for the due discharge of water without wasting money on works unnecessarily large, or to avoid the risk of damage arising from making them insufficient.

He must be familiar with the various characters of permanent way, the best description of rail, sleeper, fastenings, and ballast, and with the different descriptions of switches, crossings, turntables, signals and telegraphs.

It is somewhat remarkable that, with all experience, there should still remain a doubt amongst engineers as to the best kind of permanent way to be adopted even under similar circumstances. For although continental engineers have almost without exception adopted the flat-bottomed or 'Vignoles' form of rail, the **I** form of rail with equal top and bottom webs, and cast-iron chairs and wooden keys, is still largely used in this country.

A collection of facts with respect to the different descriptions of permanent way in use in this and other countries, with a view to a comparison of the advantages and disadvantages of each, would form a most interesting and important paper for the Institution, especially if it embraced all the recent experiments with reference to the use of steel rails.

The railway engineer should not be destitute of some knowledge of architecture and such a taste for those graceful outlines and simple appropriate details which should always characterise the works of an engineer, as to be able to avoid, on the one hand, the unnatural ornamentation which seems to have no connexion with the structure, and, on the other hand, a disregard of either form, outline, or proportion.

But all such knowledge may fail if there be not a constant supervision and control over the quality of all the materials and workmanship employed upon the railway. And it is not too much to say that without the practical knowledge which is obtainable only by the actual performance of the duties of resident engineer, it is hopeless to expect that any engineer can be competent to undertake the responsibility of important works, or be fit to have large sums of money entrusted to him for expenditure. It is in the capacity of resident engineer that all previous preparation, both scholastic and professional, and all theoretical acquirements, become utilised and rendered of practical value, and it is only after much experience on different works of varied character, dimensions, and materials, and the acquisition of the power of discriminating between good and bad materials and workmanship, that a young student of engineering can claim to take rank as a 'Civil Engineer.'

Dock and harbour engineering.

The *dock* and *harbour engineer* requires the general and much of the special knowledge of the railway engineer, such as that which belongs to railways and tramways, and warehouses for goods; and to this he must add a vast amount of other special knowledge not required by the railway engineer.

For example, he must understand the laws which govern the ebb and flow of the tides, the rise and fall and time of high and low water; and he must have a knowledge of marine surveying, or the best means of ascertaining the set and speed of currents, and their tendency to increase depth of water by scour, or to diminish it by silting; he must also know, in the case of docks, what kind and extent of entrance accommodation to provide, whether the general plan should comprise only a simple lock, or be combined with a half-tide basin; whether single or double gates should be used; and whether it would be necessary to have a tidal basin or a recessed space, or both.

The nature of the trade to be accommodated in the proposed docks must also be carefully ascertained, in order to provide a proper proportion of quay space and water space, and proper width of quays, warehouses for bonding or for goods to be deposited, sheds for temporary protection, entrance for barges into warehouses from the docks, graving docks and workshops, with mechanical appliances for gates, sluices and pumping; and for shipping or discharging minerals or goods.

He may have to deal with solid foundation, and enjoy a facility of procuring suitable materials for construction, as at Liverpool; or he may have the bad foundations of Hull and other places, where alluvial silt of great depth has accumulated. It may be that good sound stone is too costly for the mass of his work, and that he must resort to brickwork, or rubble stonework, or concrete, or to a combination of all three; but in determining such questions it is impossible that anything but previous experience and habits of careful investigation will enable an engineer to arrive at the best decision. For it is not enough that his work should be solid, permanent, and safe, but it should be rendered so at the smallest possible cost.

The *dock* and *harbour engineer* is also required to report upon, and to construct, harbours of refuge, piers, landing stages, lighthouses, forts, canals and their appliances, river improvements, and many other hydraulic works; and in short, of this branch of engineering it may be truly said that questions are continually arising which require special study and mechanical invention to a greater extent than in almost any other branch of the profession.

Harbours of refuge being large and costly works, are necessarily few in number, and they are so slow in progress, and have generally been so often changed from their original object and design, that few engineering works have given less satisfaction either to the profession or the public; but we may hope, that if governments will accurately appreciate the objects they desire to obtain, and boldly grapple with the difficulties and cost of well-matured design, better and more useful works of this nature may be accomplished than have yet been undertaken.

