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PAPER VII.—ENGINEERING AND ENGINEERS.

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"ENGINEERING is the art of directing the great sources of power in nature, for the use and convenience of man." So said Thomas Telford, the eminent Civil Engineer, just 51 years ago, when, as first President of the Institution of Civil Engineers, he delivered his inaugural address. So, with even greater justice and honest exultation, may the Engineer of the present day exclaim, looking back at the mighty strides which science has made in the last half-century, and on the amazing results which surround us.

So numerous, so vast are these results, that we are fairly staggered with the magnitude of the subject as we begin to recall them. They meet us at every turn of daily life, and fill us with ever-fresh surprise at the wonderful powers which the Divine Creator has hid in nature, and at the wonderful ability with which He has endowed man to develop those powers.

In peace and in war, in our quiet homes and in the rushing travel of the day, on land and at sea, we meet the Engineer, and enjoy daily a thousand advantages and comforts from his skill and labor. The lighthouse which welcomes us as we approach the land; the breakwater which secures the anchorage; the quays and wharves at which the ship, itself of iron, curiously wrought together, unloads; the engines within it, so mighty as to be capable of urging the mass, weighing thousands of tons, against the storm and over the ocean, to the appointed post, and yet so delicately made that a bearing scarcely heats, and that the touch of a finger can govern the whole; the motive-power of water so combined with heat as to create steam—a power so terrific, that, uncontrolled, it can shatter into fragments the vast fabric which it is made to move, and yet so exquisitely controlled as in its use to prevent the very evils that would neutralize its power, and, as in the locomotive, to fan the flame that, fanned, creates fresh steam; the railroad, which, diminishing distance in proportion as time is saved, bears along that ever-increasing freight, and those ever-increasing myriads which no other known means of communication could have borne, carries the weary man of business and the toil-stained mechanic daily from the smoky, stifling town to the clean, invigorating country, or the eager traveller from the ship to his expectant home, to which his approach has already, swiftly as by lightning, been made known by the "winged word" which electricity speeds over the earth and under the sea,—one and all of these reflect the Engineer; while that home itself, lighted with gas, supplied with water, and warmed, ventilated, and drained, presents ever-present proofs of what we owe to science, and speaks of labor and discoveries not less real, if less striking, than the steamer, the railroad, and the telegraph, and certainly not contributing less to our daily comfort and increasing health and power of life.

Or if we turn to war: those fortresses which enable the defenders of a country to resist the attack of a superior force; those torpedoed and submarine mines which defend its shores and rivers; those huge guns, 85 tons in weight, carrying a missile of 700 lbs. in weight at a distance of six English miles; the improved missiles themselves; those great plates of iron so craftily bolted together as almost to defy even such missiles; those cunning and yet simple rifles, breech-loading, deadly at 1000 yards in skilful hands; those adaptations of light, of signals and of electricity, for instant communication to troops scattered over long distances; those most ingenious means of ascertaining the velocity with which the projectile leaves the gun from which it is fired, and of ascertaining the disruptive force of the powder, when fired upon the gun itself; those carriages in which the very recoil of the gun is made of use to cover the gun out of sight of an enemy,—these and many other such-like things, among which may be mentioned the balloon, pressed into the service, present to us the Civil, the Mechanical, and the Military Engineer, combining with the Artilleryman in labors honorable to themselves and useful in the highest degree to their country.

Or, returning to the wants of peace: in the canals and locks which evade the rushing rapids, and turn the flank even of Niagara; in the improvement, generally, of internal navigation; in the drainage of low lands; in the construction and maintenance of embankments to resist the encroachments of the sea; in the formation of roads, carried with gentle gradients over the scientifically-sought lowest summits; in the erection of bridges over wide and rapid rivers—as, for example, the world-famed Victoria Bridge at Montreal; in the infinitely varied machinery, which appears almost endowed with life and reason, so wonderfully does it perform the ponderous as well as the delicate tasks entrusted to it in the factory, in the mill, in the arsenal, in water, and on land,—we recognize, once again, the skill and toil of the Mechanical and Civil Engineer.

Among the labors of the Engineer, none, perhaps, possess more interest to this country, and especially at the present time, than those connected with

CANALS.

