SECTION I.—GENERAL AND DESCRIPTIVE PAPERS.

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PATRICK M. BARNETT, President, in the Chair.

(*Paper No. 1*).

"Notes on the Education of a Civil Engineer."

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The subject of these notes is one of such vital importance to each young man who has recently entered, or is about to enter, the profession of Civil Engineering, that one might well be excused in assuming that the curriculum of training for proficiency in that profession had by this time been thoroughly matured and clearly mapped out for the guidance of the young and aspiring engineer. That such an assumption is far from the truth is, I am confident, the opinion of most engineers, and, in consequence, many young men—I had almost said most young men—for want of proper guidance, fritter away much valuable time in early life, and lose opportunities of gaining knowledge that can never be recalled.

Why this should still be the case is a question to which it is most difficult to give a satisfactory answer. Nevertheless, the fact remains, and young men are too often allowed to drift along with no particular aim in view, buoyed up by the hope that things will come right somehow in the long run. I can well remember the difficulty I experienced myself when on the threshold of engineering, and for years afterwards, in groping after a satisfactory course of training; and if, in the few notes which I have put together on the subject any of the junior members should find some assistance in selecting a course of training for himself, I shall have pleasure in knowing that the influence of our young Association has begun to be felt.

At the outset I have thought it necessary to lay before you, in as few words as possible, what, in my opinion, ought to be the qualifications or attributes of the ideal civil engineer. We will then be in a better position to say something of the education and training by which in part at least that ideal may be approached.

The qualities I have to present are as follows, viz.:—

(1) Keen observation.
(2) Absolute truthfulness.
(3) Calm judgment.
(4) Fearlessness.

(5) An intimate personal knowledge of—
  (a) Men and materials.
  (b) The laws of nature.
  (c) The application of these laws to engineering work.
  (d) The details of existing works.
(6) General culture.
(7) Courteous manners.
(8) Patience.

The engineer, as I understand him, occupies a position in the world midway between Commerce and Nature. He is, in fact, the interpreter of Nature to Commerce. On the one hand Commerce, with her frequent demands for assistance, expresses her wants to the engineer, and expects him, by consulting Nature, to satisfy her demands, and do so economically; on the other hand, Nature, surrounded as she is by her wonderful system of inexorable laws, refuses to reward the engineer with the success he desires unless he interprets these laws truthfully to Commerce through the engineering work he undertakes to execute.

The ideal engineer is a man who by keen and truthful observation collects all the data necessary for the solution of the problem entrusted to his consideration, and having all these before him, and assisted by his scientific knowledge and experience in engineering, brings a calm judgment to bear on the whole question, decides what is necessary to be done, and fearlessly submits his proposals to Commerce. His proposals accepted, he carries them into execution, consistently with his truthfulness. Work is not scamped to make ends meet, neither are cost accounts manipulated to make them tally with the estimate.

Such work, Gentlemen, carried out with the truthfulness I have indicated, forms at the present day a noble monument to many of our predecessors, and such an ideal engineer was Thomas Telford, first President of the Institution of Civil Engineers; born a poor shepherd's son, afterwards our greatest civil engineer, and at last deemed worthy to lie in Westminster Abbey among its illustrious dead.

Elementary Training.

The course of technical training I would recommend a young man of promise to adopt should be preceded by a sound elementary and secondary education, as obtainable in the best of our modern public schools. In such a case we would expect him, at the age of about 14, to have gained a good knowledge of the following subjects, viz.:—

(1) English,
  Including—reading, composition, correspondence, geography, and history.
(2) Writing,
  Including—commercial, ornamental, and phonography.
(3) Mathematics,
  Including—arithmetic, book-keeping, algebra, analytical and practical geometry, and the use of the slide rule.

(4) Elementary science,
Including—physics, chemistry, and physiography, with laboratory practice.
(5) Languages,
Including—French, German, and Latin.
(6) Handicraft.
(7) Gymnastics.

The great defect of our elementary schools in the past has been that the powers of observation in the pupil have not been sufficiently cultivated by means of object lessons and graphic representation to develop the thinking faculties, and too much time has been spent in abstract methods of imparting knowledge. At an age when the powers of observation are at their very keenest and the young brain not sufficiently matured for abstract reasoning, our methods are still the reverse of what they ought to be.

In our most progressive secondary schools we find the more advanced students being now taught the use of squared paper, in the tabulation and analysis of experimental results in elementary science, whilst the use of the slide rule is also introduced, but this is a mere smattering of the subject which ought to have been acquired in the elementary school so as to pave the way for more advanced work in the secondary.