The *waterworks* and *drainage engineer* must possess many of the qualifications of the railway and dock engineer, and especially those which concern earthwork and masonry; he must also be familiar with the means of obtaining information on the subject of rainfall in different localities, the methods of correctly gauging streams of every kind; the proportions of the rainfall available for his purposes after estimating for evaporation and waste, and the extent of the provision to be made for periods of dry weather, or for compensation to mill-owners and other interested parties. Waterworks and drainage engineering.

He must be conversant with the proper mode of executing the works of reservoirs, conduits, weirs, tunnels, and aqueducts.

He must understand, by the aid of the chemist and his own experience, the nature of the impurities in water, and the best mode of diminishing them, whether mechanically, by subsidence and filtration, or otherwise.

To the waterworks engineer we must look for the solution of one of the great problems which the rapid increase of population is now forcing upon us, viz. a comprehensive system of conservancy of the flood waters of mountainous localities for the use of large cities and towns, and densely populated districts. We are completely outgrowing our present arrangements for water supply in the great majority of instances; and the convenience, comfort, and health of the public demand that such works when required shall be no longer postponed.

The initiative has been taken as to the question of a new source of water supply for London, in a pamphlet by a well-known authority in this branch of engineering, and sooner or later the subject must command public attention.

The waterworks engineer must also be competent to design and superintend works of sewerage, as well as of water supply, for large and small towns and localities; and his familiarity with waterworks will naturally aid him in this, as the problems for the discharge and pressure of fluids are identical in both cases.

The great sewerage works of London are now far advanced and have already produced beneficial results; the attention of other still neglected cities and towns has recently been called to this important subject by the loud and startling voice of a threatened return of cholera, and it is to be hoped that the proper authorities will perform their duty promptly and efficiently in this matter: but I cannot here refrain from calling attention to a gigantic evil which has been created by certain drainage and sewerage works already executed, and where the convenience and comfort of one set of people have been secured only by the infliction of a nuisance upon others. I allude to the discharge of collected sewage, without any attempt at purification of deodorisation, into streams of pure water.

It is remarkable that an injustice so great, and an evil so intolerable, should in any case have been permitted by Parliament, or by the general law of the land; but now that public attention has been fairly directed to the subject, let us hope that as soon as possible a remedy will be applied to the cases where mischief has already been done, and that care will be taken to prevent its recurrence.

It is no longer a matter of doubt that deodorisation or purification is quite practicable in every locality, and therefore no sewage should ever be permitted to be discharged into existing streams without this purification, or it should be carried out to the sea, and there discharged, as is now proposed for the north side of London.

Mechanical engineering.

The *mechanical engineer* deals with the most varied and numerous subjects of all the branches of engineering. They require that he should thoroughly understand the means of producing mechanical power, and of applying it to all the infinite variety of purposes for which it is now demanded. To this end he should be master of the laws of motion and rest, of power and speed, of heat and cold, of liquids and gases.

He must be familiar with the strength of materials under every variety of strain, the proper proportions of parts, and the friction of surfaces.

He must apply existing tools and contrive new ones for his work, and know how to direct power in the raising of weights, or for driving all fixed machinery, or in producing locomotion on land or water.

On railways he is responsible for the vast number of objects required in the machinery for erecting and repairing shops for the engines and carriages, for the pumping and other fixed engines, and especially for the locomotive engine itself, and for rolling and fixed plant generally.

In connection with docks he is required to design the machinery for opening and closing the dock gates, working sluices, emptying graving docks, or for working the cranes on the quays, or in the sheds and warehouses.

The mechanical engineer generally also executes the designs of the gas-engineer, even when he does not originate the work which is entrusted to him; and in this branch considerable chemical knowledge must be added to his mechanical qualifications.

For waterworks he designs and executes pumping engines, sluices, valves, stopcocks.

In the case of mines he supplies designs of the engines for pumping, drawing, winding, or ventilating; for locomotives above and below ground, as well as for the various mechanical appliances required in collieries, mines, and ironworks.