It appears not improbable that the earliest canals were constructed in Egypt, and had for their object the better irrigation of the Delta of the Nile. Herodotus, whose narratives, however, must generally be taken "cum grano," speaks of the formation of a lake called Moeris, 450 miles in circumference, which was completed about 1385 years B.C. This was connected with the Nile by three canals, and its objects were to prevent the Nile continually overflowing the country, and to maintain a supply of water for irrigation. Many canals are said to have been subsequently formed in Egypt by Sesostris; and about 610 years B.C., Necos is said to have commenced a canal to unite the Mediterranean and Red seas. This was continued by several monarchs, but apparently never completed, and was finally abandoned, until the Caliph Omar, about the year A.D. 644, or some 1354 years after its commencement, re-opened it, and cut another canal, which was used for upwards of 120 years, until the commerce of Alexandria was destroyed.

In Greece, many attempts to cut a canal across the Isthmus of Corinth, a distance of about five miles, failed. The traffic, and even the smaller craft, were, therefore, carried across it, somewhat as our passengers and goods are conveyed overland between Carillon and Grenville, en route to Ottawa.

Spain is indebted to the Moors for her canals, and for her system of irrigation generally. In China, the canals were said to have been of great antiquity; but they are probably not older than 900 years ago, a hundred years later than the first irrigation of Valencia.

In Italy, canals were of very early date. That through the Pontine Marches was cut about 162 years B.C.; and the Etruscans had made many before this, in connection with the river Po. The Romans attached very considerable importance to such works, and, both at home and abroad, frequently executed extensive works to improve the inland water-communication. But these works fell into decay with the decline of the Empire, and it was not until the 12th century that the construction of canals recommenced in Italy and Holland.

Between the 12th and 15th centuries many improvements in connection with canals were made in the navigation of the rivers Brenta, Mincio, Arno, Reno, Ticino, and Adda. But it was not until the year 1481 that two brothers, said to have been Dionisio and Pietro Domerino, of Viterbo, introduced, in a canal running from Padua to Shal, the lock-chamber, enclosed by a double pair of gates, instead of the arrangement called the "conch," which had been in use in Italy since the 12th century. The fame of the invention of the lock spread throughout Europe, and the whole system of inland navigation benefited by it.

Among the first navigable canals commenced in France, after the Roman era, was that from the Saone to the Loire. This was begun about the middle of the 16th century; but progress was suspended from time to time, and it was not finally completed till about the close of the 18th century. The canal is 114,322 metres, or—English miles long; the length of each lock is 100 feet, and breadth 16 feet; breadth of the canal at the top, 48 feet; at bottom, 30 feet, with an average depth of 5 feet 3 inches. There are 30 locks from Dijon to the summit-level, giving a rise of about 240 feet; from whence to the Saone there is a descent of 400 feet, accomplished by fifty locks.

The canal of Languedoc connects the Garonne, below Toulouse, with the Mediterranean, at Cette. It was commenced about the year 1666, and completed in 15 years. It is 64 feet broad at top, 34 feet at bottom, and 6 feet 4 inches deep. The vessels which navigate it carry about 100 tons.

Another remarkable canal is that connecting the Somme with the Scheldt, which was commenced in 1766 and completed in 1810. Its length is 32½ miles, including two tunnels—one of 1200 yards, and the other of 3½ miles long. It rises in its course 33½ feet, and falls 124 feet.

There are now in France nearly 3,300 miles of canals, a vast extent, especially when we consider that such works were commenced in that country nearly 400 years after they revived in Italy, and when we reflect upon the interruptions to which they were subjected during all their earlier history.

Before quitting the subject of canals, in connection with French engineering, we must for one moment refer to the Suez canal. This canal, nearly 100 English miles in length, runs from Port Said to Suez. The mean level of the Red sea is only 6 inches higher than that of the Mediterranean, and the tides in both seas are feeble; consequently, there are no locks. It is intended to attain a depth of 26 feet of water throughout. Its cost will probably be £20,000,000 sterling. Its execution is mainly due to the rare courage and perseverance of M. Ferdinand de Lesseps, who, by cutting across the sand uniting Asia and Africa, has opened a water-communication which will revolutionize the mode of conducting the traffic between the east and west, and which will never be closed while civilization exists.

Late as France was in the field, England was even later; for the first canal of any importance in England was that from Worcester to Manchester, constructed by James Brindley for the Duke of Bridgewater, who, in 1758, only got an Act of Parliament for it in order to open out his coal-fields in South Lancashire. The construction of canals then became the rage, and prevailed during 40 years, and less ardently for nearly 30 years longer. As a result, there are about 120 canals in the United Kingdom, having an aggregate length of 3,000 miles. And as the superficial area of France to the United Kingdom is as 12 to 7, the latter possesses, in proportion to the size of her territory, very much more canal-accommodation than France.