For instance, practical geometry is a form of graphic work which is wonderfully neglected in our schools, although no subject in my opinion plays a more important part in the life-work of the engineer or artisan. We almost invariably find that boys who have reached the age of 14 or 15 years and wish to enter some branch of engineering have had little or no instruction in practical geometry, whereas the young engineer cannot take this too early. Not only does it train the mind graphically to understand and remember its simple and interesting problems, but it affords the boy the earliest opportunity of becoming familiar with the drawing tools which are to play such an important part in his after career.

This leads us to consider our methods of teaching mathematics, which with but few exceptions are quite unsuited to the practical requirements of the engineer. What we really want engineers to acquire is a knowledge of mathematics as applicable to engineering problems, mathematics in such a practical form that we can have no hesitation in using it as we would any other tool for the production of engineering work.

What we do find I shall best put before you in the words of Professor John Perry, of the Science and Art Department, when presenting his inaugural address to the Institution of Electrical Engineers as their President a few weeks ago.

He says:—

"But a time has come when we see that ciphering is not enough mathematics for us to be familiar with, we need a little algebra, we need co-ordinate geometry, we need the differential and integral calculus. The pedagogue tells us that we must follow the orthodox course of study, which takes many years; and some of us, many of us, who have followed the orthodox method find that we have spent so much time and mental power upon it and its thousands of unnecessary tricks and contrivances and philosophy, that we can take in no more ideas. We cannot utilise our mathematics on engineering problems because we are too old and tired and '*blasé*' to comprehend these problems."

Professor Perry is an engineer of great eminence, who has devoted himself chiefly to the training of young engineers, and has made the subject of "Practical Mathematics" entirely his own, a subject I would strongly recommend every engineer to make a study of. The present academic system is never satisfied unless the student is able to adduce proofs of all the formulæ he uses, and this entails a long and tedious course of study.

In practical mathematics, as in practical arithmetic, the subject is taught in such a way that the engineer may solve most of the difficult problems in engineering without this long and dreary study. As Professor Perry says, one may be permitted to wear a watch although he should never have a knowledge of how to make it. In like manner the engineer should be permitted the use of mathematics.

Technical Training and Pupilage.

Assuming that the student has acquired a good secondary education, such as I have indicated, our next consideration is his technical training and pupilage, and for the attainment of these I would offer the following suggestive course. No doubt difficulty may be experienced by some in carrying out such a course, but no single course is applicable to all cases, and here the young engineer must adapt himself to circumstances.

For a systematic course I would recommend two years at a technical college, bringing the boy up to about 16 years of age, and then a five years' pupilage with an engineer of recognised ability, including two years devoted to workshop and university.

In the technical college the student should acquire a good knowledge of the following subjects:—

(1) Practical mathematics,
    Including—arithmetic, algebra, analytical geometry, and trigonometry, and practical plane and solid geometry.
(2) Physics,
    Including—theoretical mechanics, magnetism and electricity, sound, light, and heat.
(3) Chemistry.
(4) Machine and architectural drawing.
(5) French and German.
(6) English composition.
(7) Workshop practice.
(8) Gymnastics.

He should at the same time attend evening classes in machine construction and building construction, at which he will usually find these subjects taught in a more practical way than is general in day classes.

After completing his course of training at the technical school or college, the student will be ready to begin his professional pupilage, and with this in view he ought to have previously made arrangements for being articled to some engineer with a good practice; preferably a member of the Institution of Civil Engineers.

It may be the good fortune of some young men to have the privilege of selecting the engineer they would wish to be articled to, and obtain

entrance to his office without much delay. This, however, is not usually the case, and the young engineer should make his arrangements a year or two in advance so that he may not suffer disappointment on this score. There are so many applicants now for admission to offices that the engineer finds considerable difficulty in dealing with entrants, and is not always in a position to make room for young men.

The usual term of pupilage extends over a period of three years, and in a few cases is preceded or followed by workshop training and attendance on engineering classes at a university. A good arrangement I consider is one in which the pupil is articled for a period of five years; two years being spent in office and field work, followed by two winter sessions at engineering classes in a university, the summers being spent in the workshops of some general engineering firm, and the fifth year spent in office and field work. It may not in every case be convenient to allow a pupil to break in the way I have indicated, as it tends to disarrange the work of the office, and many engineers for this reason would strongly object to such a course, but I am here looking at the matter chiefly from the pupil's point of view.

In the case of an Aberdeen student the system might work out thus. After obtaining a secondary education, at, say, the Grammar School or Gordon's College, two years would be taken at technical training in Gordon's College, and the pupilage entered with a local engineer. Two years would first be spent in acquiring the methods of office routine and draughtsmanship, and surveying, levelling, and setting out in the field, with assistance in the preparation of drawings. Six months of summer would then be spent in the pattern shop of one of our local engineering firms, and the following winter session of between five and six months of engineering classes, say, at Glasgow University. Next summer would be spent in the fitting shop of the same local firm, followed by a second winter term at the university, and the fifth year in the general engineering work of the office and field.