The adoption of the telegraph has been so astonishingly rapid and extensive, both by sea and land, and the purpose to which it has been applied so important, that a considerable body of able and accomplished engineers have devoted themselves almost exclusively to the subject for the last few years, and have already created a new branch of the profession, called *telegraphic engineering;* but to be an accomplished telegraph engineer, it is necessary first to be a good mechanical engineer and then to add the special knowledge of the electrician, and therefore I include telegraphic under the head of mechanical engineers.

I think it may fairly be traced to the distinguished ability of that class of mechanical engineers who have devoted themselves to telegraphic engineering, that already so much has been done in telegraphy. Certainly no discussions have been more ably sustained in this Institution than those upon this subject.

Allied with the mechanical engineer is the *naval architect*, and only a mechanical engineer could have constructed the vast steam-ships of modern days. The ordinary timber-ship builder of old would have been literally 'at sea' in the construction of modern vessels, wherein the material is iron, and when the size of the vessel requires scientific knowledge of form and resistance, of strains and of strength, and when steam is the motive power. The demand for large and swift vessels for ferries, for long voyages, for floating batteries, and for iron-clad sea-going vessels, has of late been so great that the construction of steam vessels has become a distinct branch of engineering, under the name of naval architecture.

Mining engineering.

The *mining engineer* must possess much of the knowledge of the railway and the mechanical engineer, and he must add to that general knowledge much special knowledge of his own. He must know how to sink shafts to the minerals if they require to be extracted from beneath the surface (which is usually the case), and how to divert or pump out the water he meets with either in the shafts or the workings.

He must know how to excavate and bring to the surface minerals, whether they be coal, copper, tin, lead, or iron, and to do this he must construct subterranean railways, provide means of ventilation by fans or furnaces, supply power to lift the extracted mineral to the surface; and when brought there he must understand the further requisite work, as the coal will probably require screening, or washing, or manufacturing into coke, and the ore will require crushing, washing, or smelting, or possibly all three operations.

In all these cases and many others, such as the collection of surface ironstone and other minerals, by railways and locomotive engines, and the working of lifts and inclined planes, the mining engineer has most important functions to perform, and has special machinery to adapt or invent; and relying on his judgment and skill alone, the investment of large sums of money for the development of the mineral wealth of this country is annually made.

Artillery engineering.

I must not altogether omit a passing reference to the scientific talent which of late years has been devoted to Artillery—its weapons of attack and works of defence, and I think we may fairly claim that it is mainly due to some of the able members of this Institution that this *art* has been placed on a new and vastly improved basis, and that as a consequence a new branch of the profession had been actually created—Artillery Engineering.

PREPARATION REQUIRED BY A CIVIL ENGINEER.

Having now enumerated in some detail the various descriptions of work which engineers are called upon to carry out, I will next proceed to point out the kind of preparation which, in my opinion, is requisite to enable them to perform their work in a proper manner.

I am aware of the difficulty of the task, and of the wide difference of opinion which exists on the subject, but I feel unable to resist the opportunity of bringing this question under the consideration of the Institution, because I feel convinced that at no period in the history of the profession has it been so important as at the present time. Those who may not be disposed to coincide with my views may at least be led by the description of them to throw new light on a subject which is of vital consequence.

We of the passing generation have had to acquire our professional knowledge as we best could, often not until it was wanted for immediate use, generally in haste and precariously, and merely to fulfil the purpose of the hour, and therefore it is that we earnestly desire for the rising generation those better opportunities and that more systematic training for which in our time no provision had been made, because it was not then so imperatively required.

The preparation and training for the civil engineer may be shortly described as follows:

1. General instruction, or a liberal education.
2. Special education as a preparation for technical knowledge.
3. Technical knowledge.
4. Preparation for conducting practical works.

All this preparation and training will have to be acquired at some time or other, and in some order or other, and it is known that in the cases of some successful persons of great perseverance, they have been acquired in a very remarkable order; but at the present time, and with all our modern opportunities, there is no reason why they should not be learned in the most convenient and methodical manner.

I will begin by supposing a boy of fourteen, in whom his parents have discovered a mechanical bias, who has made good progress in his general education, and especially in arithmetic, is of strong constitution, and possessed of considerable energy and perseverance: and unless a boy possesses these tendencies and qualifications it is quite useless to destine him for an engineer.