Among the canals in Britain, the Bridgewater canal, already referred to, is justly celebrated for the excellence of its works, constructed, as they were, in the infant days of canal-making, by which, except for a distance of 600 yards, at Runcorn, where the Mersey is entered by 10 locks, which are together 82 feet 6 inches, the navigation for 73 miles is on one level.

The Caledonian canal, connecting the Scotch lochs, and affording, with 21 miles of canal, a navigable line upwards of 100 miles in length, between the seas on the eastern and western coast, will never be forgotten by any who have had the happiness of beholding the surpassing beauty of the surrounding scenery.

"A thing of beauty is a joy for ever."

The depth of water in the canal is 20 feet. The canal is 122 feet broad at top, and 50 feet broad at bottom; and there are 23 locks, 40 feet wide each, and 172 feet long. The work occupied from the year 1803 to 1829, and the total cost was nearly £1,000,000 sterling.

On the Ellesmere and Chester canal is a celebrated aqueduct, by which the canal is carried at a level of 127 feet over the river Dee. The bottom and sides of the canal are here made of cast-iron plates, within which the water flows. The water-way is 11.10, of which the towing-path covers 4.8. The total cost of the aqueduct was about £47,000, sterling.

The Grand Junction canal, which connects the iron and coal fields of the Midland Counties with London, falling into the Thames at Brentford, is 90 miles long, 42 feet wide at the water-surface, 28 at bottom, and 4 feet 6 inches deep; lock-chambers, 80 feet long; breadth, 14 feet 6 inches. Steam-power is required to raise the water for the supply of the canal from one reservoir to another. The canal, in its course, first rises 37 feet, then falls 60, and then 112 feet; rises again 192 feet, and falls again, first 127, and then 268 feet. Its total cost was about £2,000,000 sterling.

In the Huddersfield canal, there is a rise of no less than 436 feet, made by 42 locks, and a subsequent descent of 334½ feet, divided by 33 locks. The Leeds and Liverpool canal is 127 miles long, with a rise to summit-level of 411½ feet, and a fall of 433½ feet. The locks will receive boats 70 feet long and 14 feet beam, and the least depth of water is 4 feet 6 inches.

The Shropshire canal presented a very curious feature in its inclined planes. It passed through a rugged country with a great scarcity of water. On the banks of the Severn on an inclined plane 1050 feet long, with 207 feet of perpendicular height, was a strong double railway, up which the boats, with their loads of five tons each, were drawn. They then passed along a level canal, descended by another inclined plane, and so on. These works were completed in 1792.

The canal tunnelled through the chalk between the Thames and Medway is in all 7 miles long, of which 2½ miles form the tunnel. It occasioned considerable anxiety and inconvenience by affecting the wells in the neighbourhood; but it saves the passage round the Nore and up the Medway, and nearly fifty miles in navigation.

A curious tunnel was once constructed by Brindley, only 9 feet wide and 12 feet high. It was nearly 3000 yards long, and boats could only be propelled through it by men called "leggers," who, lying on their backs, pushed against the sides and top of the roof with their feet. A boat occupied two hours in passing through. It has been replaced by more convenient works.

On the Great-Western Canal were made lifts 46 feet high, up and down which boats weighing about eight tons ascend and descend in cradles, in about three minutes, with an expenditure of about two tons of water only.

HOLLAND.

Holland, the level of a great portion of which is beneath the sea, is a country covered with embankments and canals. The very rivers are maintained within their course by artificial banks. Where the canals do not unite, vessels are transported from one to the other by mechanical contrivances. As a modern work may be mentioned a new ship-canal, to be finished in five or six years, now in course of construction, to connect Amsterdam with the ocean. The distance by the present canal is fifty-two miles; that by the new canal will be 15½ miles only, navigable for larger vessels than can now come up. This canal will be 197 feet wide at top, and eighty-eight feet at bottom; minimum depth, 23 feet; locks, 59 feet wide. It will connect with a magnificent new harbour, which is being formed on the coast by three locks or entrances. At the other extremity, below the city and wharves of Amsterdam, will be a vast dyke to shut out the Zuider Zee, with three locks and sluices. The surface-water of this canal has to be kept twenty inches under low water-mark; and the locks at each end are required for locking down. Besides the locks and sluices, three centrifugal pumps have been provided, which, together, will lift 440,000 gallons of water per minute. The shallow lakes through which the canal runs have to be re-drained to admit of this.

