A GLANCE

AT THE

VICTORIA BRIDGE,

AND THE

MEN WHO BUILT IT.

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DEDICATED (BY PERMISSION) TO THE GRAND TRUNK RAILWAY OF CANADA.

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TO THE READER.

HAVING been requested by an artist who has given to the world a series of magnificent views of the wonderful structure, to prepare an article on the Victoria Bridge, and the men who built it, the writer has endeavoured to comply with those wishes to the extent of his ability, but at the same time conscious of his inability to do the subject justice, from the great difficulty in furnishing a written description of intricate machinery and mechanical operations, without the aid of diagrams and professional phraseology, —or, in other words, to draw pictures of the work for the mind's eye to dwell upon, in language readily understood by the general reader.

This difficulty will be appreciated by his professional brethren, and must serve as an excuse for the general views given of the mode in which the works were carried on. The apology will readily be accepted when they are informed of an elaborate work on the subject shortly to be issued from a far abler pen; and, with this pleasing prospect, it is hoped that they will regard the following production with a kinldy eye, as the first effort of a younger brother.

To the critical reader and the public, the writer can only say, that he appears before them with all the nervous trepidation of a very bashful young man, anxious to please if possible, but frightened at his own temerity in venturing into this prominent and noble field of view.

A word or two may be necessary in explanation of the opening chapter of the work. It will be admitted by all, that, in drawing a sketch of the men who built the Victoria Bridge, the foreground of the picture should be occupied by the illustrious STEPHENSON; but in attempting to consider the author of the tubular system, the mind instinctively reverts to the father, whose achievements rendered necessary the great Britannia and Victoria Bridges,—structures which would be without existence, had it not been for the undaunted energy, genius, and determination of character possessed by the once poor and ignorant collier lad,—the two great developments being mutually dependent on, and necessary to each other. Following this idea, a sketch of the country which required and obtained both, to their fullest extent, has been given. Numerous authorities have been consulted and made use of throughout the entire work.

The late unhappy discussions as to the amount of credit due different Engineers for the projection and successful carrying out of this wonder of the age, led to a thorough examination into the various plans and reports brought forward by these gentlemen at different periods, and it is hoped that the impartial verdict of the reader will render justice to all. With the oil thus thrown upon the troubled waters, may they imitate that perfect self-abnegation which characterized the writings and public speeches of George and Robert Stephenson, when dwelling on their own works; resting confident, that as the Victoria Bridge was not accomplished by one man, to no one will all the praise be awarded by a discerning public, but each receive his meed of credit according to the degree entitled.

If this result will to any extent be brought about by a perusal of the following pages, the writing of them will not have been in vain.

Montreal, April, 1860.

CHAPTER I.

THE STEPHENSONS.

THE nineteenth century of the Christian Era dawned upon the world with the star of Napoleon in the ascendant, The devastations which marked the pathway of "the man of destiny," had spread over the fairest portions of the civilized world, with the exception of those inhabited by the Anglo-Saxon race; and even there, the paralyzing influences of war were felt. The arts, manufactures, and commerce had received blows from which they did not recover for years. The reaping-hook and the weaving-loom were exchanged for the sword and the bayonet. The "nation of shopkeepers" were, almost to a man, banded together with the stern resolve to hurl back the invader, and stem the torrent of conquest, pillage, and blood, which so nearly brought the human race under the iron heel of this despot; and when Providence at last smiled on the heroic efforts of those brave islanders, permitting them to bind the tyrant, Prometheus-like, to the rock in the ocean, they were enabled to start again in the race of human progress, and resolutely embarked in those schemes and enterprises which have resulted so largely in the welfare and happiness of man.

But while emperors, kings, and generals were dividing the world, as it were, among them, and sacrificing myriads to their insatiable lust of dominion and power, doing deeds, for the perpetuation of their names and dynasties, which caused humanity to weep, little did they think that the 9th day of June, 1781, had ushered into the world an infant, before the splendour of whose subsequent achievements their brightest deeds would pale, and whose name would be embalmed in the hearts of millions, ages after their memories and crimes had faded from the historic page. Little did the people of Britain imagine, that the four bare walls and clay floor of a miserable hovel, in an obscure colliery village in the North of England, contained a child whose future was to be so closely allied with the empire's welfare and glory, and by the force of whose genius she was afterwards to be indebted for the foremost place in the march of civilization and wealth. Little did Mabel, the mother of George Stephenson, think, as she held her half-starved child to her bosom, and endeavoured to still his cries with the miserable pittance their scanty means afforded, that he would in turn give food and prosperity to nations, and stand foremost as one of the greatest human benefactors the world ever produced.

We see him subsequently advancing through the period of childhood and boyhood up to the age of eighteen, at which time he was unable to read or write his own name. So severe had been the struggle for mere existence, that the situation of herd-boy to a poor widow was eagerly petitioned for, and the salary of two-pence per diem thought handsome remuneration. To be stationary in life was not in accordance with the boy's feelings, and he soon found promotion to the responsible position of guiding the plough-horse and officiating as general assistant on the neighbouring farms, in hoeing turnips, and in performing other light field work, for which he received the munificent sum of four-pence a day. Strongly impressed, however, that employment in this rural field of labour, honorable and useful as it undoubtedly was, did not offer the proper scope for his longing mind, we next find the ambitious boy at work with his father and brothers in the colliery, and rapidly rising from six-pence, eight-pence, a shilling, and at last, as fireman on his own account, to two shillings per day; and hear him, on the receipt of the first week's pay of twelve shillings, giving utterance to the joyous exclamation, "I am now a made man for life!" This extaordinary piece of good luck, instead of causing him to rest on his laurels, apparently exercised the contrary effect, proving but a stimulant to increased exertions, and resulted in the expenditure of three-pence a week as tuition-fees, to Robert Cowens, for the privilege of being initiated into the mysteries of the English alphabet and the construction of "pot-hooks." To the reflective mind, what an interesting sight is this, of a strong healthy lad, destined in a few years to revolutionise the commerce of the world, striving, by the dim light of a coal fire, after the severe labours of the day, when his companions were either seeking repose or engaging in such amusements as their condition in life afforded, to see him, under almost insuperable difficulties, labouring so earnestly in the acquisition of the most rudimentary learning, that he might be able to become more thoroughly acquainted with the construction and working of the steam-engine, and proud, at the age of nineteen, to write his own name.

The thirst for knowledge in a case like this, was not easily assuaged, and we are not therefore surprised to learn, that, during the next winter, the services of Andrew Robertson, a "Scotch dominie," and probably more advanced in the walks of learning than his predecessor, Cowens, were put in requisition, and under his supervision young Stephenson mastered the intricacies of common arithmetic.

This small stock of learning was increased by practice, and as fast as opportunity would permit. Having qualified himself for the place of brakesman, he was employed in that capacity in a colliery till 1812, when he was thirty-one years of age, never receiving wages higher than about one pound per week. His earnings were increased, however, by mending shoes for his fellow-workmen and by cleaning clocks. No mean motive prompted the extra effort to increase his income: he had formed an attachment for a respectable young woman, named Fanny Henderson, a person of excellent character, to whom he was united about the year 1802. It is related of the future great engineer, that, during the halcyon days of courtship, he had the privilege of exhibiting his mechanical ability in re-soling fair Fanny's shoes, and, lover-like, carrying them about in his pocket on the Sunday afternoon, pulling them out occasionally and gazing exultingly on the capital job he had made. Out of his first cobbled earnings he saved a guinea, and told a friend "he was now a rich man."

Well does America's most eloquent statesman* remark: "He said truly, he was rich in his joyous spirit and resolute will, rich in his industrious and temperate habits, and rich in his love for a virtuous young woman, worthy even of him."

But this happiness was of brief duration: two short years saw those beautiful blue eyes closed in death, leaving to the sorrowing boy-widower, and the world, a precious legacy in the infant Robert Stephenson. The wife's great mission in life had been accomplished. It was not for her to tread its rugged paths in company with the noble-hearted husband, to cheer and aid him in his troubled moments and exult in his success. Hers was not the task of training up the youthful Robert to follow in his father's footsteps, and eventually to see him as illustrious. But could her pure spirit have looked down from its home on high, it would have witnessed that love still unchanged, and her vacant place for seventeen long years unoccupied.

* Hon. Edward Everett.

It would have seen her beloved boy the admiration of the world, and, on the completion of his last and greatest earthly work, entombed amongst England's mighty dead; mourned over by all, from the Queen on the throne to the humblest artizan in the land.

We have thus seen George Stephenson at the commencement of his career deprived of his loved companion, and, with a helpless infant and a blind father, left to pursue his journey alone. But " Onward " was his motto, and when in after years he emerged from the depths of the coal mines, to the upper world, it was with a mind matured and equal to the position he was then to assume. At this time he was in receipt of £100 a year, a sum sufficiently large to admit of Robert, now a lad eleven years of age, being sent to a good academy, where he reaped advantages to which George had been a stranger. On Saturday afternoon he visited his father, bringing scientific books from a circulating library to which he had subscribed, and for a number of years became a joint student with him; the father not disdaining to learn from a boy, and the son happy in having the privilege of gleaning from a man.