Taking a boy of fourteen, however, who possesses the requisite qualifications, and with a determination on his own and his parents' part that he shall be made an engineer, the period from fourteen to eighteen should be devoted to the special education required by an engineer, during which mathematics, natural philosophy, land surveying and levelling, drawing, chemistry, mineralogy, geology, strength of materials, mechanical motions, and the principles of hydraulics should be thoroughly mastered.

To accomplish these studies, and, in addition, to make considerable progress in the living languages, French and German especially, it will be necessary to sacrifice to some small extent his classical studies and pure mathematics, and it is, in fact, the partial omission of these studies, and the prominence of those I have enumerated, which constitutes a 'special education.'

If from fourteen to eighteen the boy has made all the progress in these studies which can be reasonably expected from fair abilities and more than average perseverance, the next step is of great importance, and is one respecting which some difference of opinion will exist.

At eighteen a boy if duly prepared may either be at once placed in the office of a civil engineer for a period of four or five years' pupilage, or he may be placed in a mechanical workshop, or he may be sent to one of our great universities, and any one of these courses may be the best under particular circumstances, such as local convenience, or as the social position of parents may dictate.

It cannot be doubted that a period of twelve to twenty-four months may be very profitably spent in manufacturing works, before passing into a civil engineer's office; but in that case the greatest possible care must be taken that the works selected are adapted in themselves to impart the desired information; and that proper organisation exists for carrying out strict office discipline, regularity of attendance and due diligence; and that assistance be given systematically to the pupil to enable him to obtain all the advantage possible from his stay at the works.

It is of the greatest importance to the future success of the engineer that during his professional preparation he should continue his studies of mathematics and scientific works relating to his profession, and also of modern languages.

In the case of its being intended to send the boy to Cambridge or Oxford, it is indispensable that all preliminary professional work, such as practical knowledge of mechanics, mechanical drawing, surveying and levelling, should be mastered before going to the university, because it can scarcely be expected that he will submit to the drudgery of learning them after his return from a three years' university course, then at the age of say twenty-two; probably the best plan will be to take him away from his scholastic studies somewhat earlier than eighteen, if it be intended that he should go to the university, and to take especial pains to make him accomplished in the preliminary work of the draughtsman, the surveyor, and the mechanic; so that when he has taken his degree and enters as a pupil in a civil engineer's office he will at once commence useful and interesting employment, and will not require more than three years' pupilage.

If arrangements can be so made, and assuming a boy has worked well at school with his general studies, and subsequently with his special studies; and if from the age of seventeen or eighteen he does justice to his opportunities in a good workshop, keeps up his knowledge of modern languages, proceeds to Cambridge or Oxford, taking a good degree, and afterwards completes his studies as a pupil with a civil engineer; probably such a course would constitute the best possible preparation and training which could be obtained: but at the same time it cannot be doubted that it is a somewhat hazardous combination, and can only be successful with great determination on the part of the pupil to keep his future career always in view, and to prepare for it accordingly, as well before going to the university, and during his college career, as after he leaves it.

With respect to the special preparation of young men between the ages of fourteen and seventeen or eighteen, several of the largest and best proprietary schools and colleges in this country have special classes and departments for the study of the applied sciences; and thence well prepared pupils are annually sent out to commence their career with engineers, architects, and surveyors; but still the character of this special preparation, in its theoretical branches, is not considered quite equal to that of France or Germany for the civil engineer.

It is true that nearly all continental nations have an advantage over this country in the power which the nature of their government gives them of concentrating, in one recognised official school for the preparation of civil engineers, all the best available talent of their country.

This plan does not exist in our country, and on the whole we rejoice that it does not; neither does the inducement of government employment form the chief stimulus to our exertions, for which we are also thankful: but at the same time no good reason can exist why the opportunities of acquiring theoretical preparation in this country should be inferior to those of the Continent; and I have the confident hope, from the anxiety which is now manifested to increase the ranks of our profession, and the desire to have the best possible preparation for it, that even in the theoretical branches we shall shortly have to acknowledge no inferiority to any other nation. In the practical branches we are admittedly superior.