THE UNITED STATES.

It would be useless for me to enter here into any description of the canals existing in the United States. They are probably better known to most present, practically, than they are by me, even theoretically. It may be sufficient to say that in this, as in other Engineering works, the people of the United States have shewn themselves worthy descendants of the mother-country. No labor has been spared to render inland-water-communication complete. One of the peculiar features has been the admirable use made of timber in the construction of viaducts. Another is the vast length of the conjoined canal and river lines.

The Ohio canal extends from Portsmouth to Cleveland, a distance of 307 miles.

The canal between Albany and Buffalo, on Lake Erie, with its numerous branches, and that between Albany and Oswego, on Lake Ontario, are respectively 363 miles and 209 miles in length, and are capable of passing vessels of 210 tons burden; and the canal from the Hudson river into Lake Champlain is 65 miles in length, and capable of passing boats of 80 tons burden. In the Morris canal, the rise and fall, which is not less than 1674 feet in about 102 miles, was mainly overcome by inclined planes, with a lock at each end and at the top of each plane, the boats being drawn up and lowered down the planes by machinery. The length of the canals in the United States much exceeds that in Britain; and there can be no doubt, from the energy and vitality which its people display, that wherever a canal is required in the States, there it will be made.

CANADA.

In Canada itself, the Welland canal, 28 miles in length, connects Lakes Erie and Ontario. It has a fall of 260 feet, and can pass through vessels of 400 tons. From Lake Ontario to Lake St. Louis, seven short, canals of the total length of 47 miles, overcome the fall of 220 feet in the river St. Lawrence. Through these, vessels of 650 tons can pass. The United States canal, of about one mile in length, at the Sault St. Marie, connects Lakes Huron, Superior, and Michigan. Vessels of 2000 tons can pass through this canal.

By these canals, and those already referred to as connecting Lake Erie and Lake Ontario with Albany, navigation exists between the tidewaters of the Hudson, the Upper Lakes, and the St. Lawrence sea-navigation.

The further improvement of this canal-communication would appear to be of the highest importance to the development of Canada; and it is satisfactory to know that the subject is attracting more and more attention.

In connection with these canals, the Canal Commissioners, in their recent report, dated 24th February, 1871, recommend the construction of a new canal in Canadian territory, at the Sault St. Marie; the enlargement of the Welland canal and of the St. Lawrence canals; the construction of a second set of locks at the lower entrance of the Lachine canal, with 17 feet of water on the sills; and the improvement of the channels of the St. Lawrence, so as to give 14 feet of water throughout above Montreal, and 22 feet draught, at low water, between Montreal and Quebec: the canals to have an uniform width of 100 feet, with locks having 270 feet of chamber between the gates, 45 feet in width, and 12 feet of clear draught on the sills; the bottom of the canal to be at least one foot below the sills of the locks. By these means, it is considered that vessels ranging between 1000 and 1500 tons could trade between Chicago and Montreal, a distance of 1261 miles.

In addition to the above, the Commissioners recommend, as works of first-class importance, the improvement of the existing line from Allanburgh to Port Dalhousie; the Ottawa canal improvements, from Ottawa city to Lachine; the enlargement of the Chambly canal, and the construction of the Bay-Verre canal.

The locks for the Ottawa and Chambly canals are recommended to be 200 feet by 45 feet, with 9 feet draught over the sills; the locks for the Bay-Verre canal, 270 feet in length of chamber, 40 feet in width between the gates, and 55 feet draught of water on the sills.

The Commissioners further recommend, as works of the second-class, but prospectively of the utmost importance, the construction of the Upper-Ottawa canal, and the deepening of the rapids of the St. Lawrence to a minimum depth of eight feet at the lowest water.

The Rideau Canal should be maintained as one of the public works of Canada; but the construction of the Caughnawaga canal, and of the Erie and Ontario ship-canal, the Commissioners consider should be left entirely to private enterprise. The projected Georgian Bay canal, which is equal in length to that of the Suez canal, and is encompassed with natural obstacles infinitely greater, is regarded as commercially worthless, if not altogether impracticable.