While thus employed in self instruction, he was also engaged in solving the important problem of railway locomotion, and rapidly acquiring experience in that department, which soon made him the first engineer of the age. Struggling genius in this case, as in that of his predecessor Watt, found a friend in a British nobleman, Lord Ravensworth, to whom all praise is due for furnishing means by which he was enabled, in the year 1814, to inaugurate the Railway system, by starting the " Blucher Engine" up a grade of 1 in 450, drawing a load of thirty tons at the rate of four miles an hour. This engine was soon followed by an improved edition, bearing the euphonious name of " Puffing Billy," and justly regarded as containing the germ of all that was subsequently effected. From this period up to the year 1825, we find him vigorously prosecuting his improvements, in which he received valuable assistance from his son (who had returned from Edinburgh University) in all the elaborate calculations required. Rich indeed was the recompense he now received for all the care shewn and sacrifices made in the education of Robert, who, at this most important period of his father's life, wielded his powerful pen in bringing his vigorous and well-cultivated intellect to bear on the advocacy and development of the great experiment now about to be made by his revered parent.

What may well be termed the crowning and successful achievement of George Stephenson's life took place on the 27th day of September, 1825. On that day the first passenger-train in the world was driven by him, over the Stockton and Darlington Railway. Other works of greater magnitude afterwards emanated from him, but none that can for all time be viewed with the same interest.

And now commenced a movement in Britain and on the continents such as the world never before witnessed. Rivers were spanned, deserts crossed, impassable marshes bridged, valleys filled, and mountains levelled. The slumbers of eighteen centuries were dispelled, and an energy infused into the commercial community which a few years before would have seemed Utopian. The spirit of the Stephensons apparently animated kings, princes, and nations; and where before the footsteps of conquerors left desolation and misery, the shrill whistle of the locomotive brought back life and animation. From the country of the Pharaohs, the Ind, the land of the cocoa and the palm, from the wilds of America, or following the course of the sun and the drum-beat, westward till it re-echoed from the east, was heard that same piercing sound, carrying civilization and liberty in its train, and in eloquent language telling all nations and tribes the story of the collier lad's success. It would under other circumstances be a pleasing and instructive duty to dwell upon the early struggles and subsequent success of George Stephenson, but enough has been said to draw attention to how great were the first, and complete the last, to point him out as a bright beacon to young mechanics and others, now entering on the arena of active life, as well as to those who have experienced its hardships and crosses, teaching them that no matter how severe may be the discouragements under which they labour, they were far surpassed by those which attended up to middle age the father of railways; and, though they may not reach the goal he did, yet, with the same indomitable perseverance united with honesty of purpose and thirst for knowledge, the difficulties will vanish and honorable position be attained. The name of his illustrious son, though not so immediately connected with the motive power of Railways, yet in other fields bears, if possible, a still brighter lustre from the extraordinary difficulties he surmounted in developing the railway system of the world. The impetus given by the elder Stephenson, was augmented by the son. New principles of construction were discovered, and adapted to the requirements of the age. Mountains were perforated and bridges of fabulous spans thrown across mighty rivers for the accommodation of traffic, without a parallel. No space of time such as the ancients occupied in their works, was allowed, but, with the principles of construction grasped intuitively, the mighty structures, Aladdin-like, sprang into existence. A relative comparison of the genius and works of those two illustrious men, is a difficult thing to arrive at, from the circumstance of their labours being to a certain extent of a joint character. Thus the father, after having fought the locomotive battle for nearly twenty years, single handed, against the combined scientific and commercial world, who were of opinion that this wild scheme originated in the diseased brain of a "Northumbrian maniac," when after having, by the force of his indomitable will and persistent earnestness not less than by powerful arguments, induced the Directors of the Liverpool and Manchester Railway to offer a prize of £500 for the best Locomotive Engine, which by a certain day should be produced on the railway, and perform certain specified conditions in the most satisfactory manner, now saw himself in a position to carry out the daydream of his life, and, knowing that success must be now or never, determined to call to his assistance a fast friend and helper, to stand by and aid in developing his plans for the locomotive railway system, and, feeling that every dependence could be placed on the matured judgment and scientific ability of his son Robert, he consequently urged him to return from South America, which he did, and joined his father in England during the latter part of the year 1827. A gentleman yet living remembers the vivid interest of the evening discussions which then took place between father and son as to the best mode of increasing the powers and perfecting the mechanism of the locomotive. He wondered at their quick perception and rapid judgment on each other's suggestions, at the mechanical difficulties which they anticipated, and at once provided for in the practical arrangements of the machine, and speaks of these evenings as affording most interesting displays of two actively ingenious and able minds, stimulating each other to feats of mechanical invention, by which it was ordained that the locomotive engine should become what it now is. The son also found abundant occupation with his pen, in answering the arguments of the learned and scientific: "That a speed of six miles an hour was a physical impossibility; that there were strong probabilities of the engine blowing up at any moment; that the cows in the neighbouring fields would cease giving milk from the severe shocks their nervous systems would sustain from the passage of these hideous monsters; that the birds of the air, in flying over the line of railway, would suffer collapse and die; then the breed of horses would be destroyed, country inn-keepers ruined, posting towns depopulated, the turnpike roads deserted, and consequently the institution of the English stage-coach, with its rosy coachman and guard, known to every buxom landlady at roadside country inns, would be discarded, fox-covers and game preserves would be interfered with, agricultural communications interrupted, and land thrown out of cultivation, with owners and farmers alike reduced to beggary; the poor rates increased in consequence of the number of labourers out of employment; and lastly, the danger of women miscarrying from the sudden shriek of the locomotive." A peculiarity belonging to these arguments was they generally wound up with the consoling reflection that railways would prove only monuments of the folly of their crazy projectors, whom they must inevitably involve in ruin and disaster. Many wise doctors, amongst whom was Sir Anthony Carlisle, insisted that tunnels would expose healthy people to colds, catarrhs, and consumption; and, in the very laudable desire of guarding the public against such maladies, they painted in all their horrors the noise, darkness, and danger of this mode of travelling.

The most serious and original feature was the destruction of the atmospheric air, as pourtrayed by the celebrated Dr. Lardner. This gentleman went into elaborate calculations to prove that the ventilation as provided by shafts would be altogether insufficient to prevent danger arising from the consumption of coke, producing as it did large quantities of carbonic acid gas, destructive to human life. He showed, for instance, that in a proposed box-tunnel on the Great Western Railway, the passage of a load of 100 tons, would deposit about 3090 lbs. of deadly gases, thus giving a pleasing prospect of an easy death by suffocation to the passengers going over lines containing such structures. These and many other objections, which at the present day would furnish food for laughter, were at that time seriously brought forward in Parliament, and advocated on all other occasions, with the view of crushing the movement in the bud; and the assistance rendered by Robert's pen at this most critical period, in dispelling those popular and scientific errors, was often alluded to in glowing and grateful terms by the father; while, on the other hand, we hear the son, in the year 1856, when at the zenith of his fame, as president of the Institution of Civil Engineers, informing that august body, that whatever he had done, and however extensive his connection with the railway development had been, all he knew, and all he had been able to effect, was primarily due to the honoured parent whose memory he cherished and revered. It must have been a pleasing thought in after years, in recalling this discussion, to dwell upon the success of the system he had advocated so earnestly and so well. With what pride could he not point to the fact that the close of the year 1856 exhibited the enormous sum of £308,775,894 sterling embarked in the construction of 8635 miles of railway in Britain alone, the whole of which had been raised by private individuals, without the aid of a single penny from the public purse! With what exultation he might have mentioned that the almost inconceivable number of 129,347,592 individuals had travelled over this net-work of roads, at the rate of 24 miles an hour to an average distance of 12 miles, at the rate of 1¼ penny per mile, and that, during the year above mentioned, the proportion of accidents to passengers from causes beyond their own control, was only 1 person killed to 16,168,449 conveyed. And going beyond his native country, he could show 10,000 miles on the European continent, and 26,000 miles in the United States, in active operation, together with 1500 miles in course of construction in Canada, all tending practically to annihilate distance in bringing the ends of the earth together and nations into close relationship, by enabling them to exchange more freely their respective commodities, abating national antipathies, and uniting more closely the families of mankind! What a forcible answer would all this not have been to the arguments brought forward by his croaking adversaries as to the curse which would be entailed were the system carried out which was advocated by his father and himself!