In drawing attention, however, to a comparison between our own and other countries, let me be guarded against the possibility of being understood to suggest that this theoretical equality ought to be obtained by any sacrifice whatever of our undoubted great practical knowledge; indeed, on the contrary, I think that attention to the greater opportunities which young engineers in this country enjoy, by reason of the number and character of our new public works, than is attainable in other countries, should be constantly encouraged to the utmost possible extent, and that our old superiority as practical engineers should be ever maintained.

We will now suppose that the general education and the special instruction have been completed, the short probationary pupilage in workshops has been gone through, languages and mathematics kept up and improved, the university course in certain cases completed, and the period has arrived for entering a civil engineer's office.

In selecting such office for a pupil, it is important that it should be well organised and not be too large; that the engineer should be a comparatively young and rising man, and be accustomed to take pupils; but these should be few in number, and bear some proportion to the number and extent of the works in usual course of construction under the engineer's direction.

It is not necessary to follow the pupil, when once the engineer's office is entered, with any detailed advice, because he is no longer a boy, unable to appreciate his position and duty. We assume that he has been highly educated and carefully trained, and knows well that his future success or failure will depend on the degree of diligence with which he avails himself of the opportunities of acquiring knowledge during his pupilage.

The work in the office and in the field should be done to the best of his ability, and after the pupil has become a skilful draughtsman, and is capable of taking out quantities of engineering works, and preparing detailed estimates methodically arranged, he will then probably proceed to work out details of designs, and make calculations of strengths and strains, and thus become of real value in the office, at the same time making substantial progress and rapid improvement for himself.

He should avail himself of every opportunity of mastering the purpose and the principles of construction of the work brought to his notice; both in the office and in execution; and he should ascertain the cost price of all the materials and workmanship employed, separating the items into every minute detail.

The information which, amongst much beside, should be thus obtained during pupilage, and which is necessary to constitute a sound engineer, is:—

1st. A fair knowledge of the most fitting material to use for any given work, under any given circumstances.

2nd. The power of designing any ordinary work with a maximum of strength and a minimum of material and labour.

3rd. A knowledge of the means of ascertaining the cost price of any ordinary engineering work.

The information or knowledge included in this brief enumeration may be called practical knowledge, and it cannot be too often urged upon young engineers that theory and practice must always go together, hand in hand, step by step; and that they are not only not inconsistent or conflicting, but that they are necessarily united, and must both be fully developed in the same person before he can become a properly qualified 'Civil Engineer.'

The period of pupilage should be from three to five years, depending on the circumstances which have been previously indicated, and, in addition to his attention to the office, and to outdoor works, it will be well, while keeping up his preparatory studies, especially in mathematics, that he should improve his acquaintance with the French and German languages, and keep up his knowledge of their engineering literature, and also avail himself professionally and personally of the advantages offered by this Institution.

In the case of the mechanical engineer, however, it will be seen that although all scholastic and scientific training should be the same as that previously described for all other branches, the period of pupilage of the mechanical engineer must necessarily be passed chiefly in large workshops or manufacturing establishments.

The Institution.

I propose now to consider in what manner this Institution can be made available in the prepartion of the young engineer, and more useful to the profession generally; and as a first step allow me, very briefly, to trace its history and refer to its present prosperity.

It will be remembered that the Institution of Civil

Engineers was established on January 2nd, 1818, and that Telford was formally installed President on March 21st, 1820.

The origin of the Institution was very humble.

About the year 1816 Mr. Henry Robinson Palmer, who was then articled to Mr. Bryan Donkin, suggested to Mr. Joshua Field the idea of forming a Society of young engineers for their mutual improvement in mechanical and engineering science. The earliest members were Mr. Palmer, Mr. Field, and Mr. Nicholas Maudslay, to whom were shortly added Mr. James Jones, Mr. Charles Collings, and Mr. James Ashwell.

When the society was constituted, on January 2nd, 1818, these six young men were joined by two others, Mr. Thomas Maudslay and Mr. John T. Lethridge, with Mr. James Jones as Secretary, and during the remainder of that year there was no increase in the number of the members, and the only additions were three new members in 1819.

In the following year, 1820, when Telford became President, there were thirty-two elections.

At the end of 1822, when the Institution had been established for five years, there had been fifty-four elections.

Telford's name gave a great impulse to the progress of the Institution, which grew rapidly in importance under his fostering hand, so that at the tenth year of its existence,—at the close of 1827, there had been a total of 158 elections, and by June 3rd, 1828, when the charter of incorporation under the great seal was obtained, the number amounted to 185 members.