The great value of a good university course of training for the engineer is unquestionable, and year by year is becoming more indispensable.

The true function of the engineering university is to impart knowledge in the higher branches of science and train the mind to investigate engineering problems scientifically and logically.

Sir John Wolfe Barry, in one of his Presidential addresses, has said—

> "Let it be remembered that a pupil seldom gets any imparted instruction of a scientific character in an ordinary engineer's office. There are no scientific lectures for him there, and whatever science he may know must have been acquired outside office hours. Now, no doubt, the technical schools and colleges do much for us, but in my judgment not enough. Youths leave them, as a rule, too soon, and, I think, before a man becomes an associate member he ought to be able to show that he has not only had some distinctly scientific education, but has known how to apply that education in practical dealing with the engineering problems of an office."

If such higher scientific training be taken before pupilage is commenced, I have always had the impression that the engineering student cannot fully recognise the importance it bears to his professional work, and this is my reason for recommending it to be taken after two years of office work.

I cannot speak of university work without mentioning the name of Professor John Macquorn Rankine, late Professor of Engineering in Glasgow University, who has done so much for the profession in establishing and consolidating our knowledge of the theory of engineering. This giant mind has vied with that of Telford in creating the profession.

Both were Scotchmen, and they have left, each in his own sphere, enduring monuments behind them.

Telford in his magnificent constructional work and noble example. Rankine in his profound writings.

Strange to say both were gifted with the poetic temperament, which may have had much to do in moulding the character of their work. Their lives would form the subject of one or two splendid papers to our association.

Workshop Training.

The importance of a personal knowledge of workshop practice and the acquisition of skill in some department of it cannot, I think, be estimated too highly in the training of the civil engineer. Many branches of practical work might be recommended as of great use, but of the various departments of work which are related to civil engineering, I do not know of one more beneficial as a training than patternmaking. In this one acquires skill in the use of tools, accuracy in the execution of work, with knowledge of how the metal ought to be disposed to ensure sound castings, whilst all the time one is brought into close contact with workmen and their methods of work. With my own pupils or apprentices I endeavour to give each at least six months of work in the patternshop, and I am confident that in after life they will fully appreciate the value of this. Telford used often to congratulate himself, even when he had reached the highest rank in his profession, upon the circumstances which had compelled him to begin his career by working with his own hands. To be a thorough judge of work he held that a man must himself have been practically engaged in it.

> "Not only," he said, "are the natural senses of seeing and feeling requisite in the examination of materials, but also the practised eye, and the hand which has had experience of the kind and qualities of stone, of lime, of iron, of timber, and even of earth, and of the effects of human ingenuity in applying and combining all these substances, are necessary for arriving at mastery in the profession; for how can a man give judicious directions unless he possesses personal knowledge of the details requisite to effect his ultimate purpose in the best and cheapest manner? It has happened to me more than once, when taking opportunities of being useful to a young man of merit, that I have experienced opposition in taking him from his books and drawings and placing a mallet, chisel, or trowel in his hand till, rendered confident by the solid knowledge which experience only can bestow, he was qualified to insist on the due performance of workmanship and to judge of merit in the lower as well as the higher departments of a profession in which no kind or degree of practical knowledge is superfluous."

In concluding my notes on the subject of education, in which I have tried to shew the necessity for organised training of as complete a nature

as possible, it may appear strange for me to add that every engineer must educate himself. But there never was a truer statement. Our knowledge as engineers, in the truest sense, is not acquired, either in school or university, but in personal investigation and after study. The training we receive from our teachers in such seminaries is only meant to provide us with the mental tools for after study. No such instruction will ever meet the complexity of detail the engineer has to deal with in the innumerable problems of his daily practice. For these special study is required, and the exercise of judgment.

By the term judgment I mean that which in ordinary language goes by the name of commonsense, but it must be the commonsense of the engineer in dealing with engineering problems. The cultivation and exercise of this faculty cannot be too strongly insisted on in the engineer. It is by the employment of judgment or commonsense that many of his most difficult problems are brought to a successful issue, where mere calculation would be inapplicable.

Judgment is that fine balance of the mental powers, where scientific knowledge in the one scale controls practical conception in the other, neither prepondering but both instinctly and unconsciously operating on the mind.

In these imperfect notes, Gentlemen, which I have essayed to put before you for the benefit of our younger members, I have endeavoured to hold aloft the ideal of what is best in engineering, and to some this ideal may seem the unattainable. To such I would reply, all true ideals should be unattainable, and without some ideal before us how can we know what to strive for.