Deeming it therefore impossible to shew wherein one excelled the other, in so far as original conceptions or mechanical resources were concerned, we will, after having thus far dwelt on the Locomotive, which in a great measure must be attributed to the father, turn our attention to the, in other respects, equally important problem solved by the son; namely, the discovering of the principle and consequent establishment of the Tubular system of Bridging. The connection of London and Liverpool by rail having been made, public attention was now directed to further improvement of the communication with Ireland, by extending the land journey and diminishing the sea voyage, or, in other words, increasing the comparatively certain, and diminishing the uncertain portion of the journey. The two ports of Holyhead and Dynllaen, had each their advocates, but the preponderance of evidence as to suitableness terminating in favor of Holyhead, the line previously surveyed by Mr. George Stephenson was adopted with a short deviation of five miles. The mechanical structures on this line were of the most gigantic character. Never before in the history of modern engineering, had difficulties so great been met with, or so ably surmounted. The project of throwing railway bridges over the Menai Straits and the Conway River, was sufficient at first to appal even the mind of Robert Stephenson; but having once embarked in the scheme, the resolute spirit inherited from his father deterred him from giving up the task as hopeless, but rather urged him to the accomplishment of this herculean labour. The idea of making use of the present Suspension Bridge erected by Telford had occurred to George Stephenson in the year 1840, but as the present strength, together with any addition which might be made to it, was not thought adequate for the passage of railway trains with ponderous locomotives, the idea was abandoned by his son, and an independent bridge recommended about a mile to the south, at a site known by the name of the "Britannia Rock," in every respect an eligible point for crossing. The suspension principle for railway purposes, though since successfully carried out in America, was gone fully into in all its details; but with the recent failure of a bridge on this plan at Stockton-upon-Tees, before his eyes, and while acknowledging the possibility of stiffening the structure to such a degree as to admit of railway traffic, yet from the circumstance of the greatest portion of the material used in construction being wood and therefore possessing a perishable nature, and liability to destruction by fire, caused the adoption of this plan for overcoming the difficulties to be abandoned. The Britannia Rock being in the centre of the channel, rendered it possible to obtain two spans of 350 feet each, and, as the clear headway of 103 feet afforded by the existing suspension-bridge furnished a guage-height for this, Mr. Stephenson was consequently enabled to establish at once the governing data of the proposed structure, and proceeded to design two cast-iron arches, of the unprecedented spans above mentioned, with a versed sine of 50 feet, carrying the roadway at a height of 105 feet above the level of the high water at spring tides. The ordinary mechanical difficulties in the way of carrying out this plan under more favorable circumstances, were immeasurably increased in this instance, from the depth of water in the channels ranging from 50 to 60 feet, with a rush of tide at least seven miles an hour, which rendered the adoption of scaffolding impossible, even had the requirements of the Admiralty for keeping the navigation uninterrupted, not been a fatal condition. The resources of the Engineer were equal to even these emergencies, and the ingenious method proposed for overcoming the difficulties in the erection of those collosal spans without the aid of scaffolding or supports from underneath, will remain almost as enduring a monument of talent, as the wonderful creation of his genius which now spans the enormous chasm. On its becoming known what description of bridge it was proposed to adopt, an agitation was immediately commenced, by those interested in the navigation of the straits, who argued that it would be seriously impaired, by the contraction of the channels from the piers and from the spandrils of the arches, and that at the present time the navigation required the utmost skill from the great tidal currents, rapid eddies, sunken rocks, and baffling winds, without, as they alleged, having those dangers augmented by additional obstacles. So strong a power have vested rights in England, that Robert Stephenson recognised in this opposition the death-knell of his magnificent scheme, and resolutely set himself about the apparently impracticable problem of devising some other plan by which all these conflicting interests might be reconciled. In the meantime a Government Commission had been appointed to report on the affair, and, after mature deliberation and extensive examinations, gravely recommended that the two spans should be increased from 350 to 450 feet each, and, what was of still greater consequence, instead of being circular or arched, as in the original plan, they insisted on their being flat or straight throughout their entire length. And in the event of, as they supposed, these impossible conditions being complied with, ironically suggested that no opposition should be offered, or obstacles thrown in the way of the railway company bridging the Menai Straits. We have often wondered what were the thoughts of the directors of this road on being made acquainted with this ultimatum,—gentlemen who had previously regarded the proposed arched spans of even 350 feet with the utmost suspicion, as being too great a departure from precedent and possibility; or what were the feelings existing in the mind of the engineer to whose resources the company naturally looked for aid in this dark hour; but still more have we marvelled at the astonishment which must have pervaded Parliament, when Robert Stephenson appeared before their select committee and announced that he was prepared to comply with the stipulated conditions to the letter. This surprise could scarcely have been mingled with distrust or doubt, as they had before their eyes, and fresh in memory, the miraculous achievements of "the old Northumbrian maniac" of the same name and lineage as the gentleman who now stood before them, so calm in his simple manhood, and earnest in the belief of his ability to perform what he proposed. It is an interesting study to trace the various stages from the first conception to the successful carrying out of a great principle; to thus follow, step by step, the experiments and deductions in the establishment of the Tubular System from the time the idea flashed across the mind of the author, when reflecting on the numerous instances of extreme rigidity and strength in circular tubes belonging to the vegetable kingdom, the common wheat-straw and the river-reed in our own climate, and the gigantic stems of the bamboo in the tropics, towering sixty feet above the jungle. The idea thus suggested by nature of arrangement of material for strength, stiffness, and lightness combined, was eagerly seized hold of by the eminent engineer, enabling him boldly to inform the world that he was prepared to throw a straight tubular beam over the Menai Straits.

Being warned of the length this article has already reached before coming to the subject in view, we are unable to follow Mr. Stephenson through his interesting experiments, which resulted in the Britannia and Victoria Bridges,—two of the most stupendous and useful monuments ever produced by man, and destined to remain as such, it is hoped, till time shall be no more. We have written at some length on the Father of Railways, and on his son, the designer of the Tubular System, which now spans the Menai Straits and the mighty St. Lawrence. It has been done with the belief that many who read this, will for the first time be made acquainted in a slight degree with the early history of those remarkable and noble-hearted men, and lead them to a more intimate knowledge, from other sources, of the talents and energies they devoted to the material welfare and happiness of the human race, in all countries and of every tongue,—to know and thereby honour individuals, who, by the force of circumstances they themselves created, were brought into close and intimate relationship with kings, princes, and dukes, yet, while yielding the respect due to their exalted rank, never forgot they sprung from and belonged to the people, proudly preferring the simple appellations of George and Robert Stephenson to all the titles and distinctions repeatedly pressed upon their acceptance; and as the ponderous locomotive, instinct with life, drawing its enormous train of living freight, dashes past, causing the very earth to tremble, to lead the mind of the spectator back to the humble inmates of the clay hovel, and the long weary years of struggle before George Stephenson was enabled to bring forth this creature of his brain, and, while following with the eye the resistless, rushing, thundering mass, as it approaches and enters the gigantic structure high above the angry waters, cause the thoughts to revert to the genius of him who planned it, and now resting from his labours in the venerable and time-honoured Abbey, surrounded by Britain's illustrious and mighty sons.

CHAPTER II.

CANADA.

It may be proper, before commencing with the Victoria Bridge, to give a glance at the previous history of the country, whose recent development has resulted in the erection of the eighth wonder of the world, and in doing so to describe a few of the most prominent features. The time exists in the memory of many now living when the whole expanse of Western Canada was covered with a dense wilderness, with the exception of small settlements at different stations, between Lake St. Francis and Amherstburg, containing a population of not more than 20,000 souls at the time it was formed into a separate government in the year 1791. About the same period, the number of inhabitants in the eastern sections, or Lower Canada, did not exceed 130,000, principally scattered along the banks of the St. Lawrence from Montreal eastward. A rapid tide of immigration soon increased the numbers. From the overcrowded counties of Merrie England, came her brave and resolute sons, ready and willing to meet hardships and perils, that they might have a hearth and homestead of their own; Bonnie Scotland sent her stalwart, cannie, and industrious chiels, as pioneers in the march of settlement; while from the Emerald Isle, came thousands of her fervid children, happy in escaping from the clay cabins and misery of their green island home, with the prospect in view of an improved condition in the land of their adoption. Allured by the cheapness and good quality of the soil, together with the fine climate, many poured in from the neighbouring republic, all willing to acknowledge

Canada as their home, and, by their obedience to the laws and industrious and hardy habits, proving good subjects and settlers, none more gallant in assisting to roll back the tide of unprincipled invasion, by their late fellow countrymen, in the war of 1812.

If Canada possess none of the historic interest, which attaches to older countries, she can with pride point to the undaunted and successful efforts of those brave pioneers, in conquering the difficulties of nature; the privations endured, the dangers encountered, with miraculous escapes in the forest and on the wave, from the wild animals and still more savage Indian, will furnish themes for the pages of the historian and novelist as prolific as did the days of crusades and chivalry in Europe. The picture so graphically drawn by one of Canada's historians, will place before the reader, the early settler in his most favourable condition:—

"The backwoodsman whose fortunes are cast in the remote inland settlements of the present day, far removed from churches, destitute of the ministers of the gospel, and medical men, without schools or roads or the many conveniences that make life desirable, can alone appreciate, or even understand, the numerous difficulties and hardships that beset the first settler among the ague-swamps of Canada. The clothes on his back, a rifle or old musket, and a well-tempered axe, were not unfrequently the full extent of his wordly possessions. Thus lightly equipped, he took possession of his two hundred acres of closely-timbered forest land and commenced operations. The welkin rings again with his vigorous strokes as huge tree after tree is assailed and tumbled to the earth, allowing the sun to shine in on his little clearing. The best of the logs are partially squared and serve to build a shanty; the remainder are given to the flames. Now the rich mould, the accumulation of centuries of decayed vegetation is gathered into little hillocks into which potatoes are put; Indian corn is planted in another direction, and perhaps a little wheat. If married, the lonely couple struggle on in their forest oasis, like the solitary travellers over the sands of the Sahara, or a boat adrift on the Atlantic. The nearest neighbour lives miles off, and, when sickness, comes they have to travel far through the forest to claim human sympathy. But fortunately our nature, with elastic temperament, adapts itself to circumstances. By and by the potatoes peep up and the corn-blades modestly show themselves around the charred maple stumps and girdled pines, and the prospect of sufficiency of food gives consolation. As winter approaches, a deer now and then adds to the comfort of the solitary people. Such were the mass of the first settlers in Western Canada. Within the brief space of sixty-four years, six years less than the allotted life of man, how marvellous the change!"