Telford continued to be the President until his decease occurred, which took place on September 2nd, 1834, and at that time the *actual* number of members on the books (as distinct from the number elected) was 200.

Mr. James Walker, the second President, was elected to that post on January 20th, 1835; and after occupying the chair for ten years, he declined to allow himself to be again put in nomination, in consequence of a strong expression of opinion from several influential members, that a shorter period for the term of the office of President had become necessary.

Accordingly on January 27th, 1845, Sir John Rennie was elected President and served for three years.

Since then the chair has been successively filled by Joshua Field, Sir William Cubitt, James Meadows Rendel, James Simpson, Robert Stephenson, M.P., Joseph Locke, M.P., George Parker Bidder, John Hawkshaw, and John Robinson McClean, each of whom has served for *two* years, the maximum time now allowed by the bye-laws.

It should be mentioned that in the ordinary course of rotation Isambard Kingdom Brunel would have succeeded Robert Stephenson, but Brunel requested that he might not then be put in nomination, owing to ill-health and the pressure of professional duties, and unhappily his early subsequent decease deprived the Society of any future opportunity of electing him. It must always be a subject of regret to the profession, that in the annals of the Institution a member so gifted and accomplished should not appear on their list of Presidents.

At the close of 1836, when the Institution had existed nineteen years, the number of members of all classes who had been elected was 369, and the number of those still remaining on the books was 252, or about five-sevenths of those elected.

At the close of 1860 these numbers were 1535 and 930 respectively, from which it appears that three-fifths of all those elected still belonged to the Institution, being a decline of only *one-seventh* in the relative proportions after a further existence of twenty-five years.

The average annual effective increase of members and associates during the ten years from 1840 to 1850 was 25, and from 1850 to 1860 it was 27, the actual increase in 1859 and 1860 being 37 in each year. In 1861 it was 20, and in 1862 the number was 57.

The number of members of all classes on the books on November 30th, 1865, were :—

Honorary Members	20
Members	486
Associates	689
Graduates	8
Total	1203

or an effective increase in one year of 108 members of all classes.

It will thus be seen that a steady annual increase has been the characteristic of the Institution from its commencement, and it may be noted in this, the forty-eighth year of its existence, that, when it had been established twenty-four years, the number of members was almost exactly one-half of the present number.

Attendance. The experience of the last few sessions shows us clearly that we may expect the future rate of increase to be at least equal to the past, and the attendances on the Tuesday-evening discussions show that the interest attached to the proceedings of the Institution increases in at least an equal proportion with the augmentation of the numbers.

It is now not uncommon to find our meeting-hall inconveniently crowded, and occasionally it is altogether inadequate to accommodate the numbers who desire to be present; and many persons who, from the public interest attached to some of the subjects, desire to hear or to take part in the discussions, are now prevented by our restricted accommodation from doing so.

Finance. For some years in the early history of the Institution it was a work of considerable difficulty to keep the disbursements within the receipts, and except for the admirable management of our late Secretary and now Honorary Secretary, Mr. Manby, it is hard to know what difficulties we might not have experienced. It was not until its income became sufficiently increased by the liberal donations of the council and other members, by trust-monies and bequests, and by the increase in its numbers, that the Institution was in a financial position to give increased accommodation and assistance to its members.

It may be stated that during the last ten years the average increase on the receipts has been forty per cent., whilst the increase in the disbursements has been only twenty per cent.; and that the present amount of the realised property of the Institution may be safely taken at £25,000.

It will have been observed that considerable improvements have been made in the library of the Institution, and in its arrangements and facilities; and no doubt the Council and Secretary will continue to give this important department their earnest attention, and we may reasonably expect that both the contents of the library and its accessibility will be still further increased. Library.

It is, however, somewhat remarkable that a greater number of members do not avail themselves of the additional opportunities of reference to the library which have been afforded them, and this brings me at once to the consideration of the important question of the manner in which this Institution may be made more useful to its members. Additional facilities.