The cost of the improvements recommended is estimated at \$13,170,000. But this expenditure is considered as insignificant when compared with the immense benefits that would arise from the carrying-trade of the great West passing through Montreal and Quebec, instead of through New York. The Government, as I gather from the columns of the daily press, have decided to proceed with a portion of the improvements recommended for the Welland canal, for the Ottawa canal at Grenville, and for the St. Lawrence; but have deferred action regarding the remaining recommendations, on various grounds. Cordially must we all unite in hoping that in these most important works, Engineering and Engineers may assist its people to the utmost possible extent in developing the resources of this noble country, before which such prospects of a great, useful, and happy future are being so continuously unfolded.

RAILROADS.

The question of railroads is not of less importance to the Dominion of Canada than that of canals.

Prior to the 17th century, wooden railroads were in use at the Newcastle coal-fields. Originally, the waggons worked along single lines of longitudinal timbers; but as the frequent repair interfered with the traffic, an upper rail of wood was pegged to the timbers, and renewed as it wore away.

The first iron rails were probably those of cast-iron used at the Norfolk colliery, near Sheffield, about 1776; but cast-iron wheels had been introduced about ten years before at the Colebrook-Dale iron works. At this time the flange was on the rail, instead of on the wheel, as at present.

Various improvements succeeded; and in 1820 a patent was obtained, embodying the principles upon which rails are now made for railroads, viz., by passing them, when red-hot, through rollers grooved in the required form.

In 1802, the first patent was taken out by Richard Trevithick for a locomotive-carriage, on the high-pressure principle, to work on a road or railroad. In 1811, Mr. Blenkinsop took out a patent for the first double-cylindrical engine. This weighed five tons, and drew 94 tons on a level, at 3½ miles an hour; one wheel being toothed, and working in a rack on the side of the railway. Various improvements followed; and in October, 1829, took place the famous trial in which Mr. Stephenson's and Mr. Booth's locomotive, the *Rocket*, won the prize.

The *Rocket* and tender weighed only 7½ tons, and drew 44 tons, gross, at the rate of 14 miles per hour. From this may be said to date the present locomotives.

Between 1811 and 1822, increasing attention had been drawn to the subject of railroads. In that year the Stockton and Darlington Railway was proposed; but, from the opposition met with, the act was not obtained until the following year. This was the first railway opened in England. In 1824, the bill for the railway between Liverpool and Manchester was lost, in committee, from a similar cause, and withdrawn. It was not again introduced until 1826, when it triumphed over all opposition, and the line was at once proceeded with. From that time the construction of railways proceeded with increasing rapidity in England, until it became almost a mania, which reached its climax about 1845, and vast fortunes were made and lost in railway speculations. Since that time, however, many lines have been made, but with more consideration as to their necessity and probable commercial results.

From England the construction of railways spread over Europe, and extended to the United States. But it is a fact, and remarkable as shewing how slow the ablest men sometimes are in grasping the value of the results of science, that, soon after Louis Philippe came to the throne of France, Monsieur Thiers, now president of the present government in France, was sent to England to examine as to the advantages of the railway system, and reported against its adoption in France; and that thus the introduction of railways in France was postponed for eight or ten years. Such an error of judgment may, however, be the more readily excused when it is remembered that so late as the year 1835, Dr. Lardner, a man unquestionably of the highest ability, declared that it was a mechanical impossibility for steamers successfully to cross the Atlantic.

As a sort of contrast, and as among the most interesting works of the period, we may turn to those known as the Mont Cenis Tunnel and the Mont Cenis Railway. The estimated length of the tunnel, which does not pass under Mont Cenis, is 7½ miles (English), and the cost not less than £4,000,000. It is intended to connect the railways of France and Italy. The rails of the Mont Cenis railway, which is altogether independent of the tunnel, follow the surface of the road over Mont Cenis. The necessary adhesion is obtained, and also perfect safety to the train, by the pressure of horizontal wheels on a central rail. The new engines will take up loads of 50 tons. Between St. Michel and Susa, the line is 50 miles in length. It cost, with engines and rolling-stock, about £5,000 a mile, and affords an admirable solution of the difficulty of surmounting mountain ranges at a moderate cost. The working expenses are, however, heavy.

There are now in England between 14,000 and 15,000 miles of railway; in France, between 10,000 and 11,000 miles; and in the United States, upwards of 43,000 miles. The latter lines, however, though made to carry the traffic which passes over them, cannot compare for finish with the lines at home.

(TO BE CONTINUED.)