This description of the hardships incident to a settler's life, falls in innumerable cases far short of the reality. The axe being the most necessary tool in the hands of the immigrant while it was quite familiar to the partially acclimatized American, was to the newly arrived Briton a totally different instrument, and the months that must elapse before he could become accustomed to its use, with the long season of illness which himself and family must pass through, brought on by the deadly malaria arising from the swamps and decaying vegetable matter by which he was surrounded, far away from human sympathy and assistance, shows the metal those brave men were made of, enabling them to triumph over all.

The tide of immigration continued to flow; those trials and difficulties became less from year to year, as the country became opened up. Montreal was brought within four weeks' journey of Toronto and that harbinger of progress, a newspaper, started. Slavery was declared in both provinces incompatible with the institutions growing up, and was at once and forever abolished; the fetters which bound slaves then in the country were knocked off and the liberated Africans declared British subjects, and as such free men. The second steamboat in the New World, first ploughed the blue waters of the St. Lawrence about the year 1809, reducing the journey between Montreal and Quebec to 36 hours, and was quickly followed by additional ones in both provinces. A fierce and deadly struggle for British supremacy, against almost overwhelming odds, was brought to a successful termination, and the neighbouring power taught a lesson they have not yet forgotten. Commerce increased, manufactures were established, schools opened and churches built, even in defiance of obstacles thrown in the way by a government at the distance of 3000 miles, whose officials were profoundly ignorant of the resources and growing importance of the rising colony, as may be inferred from a single illustration. So late as the year 1812 the wood-work of the Psyche frigate, intended for naval operations on Lake Ontario, was sent out from England, to a country where it could be provided on the spot in one tenth of the time necessary to carry it from Montreal to Kingston, and at the twentieth part of the expense; even wedges were included in the stock sent. And to exemplify more completely the information possessed at that time by the Admiralty, full supplies of water-casks were forwarded for the use of the ships of war on Lake Ontario, when it was only necessary to throw a bucket overboard to draw up water of the best quality. An amount of ignorance like this, when shewn by this department of government, that should have been better posted up, was bad enough even though the money squandered did not directly affect the people's interest, but when, from the numerous suicidal acts that emanated in the Colonial Office, the shoe commenced to pinch, petitions, addresses, remonstrances, and at last armed rebellion, opened the eyes of the mother country to the injury and injustice her children in the West were suffering, and, after crushing the unconstitutional movement, at once proceeded to devise a system of responsible or self-government, and, with a generous confidence in the attachment of her sons in Canada, and assurance in their ability to take care of themselves, slipped the leash, and left her full fledged offspring to go on its journey for weal or for woe.

But a few years have elapsed since this boon was granted, and already Canada can point to the enormous strides made in every direction, as a proof that for the Anglo Saxon race self-government is requisite. She can proudly make known the fact that as the commencement of the century saw her with a population of 150,000 inhabitants, she now claims the allegiance of 3,000,000, a case of rapid increase without a parallel, if the auriferous countries are excepted, and point to her broad expanse of unoccupied territory stretching far north and westward to the Pacific Ocean, with her noble lakes and unrivalled rivers, to her rich soil and healthy climate, in all its different variations, together with inexhaustible mines of iron, copper, lead, and other minerals, as the future homes and means of support for hundred millions more.

She can at the present time show a chain of inland lakes and rivers, connected together for commercial purposes, by a series of the most magnificent canals in the world, enabling vessels of 800 tons to ascend from the

Ocean to Lake Ontario, and vessels of 400 tons from thence to Lake Erie, with an increased commerce from about $3,000,000 in the year 1800, to $75,631,404 in 1856. But a few years since, where the solemn silence of the forest was interrupted but by the wandering Indian or wild animal, and where the foot of a white man had rarely or never trod, she can now point out numerous cities, towns, and villages, with populations ranging from 40,000 downwards; many of them second to none on the continent for the enterprise and public spirit of their inhabitants, the architectural ornament and solidity of public and private buildings, for the extensive works of utility they have completed, and to their mammoth warehouses and harbours filled with the produce of a still further west; and exult in those busy marts of commerce as evidence that she is on the high-way to prosperity. She can show extensive regions once the scene of the beaver's labours, and the home of the sickening fever, from which the forests have fled as if by magic, now converted into smiling fields of plenty and peace, and filling the land with the ceaseless hum of industry and happiness. She has produced a system of railways extending over the entire country, unequalled for solidity and permanency of construction on this continent, amounting to about 2093 miles, nearly all of which have been put in operation within the last ten years, bringing the extreme portions of the province within a few hours of each other. The large number of 1,613,935 persons have travelled by this means a total distance of 91,027,299 miles, or an average for each passenger of 56½ miles, at the rate of 26 miles an hour, with only one passenger killed for every 13,003,900 miles travelled during the year 1858, but which is regarded by the Government Railway Inspector as being unusually severe in so far as loss of human life is concerned. It will be remembered that during the summer season those floating palaces the steamboats attract nearly all the pleasure travel, which would otherwise swell the number by railway to an enormous extent. Distance and time are completely annihilated by the flashing of the electric fluid along the telegraphic wires and brings all sections of the country within a moment's distance of every portion of the continent connected by the magic wire. That great engine of popular instruction and freedom the press has increased beyond calculation from the days of its infancy, when the solitary Government Gazette in 1795 sent forth its 100 copies per week, with the latest intelligence from New York and Quebec a month old, to the present time, when from the city mammoth daily to the village modest weekly, the country is deluged with reading matter on all conceivable subjects and with intelligence a few hours old from all parts of America. This enormous power is controlled and directed by men from the highest order of newspaper talent, down to those possessing only a mediocrity, but all working with the common view of instructing and improving their readers. With still greater pride can Canada point out the high position she has attained in the education of her children both spiritually and intellectually; to the complete religious toleration which prevails, allowing every man to worship his Maker according to the dictates of his conscience, none daring to make him afraid; to the countless spires rising towards heaven from one end of the land to the other, all uniting on the calm Sabbath morning in a melodious but solemn summons for the people to attend the house of God. With just exultation she may also call attention to the universities, academies, common schools, and mechanics' institutes, which stud the whole face of the country, and attended during the year 1858 by 463,288 pupils, at an expense of $2,493,811, furnishing a system of education embracing classics, belles-lettres, law, medicine, mathematics, and the whole range of sciences, down to rudimentary instruction in the English language. These institutions are open to all, from the highest to the lowest on the same terms, with no merit recognised but ability. She can point to the upright, learned and eloquent men who grace the ermine they wear, and as fountains of justice distributing it in streams, as clear and irresistible as the limpid waters of the mighty St. Lawrence in its majestic flow; to her men of science, her Logans, Dawsons, Hunts, Smallwoods, Billingses, and a host of others with world-wide reputations, all actively engaged in bringing their knowledge to bear on her physical development; to her Keefers, Pages, Shanleys, and others, as engineers who have made themselves eminent and their country celebrated for the colossal public works they have planned and executed; to the free and elective government with its constitutional opposition, to guarantee that the rights of the people shall not be invaded nor the public funds mis-appropriated, and, when in the course of time changing places, to see the late ministers converted into watchful sentinels on their successful adversaries taking the helm of state,—all equally zealous in the maintenance of their country's credit, honour, and prosperity; and above all, to the feeling of loyalty and devoted attachment to the land of their forefathers, burning as brightly as the patriotic flame on their own country's altar,—to the thrill of joy and pride which pervaded all classes on the glorious termination of England's conflicts—to the gratification felt on being allowed to contribute a regiment to her army, with a contribution to the widows and orphans of her brave defenders, and able, in the event of an emergency, to send into the field a hundred thousand of her sons with the deadly minie-rifle to sustain the prestige of "the flag that's braved a thousand years the battle and the breeze," with arms as strong and spirits as brave, as those of their common ancestors who conquered on the fields of Agincourt and Waterloo.

CHAPTER III.

VICTORIA BRIDGE.

THE year 1859 closed with the addition of an eighth wonder to the world's museum, in the completion of the Victoria Bridge, and adding another trophy to the power of mind over matter. The important connecting link of the Canadian railway system was completed, and the Far West put in immediate connection with the Eastern seaboard. The hopes of its projectors were realized and the doubts and fears of its friends dispelled. The difficulties of nature in their most formidable type were surmounted, in a shorter space of time than anticipated by the most sanguine.

The mighty river was girdled and brought under man's control, and fruitless are the efforts of her deities to escape from the thraldom of his iron bands. Her mad waves and rushing currents may break against his bulwark in vain, with her heretofore irresistible winter forces laughed to scorn by this creation of the genius of her victors, whose mission it is to go forth and conquer. Who were they, and by what means did they gain this triumph? may be asked when the dim vista of centuries intervene. What mechanical appliances were made use of, and did giants live in those days? or, coming back to our own time to satisfy the reasonable curiosity of the beholder as he gazes upon this crowning achievement of intellect and sinew combined, is the object of the following pages.