The state of the finances, as we have already seen, will prudently permit the expenditure of a larger annual sum than we now disburse, and therefore we are at full liberty financially to consider the question of additional accommodation for the members, and I believe the library of the Institution would be far more valuable if an arrangement could be made by which it might be kept open in the evenings for a certain number of days in the week, say until nine or ten o'clock. I have ascertained that no practical obstacle to this extension of use exists, and that the additional expense would not be considerable.

Most of the members of the Institution are necessarily engaged in their ordinary daily professional duties during the only hours when the library is at present available to them, and it is obvious that it is only in the case of a special reference being required, or for some statistical purpose, that the library can be useful to members generally under the present arrangement.

I can say from my own experience that I should have felt it a great boon, as a young man, to have had the opportunity of spending an occasional evening in the library, and of reading and consulting the rich record of professional learning and experience now collected there, and therefore I throw out this hint respecting the extension of the hours for reading.

Another step might probably be taken with great advantage to students and engineers generally, viz. the systematic collection of good working drawings, specifications, and contracts for important works in progress or completed, with facility for reference to them in the library, and permission to make tracings or copies.

There can be little doubt but engineers in large practice would permit copies to be taken of their working drawings and specifications for this purpose, and in addition to this assistance with respect to drawings, it would not be difficult to obtain permission for the inspection of the works themselves, during their execution, so that young engineers might have the opportunity, especially during the summer months, of seeing works as they are carried out, and comparing them with the drawings and specifications to which they have had access in the library.

Lectures.

I would also venture to suggest that, in addition to the greater advantage which may be conferred on those using the library by extending time of access to it, and to the collection of working drawings and specifications, with arrangements for inspection of practical works, a limited number of lectures would be very valuable if given by members who were especially conversant with any given subject, on other evenings than those of the ordinary meetings during the session of the Institution.

I now approach a question in connexion with the Institution and its functions upon which, in common with the profession generally, I confess I feel very strongly, and that is, the necessity of providing, as soon as possible, a building more commodious and more convenient than that which we now possess. **New Building.**

Our rapidly increasing numbers have already reached the point when, as I have previously stated, the theatre in which we are now assembled is admittedly insufficient for the accommodation of those who wish to attend our discussions; and, in addition to inadequate space, there are conditions inseparably attached to the present building which prevent this room being properly ventilated and rendered comfortable.

The other rooms of this building are also totally inadequate for the ordinary purposes for which they are required, and on the evenings of our annual *conversazione* especially, the crowding and discomfort are such as to repel many of our best friends from venturing to be present with us.

With a proper building and well-arranged rooms, we shall also be able to have many objects of professional interest for our inspection and study, of which we are at present deprived—such as models of works and machinery, new articles or new combinations, or, possibly, even a good museum.

I hope, however, we shall shortly be in a position to consider a distinct proposal for a new building, worthy of the present position and the future requirements of the Institution.

CONCLUSION. Having now frankly brought before the Institution some of the more important matters which appear calculated to influence the future of the members of our profession, permit me to say, in conclusion, that I am not sanguine enough to expect that I shall accomplish more in this Address than direct the thoughts and attention of my professional brethren to the subject, and induce others more able than myself to take it up.

It cannot be doubted that the rapidly increasing prominence and importance of our profession imposes upon us grave responsibility and the duty of vigilant watchfulness, so that the character of our members, and the success of our works, may be all that greater knowledge, wider experience, and more cultivated taste ought to make them, and that every new work of importance may be better than that which has preceded it, and remain as a monument of progress of which all may be proud.

It is not now sufficient that an engineering work should be durable and free from failure, but, with our present means of study and of knowledge, it will be expected that our works should display in a satisfactory degree the qualities of fitness, economy, and taste, in addition to that of durability.

With deeper study and more complete preparation, the love of our profession and pride in its noble works will become greater and greater in its students, and lead to that intense devotion and application which history teaches us has alone produced the greatest works in art and science; and we cannot doubt that far greater triumphs remain to be, and will be, achieved, by those whom I now see before me, than have yet been realised by either ancient or modern engineers.

Amidst all the excitement of our professional avocations, however, let us constantly bear in mind, and endeavour to imitate, the example of the distinguished men who have been removed from amongst us during the last few years in the happy manner in which they succeeded in combining personal friendship with professional rivalry, and in their never-failing interest in the prosperity and usefulness of this Institution.

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