In the projection of her public works, Canada was fortunate above most new countries, in the possession of a class of men with enlarged and far-seeing minds, enabling them, instead of seeking a mere temporary accommodation for the local trade, which even a few years would prove insufficient, to look forward to the future with its great increase and to the Far West or granary of the continent, as requiring an outlet for its enormous surplus, and, with this object in view, to advocate for their different projects, a scale commensurate with the work to be done. While at the time many persons of less sagacity, offered strong opposition to the vast expenditure entailed on a young and poor country, maintaining that the present generation should not suffer in their pockets, for those coming after, but leave them to provide for their own requirements, we cannot sufficiently admire the spirit which impelled those projectors to adhere to their convictions, as to the magnitude of the works required, and which the experience of a few years has demonstrated to be correct. It was under such circumstances, and with those objects in view that the canals were built, and the inland waters lighted up, from Gaspé to Goderich, enabling her to enter into successful competition, as a public carrier of the products of the West, about the year 1846. But as during the winter season she was obliged to withdraw from the contest, on account of her ice-bound waters, another system had to be adopted to prevent the trade when once introduced into Canadian channels, from being diverted to the American lines of railway, from which it would be difficult to regain it. The necessity of immediate action was generally felt throughout the Province, but in no place more than Montreal. She saw at once the necessity of prolonging the advantages gained during navigation to the winter season, by the construction of a trunk line of railway from the most eligible winter sea-port to the extreme West, and thus be in a position to compete with her rivals the year round, on her own terms. The St. Lawrence and Atlantic Railway leading from Montreal to Portland, was projected and its construction vigorously urged on by the mercantile community of this city, but unfortunately, owing to a season of great commercial depression and political agitation throughout the Province at that time, the extension of the line westward from Montreal was allowed to remain in abeyance and all the means which could be raised were devoted to the completion of the first link already commenced. During this period of stagnation, however, a question was raised of the utmost importance to the whole system of future extension: we refer to the project of bridging the St. Lawrence at Montreal with a view to a continuous rail from one end of the line to the other. The conception of an idea so bold and original as this met with the reception which usually attends the first introduction of a project so novel and apparently impossible; it was immediately set down by the public as the production of a man who had taken leave of his senses, and scouted accordingly; ridicule and laughter attended the discussion of the subject in public and private, and the opposition which attended the introduction of the locomotive system by George Stephenson was re-enacted on a smaller scale in Canada with reference to the Hon. John Young's mad scheme. But fortunately for the interest of the Province, that gentleman was in possession of a mind singularly characterized by his countrymen's peculiarities, and the pertinacity of the Scotsman, in the advocacy of this idea, which his acute, shrewd, and far-seeing mind held to be of the utmost importance to the country, enabled him to triumph over all opposition, and in time, by his powerful arguments, in the newspapers and on 'change, before the railway board, and public assemblies, to bring many to see the subject in the same light. He could now have the satisfaction of introducing the project to his brother directors of the St. Lawrence and Atlantic Railway without the fear of disturbing their risible faculties or that decorum which should characterise so grave a body, and urge on their attention the strong necessity of taking the matter up at once and giving it a thorough examination.

CHAPTER IV.

MR. GAY'S PLAN.

THE effect of this modified opinion, became evident by the instructions which were issued to Mr. Morton, the then chief engineer of the road, to make the necessary surveys, plans, and estimates of a suitable bridge for railway purposes. We are unable at this time to state what were the distinctive features of this gentleman's plans and report further than his proposed line crossed Nun's Island about a quarter of a mile above the foot and thence diagonally over the river to the south shore, making the entire length over both channels about 11,540 feet. Several other lines between the foot of Nun's Island and Montreal were also examined. The result, whatever it may have been, apparently did not satisfy the projector, judging from the communications which appeared in a newspaper of that day, and generally attributed to him. So forcibly and clearly was the importance of the bridge made evident, that a committee was organized of which Mr. Young was chairman, for the purpose of procuring a second examination, to show the feasibility or otherwise of the undertaking. On this occasion an American engineer of great experience in this branch of the profession, was requested to make a thorough reconnaissance of the river between Laprairie and St. Helen's Island, including the site which had been proposed by Mr. Morton. Mr. Gay, on his arrival in Canada, proceeded to make himself familiar with the general character of the river during the formation of ice in the early part of the winter and breaking up in spring, from which he was led to believe, in connection with his previous acquaintance with the operation of large bodies of moving ice on other rivers, that any attempt to construct a permanent bridge across the river St. Lawrence between Nun's Island and the lower end of St. Helen's Island, would be attended with great risk, if not a total failure. This opinion having been formed, his attention was then devoted to the section above, and, after a thorough examination resulted in the selection of two different lines, either of which would answer the conditions of the problem in so far as danger arising from ice was to be apprehended. These lines for convenience of reference, are distinguished by the terms " upper " and " lower," and may be described as follows:

The upper one extended from a point on Nun's Island, about a quarter of a mile from its head, over to a point on the eastern shore two and a half miles below Laprairie, and embracing both channels was 14,960 feet in length. The lower one extended from a point about half a mile above the foot of the island to the opposite shore, and with both channels was about 12,540 feet long. In discussing the merits of the two lines, Mr. Gay evidently leaned to the upper or longer of the two, in so far as danger from ice was to be feared, on account of the additional water space it offered, and less liability of jamming, while on the other hand its greater length and consequent additional expense of construction made the lower one preferable even with the somewhat increased risk of the ice accumulating. Under such consideration the lower line was recommended for adoption. The following brief description will give the reader an idea of the bridge proposed by Mr. Gay for this site. The superstructure was to consist of wood, arranged in that form of framing known by the name of " Burr's combined arch and truss," and supported on two abutments and 55 piers, at clear distances of 200 feet, with the under side of the chord and truss work raised twenty-five feet above low water, but the ends of the arches approaching it within eighteen feet. The masonry of the abutments and piers was to be of the most substantial character. The surface of the external stones to be dressed in courses and the interior work laid with level beds, uncoursed and well bonded. The pier heads forming the ice-breaker, to be faced with timber one foot thick secured to the walls with iron straps and bolts in such manner that it could be renewed at pleasure. The masonry of the pier-heads was also to be secured in each course with iron clamps and the piers to be 18 feet in thickness at the "skew-backs," or springing-line of the arches. The faces of both abutments and piers to have an even batten of one inch per foot rise from bottom to top; no offsets, or projections were contemplated for ornament, in order that a smooth and even surface might be presented for the action of the ice. The masonry of the piers where the water was more than two feet deep to rest upon a solid foundation of hewn timbers bolted together and sunk upon the solid rock-bottom of the river, from which all earth or loose stones were to be removed by dredging.

In this plan it is evident that no provision was contemplated for the navigation of the river, although Mr. Gay stated that a draw-bridge, not exceeding sixty feet in length, might be placed over the navigable channel, if insisted on, but as its erection would necessitate the two piers being within that distance apart, great dangers would be apprehended from the obstruction of the ice, especially as 120 feet of one span would have to be constructed three feet nearer the surface of the water, than would otherwise be required, to allow the draw being moved back within it, and therefore jeopardise the safety of the bridge; and concluded with the hope that in obtaining the necessary authority for its erection, no such conditions should be coupled with it, as tending to impair its safety or usefulness when done. In addition to railway traffic, it was also designed for ordinary bridge purposes for the common roads leading into Montreal from the south side of the river. The estimated cost of this bridge was $525,693, or if built on the upper line $613,321. In taking a general view of this scheme, we will confine ourselves to the consideration of a few of the most prominent features involved in its erection. The superstructure being on the arch and truss principle, was capable of being made abundantly strong for the purpose intended, under other circumstances, having the truss portion to sustain its own weight, and the arches as auxiliaries for passing loads, but, as before stated, in this instance the most vital parts of the sustaining arches are brought within eighteen feet of low water and as it is known to have risen 22½ feet above that point, at the time the ice was flowing in the fall and spring, and frequently above the limits prescribed by Mr. Gay for the springing of the arches, the ice under such circumstances would come in contact with and destroy the most essential part of the structure, and probably involve the whole in the same calamity. Mr. Gay proposed to build the piers without the aid of coffer dams, by dredging the bed of the river down to the smooth rock and starting the foundation on a solid timber platform; but as he did not indicate the *modus operandi*, we are at a loss to conceive how it could be effected, from the fact that the deposit is made up in many instances of large masses of boulders, with interstices filled with gravel, sand, and mud, forming a hard concrete mass, at other times the reverse, while, occasionally, the treacherous quicksand is met where least anticipated, forming altogether a stratum ranging from three to ten feet in depth, or how, by any process of dredging, this accumulated and varied mass could be removed from the rocky bed, so as to admit of the timber coming in immediate and close contact, as an essential to stability, for the sum of $200 a pier, is more than we can comprehend, to say nothing of the difficulty and expense of placing the masonry under water, in so strong a current, either by diving-bell or otherwise than coffer-damming.

The site selected in no way favored the interest which it was intended to serve, either for railway purposes or ordinary travel, being at too great a distance from Montreal, on which the project at that time was dependent for the support necessary for prosecution, from the fact of it being regarded in other quarters as a purely local measure, and as such not entitled to public sympathy or support, but rather the reverse, from the interruption it offered to the navigation of a river for the improvement of which some 10,000,000 of dollars had been previously expended by the Province. Notwithstanding the disadvantages under which it labored, an application to Parliament for the necessary powers for enabling the work to be proceeded with, was favourably entertained in the House of Assembly, through which a charter was carried in the year 1847, but was subsequently arrested in the Legislative Council, from whom it received its quietus. With so unfavourable a result to all the efforts which had been made by the projector for carrying out this great idea, it would naturally be supposed he would allow the subject to drop, as an impracticability, and take no further action in the matter.

An eminent engineer selected by himself had pronounced a bridge below Nun's Island a physical impossibility, while he in turn knew full well that the one designed and located by that engineer was a moral one, and for four years brooded over the subject with the pertinacity of a Merritt or a Clinton, every day becoming more convinced of its commercial importance, and stronger in faith that it would yet be accomplished. We have before alluded to a season of depression in business matters which visited Canada about this time, involving the suspension of many improvements until better days would dawn, to which happy period we will now proceed.

CHAPTER V.

MR. T. C. KEEFER'S PLAN.

DURING the early part of the year 1851, the subject of extension westward from Montreal was again taken up, and a committee appointed to procure an examination of the country between that city and Kingston. The conduct of this important survey was intrusted to Mr. T. C. Keefer, a young Canadian engineer of great talent, but at that time more widely known for the clear, able, and eloquent manner in which, as a writer, he had advocated various public works of utility, than as being the possessor of that practical ability afterwards displayed in the origination and construction of some of the finest hydraulic works on the continent. In the general instructions issued to him by the chairman of the committee, Mr. Young, under date of 3rd June, 1851, we find that gentleman still as resolute on the bridge question as when we took leave of him in the year 1847. In making Mr. Keefer acquainted with the committee's desire for a third examination of the river, he suggested starting from a supposed terminus near the Wellington Bridge, and thence to the opposite bank of the St. Lawrence to the best point of intersection with the Portland Railway; adding, that on the completion of the surveys, plans, &c., although having every confidence in his professional abilities, yet as the work was of more than ordinary magnitude and responsibility, the documents would be submitted to a board of engineers to be named by the committee jointly with himself. It is not our purpose to go into the subject of the general survey of the line between the before-named cities, further than to say that political considerations alone led to the change afterwards made in its location; we will therefore confine the present remarks to the subject of the bridge.

A better selection could scarcely have been made for this work, than the professional gentleman in question, from his intimate acquaintance with the St. Lawrence in all its yearly changes, acquired in the prosecution of extensive hydrographic surveys lately carried on for the Provincial Government, together with the schooling obtained as engineer of the works on the Ottawa, a river second only to the one he was now to contend with. In fact, the wisdom displayed in the choice of Mr. Keefer for this onerous office, is abundantly demonstrated by the bold and original views he took of the subject, and the able and scientific embodiment of them in the plans and report laid before the directors. In order to obtain a correct knowledge of the bed of the river, position of shoals, &c., a thorough hydrograph survey was resolved on; but as the great width, together with the strong currents, rendered it a difficult and expensive proceeding during the summer months, Mr. Keefer was under the necessity, after a preliminary examination, of allowing it to remain over until winter, when the ice would give an opportunity of gaining the important information with the utmost degree of certainty. The result abundantly confirmed his previous anticipations, with respect to the peculiar conformation of the bed of the St. Lawrence opposite Montreal, and its remarkable adaptation for a Bridge. The line subsequently selected, the result of this survey, as offering the greatest facilities for crossing, left Point St. Charles about a quarter of a mile below the present bridge, thence diagonally across the river in the direction of Moffat's Island, and striking the St. Lambert shore at the distance of three quarters of a mile below the south approach of the Victoria Bridge, and in a direct line of connection with the Grand Trunk Railway at Longueuil. It is a remarkable fact, that on this line the shallowest water is found between Lake Ontario and the Ocean, and flowing over a bed composed of trap-rock, (through which a single channel has been cut near Moffat's Island) about 360 feet in width, allowing a depth of nine feet at low water, or about 300 feet between the lines of ten feet at a like period, which guage no vessel descending the rapids would exceed, while over the remainder of the shoal followed by the bridge, nearly one half of the distance does not exceed five feet in depth, and consequently not admitting of vessels taking any other route than the one indicated by the narrow channel. This information being obtained, the Engineer was in a position to proceed with the general design of the bridge. The fate that attended the late project in the Legislative Council, warned him against attempting any similar one, that would interfere with the navigation of the river, more especially as it had been laid down by the Supreme Court of the UnitedStates, in the Wheeling bridge case, that no draw under 200 feet in length would be accepted, and as this decision would no doubt be quoted by parties opposed to the scheme, and fond of applying to that country for precedents, together with the impossibility of complying with such a requirement, as well as the opinion he had formed from previous knowledge of the height the water had risen on various occasions, requiring the superstructure to be at least 45 feet above low water for safety, led him to the bold conclusion that nothing short of a high level bridge, admitting vessels to pass underneath, would suffice. The site selected being above sea navigation, it was only necessary to provide for lake craft, but as many of the vessels used in those inland seas rivalled their brethren of the salt water, it became necessary to furnish a clear head-way of 100 feet from low water, with a span of four hundred feet over the channel before alluded to. Those two important points having been established, Mr. Keefer's attention was directed to the dimensions requisite for the additional spans, and gradients each way from the centre, as governing the heights of the remaining piers. In determining the sizes of bays or distances between the piers, it was evident, even in an economical point of view, they should be as few as possible, and as great in length as the style of superstructure would admit, as offering less obstruction to the ice when flowing in spring and fall. Another consideration was to be observed, which to a certain extent called for at least clear openings of 250 feet. We refer to the requirements of the timber navigation. The timber is put together in sections ranging from 200 feet to 240 feet in length, and shot down Lachine rapids, and frequently during the prevalence of winds becomes unmanageable to the men who are guiding it, and liable to take any of the openings broadside. The danger arising from this is obviated to a great extent by having all the spans the length above named. The fact of the channel for boats being confined to the centre opening, those two piers were raised to a height of 100 feet, and the superstructure so arranged as to admit of the train passing through, while for the succeeding openings on either side, it was dropped below rail level thus allowing the train to pass over the top, and thereby reducing the elevation of the two neighbouring piers to 70 feet, whence the grade descended to the abutments at each end, leaving a height of about 45 feet from the lower side of the truss to low water, at these points. The bridge as thus arranged, contained twenty-two piers and two abutments, with solid approaches from either shore, extending out to a depth of five feet of water, and measuring 1350 feet on one side and 1710 feet on the other, making the entire length of the bridge about ten thousand feet. This is the first instance in the history of the bridge, of embankments being made use of, and regarded as an essential feature in the design, for without them the gradient in descending from the centre, in order to bring the level of the rail within a useful limit for commercial purposes, on each side of the river, would, before reaching the shore, cause the superstructure to be brought within the range of the ice, and so cause its destruction. This might indeed be obviated by carrying the piers near the land up to rail level, but as this would necessitate running through the superstructure, instead of over, the general symmetry of the bridge would be destroyed, or, apart from economic considerations, if the piers throughout were brought up to rail level, and the superstructure arranged accordingly, then we have the passengers confined in a tunnel two miles long, with all its disagreable connections, or if the spans were so arranged as to admit of an iron bridge open at the top, the side trusses would be so high that it would become a long trough, which, unless open at the bottom, would fill with snow, and in summer effectually deprive the passengers of that view from the windows of the train constituting one of the great attractions of the bridge. On the other hand, by the arrangement proposed, the appearance of the bridge with passing trains is improved, the snow avoided, and the monotony of the outline broken by the single elevated tube in the centre, which would so clearly indicate the channel to those navigating the river,—the pleasure and comfort of the passengers enhanced, economy and safety to the structure secured, and if built of wood, the risk of fire greatly diminished. The above form some of the arguments brought forward by the Engineer for the solid approaches in so far as they are necessary for the bridge proper. We will now refer to another useful purpose they were intended to serve, in connection with the semi-annual flooding of Montreal, caused by the ice-jams opposite the city. In examining the local phenomena of the river at this place, Mr. Keefer went into the subject at length, from which the following theory was adduced. The destructive effects of the ice are incident to the elevation of the river, and the sudden slipping of some of the ice dams formed during the season of the flow. This led him to the consideration of the localities and mode of formation of these obstacles, and whether any means could be devised for overcoming or guarding against their future occurrence. After starting with the fact that the ice first takes in Lake St. Peter, fifty miles below the city, at a point under the junction of the main branch of the Ottawa, and several other large rivers, he shows that the ice lodging on the shoals at the entrance to the lake, causes an elevation of the water between that place and Point-aux-Trembles, near the city, seldom higher than five feet above the ordinary summer level, while at the same time in the harbour of Montreal, but a short distance farther up, it ranges from 15 to 25 feet above the same datum. The causes leading to this great difference could not be attributed to any action of the ice below, and must therefore arise from circumstances governing its formation and movements above Montreal. In tracing this result to its origin, he arrived at the conclusion that the large area of water between Montreal and Lake St. Francis, remaining open after other portions of the river were closed, furnished the fields whence the supplies of ice were obtained for forming the dam at Montreal. Thus Lake St. Francis, from its comparatively still and deep water, closes early and arrests the ice coming down the St. Lawrence from Prescott, causing the river to flush back to Cornwall. Now did the comparatively shallow Lake St. Louis, with its strong current, close before, or at the same time, with its neighbour above, it would in turn arrest the ice escaping from the lake, and prevent it descending the Lachine rapids to Montreal, together with the large amount of bordage-ice formed on its own bays and shores, frequently broken up by winds and waves before the lake is entirely closed up, and probably lessen the inundation at Montreal fifty per cent. In fact this result is demonstrated during any winter which sets in with uninterrupted severity, closing the lake early, causing less time and opportunity for the ice to become detached from the shore, and followed by a diminished rise at Montreal. But if on the other hand the early part of the winter be mild or changeable, and accompanied by much wind, the bordage-ice may be broken off repeatedly, by the swell, and a large amount is furnished for the dam at St. Helen's island, thus explaining the apparent anomaly of greater inundations in "open" winters and less in severe ones. A second fruitful source of supply is the large basin existing at Laprairie, a few miles above Montreal, which remains open until its depth is increased about ten feet by the ice-dam below. Its extensive shoals and margins are converted into fruitful nurseries of bordage ice, constantly augmented by fragments brought down from above, so that when liberated by the rising of the waters, or action of the winds, large fields of strong clear ice are sent down as extensive contributions to the fund below. From this Mr. Keefer draws the inference, that if the bordage-ice can be retained *in situ* and the taking over of the Laprairie bay expedited, a very large proportion of the supply furnished for the dams would be cut off and their extent correspondingly diminished, which duty he proposed to accomplish by the solid approaches from either side of the river thus converting them into a source of protection, rather than as many would suppose of danger, from any anticipated rise of water which might follow their construction. We regret that this occasion does not admit of more than the foregoing imperfect synopsis of this ingenious theory, and the clear and able arguments with which it is substantiated by the originator.

In the erection of the piers, Mr. Keefer proposed using coffer-dams to admit of the water being pumped out and the foundation properly started from the solid rock. It does not appear from his plan and report, that any provision was made in the design of the piers to resist or throw back the descending ice. This he proposed doing by an extension of the coffer dam on the upper side, elevating it to a height of about 30 feet above summer water level, and providing it with a sloped face in front for the ice to slide up on, and fall back on itself, thus preventing it coming in contact with the pier sheltered behind this bulwark. These cribs or rather islands, as they might be termed, were entirely detached from the masonry, and calculated to yield slightly by their elasticity to the shock, pressure, and grinding of the ice, and, from the description of material used in their construction, admitting easily of repairs when necessary. They were large enough to furnish service ground for material, machinery, plant, &c., used in the construction of the bridge, and forming still water in their lea for mooring scows, barges, &c. They likewise yielded protection for the springing of the arches, the lowest and most exposed part of the superstructure, if wood were used. To arrest partially the flow of ice from above, and so break its force before coming in contact with the ice-breakers of the piers, detached cribs were to be placed on various shoals above the line of the bridge. This method of protecting the bridge by detached-ice breakers, constructed of crib-work, is probably the only weak point in this otherwise admirable design, but, as the subject will be more fully gone into further on, we will in the meantime only add that the first design, prepared by Messrs. Stephenson and Ross, was provided with ice-breakers very similar to those proposed by Mr. Keefer. In considering the important subject of superstructure, the Engineer's attention was directed in the first place to the suspension principle at that time about being applied to railway purposes at Niagara. In the investigations then entered into, he arrived at the conclusion, that where a channel is too wide to be spanned by beams, or arches, and when the depth of the water or narrow chasms makes piers or towers impracticable, the suspension bridge is the only and most economical resource. For railway purposes a single span may be made available, but for a long bridge, where a succession of spans are required, if constructed in the ordinary manner, the vibrations would be destructive to the work, and if built on any other principle, their economic advantages disappear. This, taken in connection with the vastly increased quantity of masonry required, rendered a bridge on this plan far more expensive than any other class of structure adapted for the same site, and at once precluded its adoption. In thus disposing of this character of roadway Mr. Keefer had the satisfaction afterward of having his views fully and strongly substantiated as will be seen when we come to the designs as prepared by Messrs. Stephenson and Ross.

This conclusion having been arrived at, it became evident that nothing short of a solid bridge, either in wood or iron, would answer the purpose, two classes of material widely differing in character, yet both extensively used for the accomplishment of the same end. At this period iron bridges had not been introduced into the railway system of America, where its rival wood, offered so much cheaper a substitute. The importance of substituting imperishable for perishable and inflammable material in the erection of this great bridge, was strongly felt by Mr. Keefer, who had in view the tubular principle as discovered and developed by Mr. Stephenson, but as its adoption would entail an additional expenditure of $2,000,000 he knew it would prove a fatal condition to the then purely private commercial project, if demanded as an essential feature in the design. He insisted however on the centre span being four hundred feet in length and surmounted by a tubular iron beam at an additional expense of $172,000 than if it were of less width and built of wood. This he considered essential for the navigation, as well as to afford security against the chimneys of passing steamboats, and cutting off communication in the event of fire occurring, thereby exposing only half of the structure to destruction.

This being the extent to which under the circumstances he was justified in making use of the more expensive roadway, and, after expressing a hope that the superstructure, he was now to propose, would in course of time be replaced with the more durable iron tubes, in the event of the project being taken up at any future period as a public undertaking, he then proceeded with the general design for the remainder. The class of superstructure determined on, consisted of a strong rectangular open built hollow beam, assisted by deep open built arches. The two systems of arch and truss, however objectionable in iron bridges, have proved to be susceptible of advantageous combination in numerous instances when built of wood, as the elasticity of timber permits both systems coming into play without injury to either, when a strain is upon them. Mr. Keefer refers to the experiments at Menai as establishing the superiority of the rectangular form for hollow beams in iron, and remarks, as a singular fact, that the best form of wooden bridge for wide spans in America, was long previous to the Menai tube, a type in wood, of that celebrated work, adding that the strength in both cases is collected near the four angles. The sides, top, and bottom in the iron wonder serving chiefly to maintain the relative position of the vital parts, while in the wooden tube the strength must be in the top and bottom chords, assisted and retained in place by the introduction of the auxiliary arch. He then speaks of the gradual improvements which have taken place in this species of wooden bridge, from the days it served for common traffic up to the time it was adapted for heavy locomotives, and argues that inertia has been sacrificed for mere stiffness, and therefore prejudicial to the structure when absorbing the momentum communicated by the sudden impact of locomotives weighing thirty tons and moving with a speed of 30 miles an hour. To obviate this, he recommended a heavier class of superstructure than generally made use of, and designed the truss part with a view to support its own weight and introduced the arches as auxiliaries for the passing loads. The truss was thirty feet deep, and so arranged as to permit the road being carried over the top, and effectually protected from danger of fire by having the sides, top, and bottom cased in, and under a constant surveillance for additional precaution. The life of the bridge thus constructed, and protected from the action of the weather and contingency of fire, was estimated to be about half a century. No provision was made for ordinary traffic, as in winter during the few days it would be required before the taking of the ice, the carriage way inside of the truss would be impassable for want of snow, and in summer the ferry boats running to different points of the harbour, would successfully compete with the bridge for local trade; the revenue consequently would not pay the cost of collection, though a footpath could be projected from the side and become profitable, as it would be a favourite resort during the summer months to tourists and others. The estimated cost of the bridge, if built on the foregoing plan, with the large span of iron, was $1,600,000, or if iron tubes were used throughout $3,600,000. We have endeavoured to give a short account of this bold proposal for crossing the St. Lawrence, at a point pronounced impracticable by Mr. Keefer's predecessors, but are aware of the utter impossibility in this imperfect sketch of doing the subject that justice to which it is entitled. The idea brought forward of carrying the railway traffic over the St. Lawrence, above the tallest masts of the lake craft, on a structure that would bid defiance to all the powers of the river, must have been as startling to the committee, as was the nearly similar project of Robert Stephenson to the British House of Parliament. It is true, the genius of that illustrious man was to be invoked in the erection of the tube over the channel, and, did the means admit, the remaining tubes likewise; but at the same time, apart from this, every unprejudiced mind must admit, as did Stephenson himself, that an enormous stride towards success had been taken by Keefer; that he had in fact solved the problem, in reducing the question from a dead impossibility to a living certainty. The father of the bridge and his friends could now exult in this successful result as an earnest of what must speedily follow. The confidence, even in the darkest hours of its history, which led them to become personally responsible for the sum of $6,600 to enable Mr. Keefer to proceed with the survey, was about to receive its full fruition in the prospect of the bridge becoming a reality; but apart from such minor considerations, so satisfactory a demonstration that the object for which they had contended for years, was not a phantom of the imagination but soon to assume shape and being, must have furnished food for deep gratulation.

CHAPTER VI.

ALEXANDER M. ROSS.

We are now approaching a period when the railway system of Canada was fairly launched into existence, embracing in its ramifications the construction of a continuous line from Trois-Pistoles, about 150 miles below Quebec, to Port Sarnia on Lake Huron, and thence to Detroit. The apathy engendered by hard times had passed away with them, and railways became the politics of the country. From the Governor General and the premier down to the humblest political demagogue, "the civilizing influences" formed the topic of the day. The Province was seized with a railway mania, and granted charters to projected lines in every direction. Newspapers teemed with leading articles and pamphlets multiplied. Railway literature was in the ascendant and plank-roads at a discount. Macadam, engineers, and canal men were voted slow and unable to keep up with the times, while railway professionals were the bright particular stars on whom the destiny of the country hinged. In the midst of all this excitement appeared the celebrated railway letter from Mr. Hincks, addressed to Sir John Packingham, closing abruptly the negotiation with the Imperial Government for the needful, and followed shortly after by an announcement of the birth of the Grand Trunk Railway Company, with a capital of $60,000,000, and subsequent agreement with the firm of Jackson, Peto, Brassey and Betts, to build the road. It is not our intention to glance at the difficulties which occurred relative to the settlement of this contract. The work is now accomplished, and the bad feelings which were engendered at the time have passed away and are buried in oblivion: their disenterment would serve no good purpose. We will therefore welcome the arrival in the Province of Mr. A. M. Ross, the chief engineer, and destined to be intimately connected with the work which constitutes our country's boast and the wonder of the world. This gentleman had long been associated with the Stephensons, on some of their most important works, and was justly regarded as their right-hand man, and one of the most competent men in England to be entrusted with the supreme conduct of this gigantic colonial undertaking. He had rendered most valuable assistance in the construction of the Holyhead line and Conway Bridge, alluded to in a former part of this article, as well as having been connected in a very prominent manner with many other works, if not so extensive, yet as important, and was generally regarded by the profession as *par excellence* a bridge engineer.

On his arrival in Canada, he put himself in communication with the Government, and was referred to a prominent member in the person of the Hon. John Young, at that time Chief Commissioner of Public Works. What a fortunate meeting was this for a bridge projector and bridge engineer; we can fancy the topic of conversation to have been "the bridge," as both gentlemen left Quebec the same evening for Montreal, one of them no doubt fully charged with interest in, and curiosity to become acquainted with the place so graphically described by his companion, while the other would in turn burn with anxiety to learn the views of the celebrated engineer on his visiting the locality. The day following their arrival in Montreal, the two gentlemen, in company with a third, visited in a canoe the different sites proposed for the bridge, not forgetting the special project of crossing from St. Helen's island to the east of the Market Place, with a span of unheard of dimensions, and thence by arches northward to Cote à Barron. After several hours cruise on the water, in the primitive vessel, Mr. Ross argued at some length against the proposition of building a bridge of such character and cost, of wood, strongly advocating the introduction of iron, and, to use Mr. Young's words in afterwards writing of what then took place, " described the identical structure subsequently adopted." With all due deference to that gentleman's recollection of what transpired so far as pertains to the iron superstructure, we think his memory scarcely serves with regard to the masonry, from the circumstance of the first arrangement actually proposed by Messrs. Stephenson and Ross, differing materially in so far as the piers were concerned, from the one at present existing. To prove this a short quotation from Mr. Stephenson's report in 1855 will suffice: " In the first design for the Victoria Bridge, ice-breakers very similar to those prorosed by Mr. Keefer, were introduced. In European rivers, and I believe in those of America also, these ice-breakers are usually placed a little way in advance of, or rather above the piers of the Bridge, with a view of saving them from injury by the ice shelving up above the level of (frequently on to) the roadway." Thus we find the incipient design at that time bears a strong resemblance to the one proposed by Mr. Keefer, when divested of its wooden superstructure and replaced by iron tubes. We make this extract to shew that the piers then projected did not assume their present form until an after period. The result of the voyage was on the whole most satisfactory both to Mr. Young, as giving assurance that the subject would receive the earnest consideration of the eminent engineer, and to Mr. Ross, as furnishing a splendid field for the exercise of his " peculiar talent" in the event of the structure being proceeded with. Before going further with the subject, it is necessary to revert to circumstances connected with the history of the road, as furnishing a clue to what subsequently followed. Prior to the formation of the Grand Trunk Railway Company, a charter had been granted to a company consisting of Messrs. Young, Galt, Holton, and others, with the view of constructing a road to Kingston, to which reference has been made as the one surveyed by Mr. T. C. Keefer. The location of this line was some distance back in the country, and therefore removed from the most influential and populous portions bordering on the St. Lawrence. So much was this felt, that a strong political pressure was brought to bear against the scheme, and resulted in the government directing their chief engineer, Mr. Samuel Keefer, to have additional surveys made between Kingston and Montreal, on what may be termed the front or river line. This gentleman's examination ended in the present admirable location. A difficulty now arose in bringing this section under the control of the Grand Trunk Railway Company, owing to the existence of the charter in the hands of the parties above named, who were prepared to comply with its requirements and anxious to proceed with the work in accordance with its stipulations. Before this period Mr. Young, on his accession to the Government, had resigned his official connection with the Company, and was at the juncture applied to by his late confreres, for advice as to the course they should pursue in the emergency. That gentleman, still adhering to his purpose of years, recommended the surrender of the charter, in the event of the Grand Trunk making the construction of the Victoria Bridge a prominent feature in the agreement. This advice was acted on, and thenceforth the history of the work became intimately connected with the Grand Trunk enterprise. In the prosecution of this survey, Mr. Samuel

Keefer's attention was directed to a re-examination of the river to ascertain whether any improvements could be made in a site for the bridge to that previously adopted by his brother Thomas. Accordingly in the month of February, 1852, a most extensive and minute survey was instituted, and an amount of information gathered, which admitted the exercise of the nicest judgment in the decision to be arrived at. On the elaborate chart of the River St. Lawrence at Montreal, prepared from this hydrographic survey, he proceeded to lay down the present line of the bridge, differing from the previous one in being at right angles with the axis of the river, and about half a mile higher up, or starting from Pointe St. Charles, ¼ of a mile above, and resting on the opposite shore ¾ of a mile from the point reached by the original line, and shortening the distance materially. On the return of Mr. Ross from England in the Spring of 1853, this deviation was submitted for his approval, and met with his unqualified approbation. The site of the Bridge definitely determined, and a section of the river obtained, Mr. Ross proceeded, during the summer of 1853, to mature the general design of the present structure, with which his name must ever be intimately associated. The clear headway over the navigable channel being established by the authorities at 60 feet, as affording sufficient height for steamers, the only class of vessel capable of descending the Lachine Rapids, in the present state of the river at that point, enabled him to introduce the easy grade of 1 in 130 each way from the centre opening; and having determined on 36 feet as the limit which would afford ample security against any probable rise of water and action of ice, produced the skeleton line of the superstructure each way from the centre on the grade mentioned to that level, and converted the remainder of the distance to the shores on each side into solid approaches forming 1200 feet in length at Pointe St. Charles, and 800 feet on the opposite side of the river. This arrangement brought the rail level to the natural surface of the ground, and in immediate connection with the extensive machine-shops and station-buildings, afterwards erected near the end of the north approach. In dividing this intermediate space into spans, it became an important question to determine the economic relation, which should exist between the piers and superstructure, keeping in view also the governing consideration of navigation, and the ice-way requisite for preventing the obstruction of the river by dams. In making this nice calculation, Mr. Ross arrived at the conclusion, that the side spans should not exceed 242 feet opening, while the centre one, being over the main channel, and from other local causes, must be at least 330 feet. That this was a correct arrangement may be inferred from a subsequent estimate with the view of ascertaining whether the spans might not be increased in length, and the masonry made less. Thus, to diminish the number of piers, by one only, on each side of the centre span, would in the item of masonry save nine per cent. or about $200,000, while on the other hand, the spans would be increased exactly ten pent. adding 20 per cent. to the cost of superstructure, as the proportion due to the sectional area of the tubes by this increase, which would amount to about $320,000, or $120,000 in excess of the present arrangement. This result bears a striking resemblance to Mr. Keefer's proposed spans, but arrived at by an entirely different process. The arrangement gives 24 spans of 242 feet in the clear, and one of 330 feet. These important points having been established, Mr. Ross's attention was then directed to another feature in the design, of still greater consequence, viz. the determination of the most suitable form of pier for resisting successfully the force of the ice. In considering this part of the subject, he was fully alive to its great importance, as constituting the vital condition in the stability aimed at, being well aware, from what he had seen personally, as well as learned from others, of the enormous forces to be encountered by the piers, and abutments, (roughly estimated in Sir Wm. Logan's article on the subject, as exceeding one million tons of ice each minute). We have before referred to the circumstance of the original design, containing detached ice-breakers placed in front of the piers, resembling in some respects those proposed by Mr. Keefer. On more mature consideration, this arrangement was abandoned by Mr. Ross, and the masonry of the pier extended on the up-stream side with a slope of 1 to 1 presenting an angular face to the ice. This was done partly with the view of gaining the assistance of the whole weight of the pier, to resist the pressure of the ice, and at the same time present the least amount of surface for it to impinge upon, obviating a considerable annual outlay for repairs. In treating on this part of the subject, we think it necessary, in order to a correct understanding of this most important change made by Mr. Ross, to give an extract from his letter to Mr. Stephenson, as joint engineer, dated November 30th, 1855. In arguing against Mr. Keefer's ice-breakers he observes, "You will also perceive that those quarter-acre islands would occupy 25 per cent. of the water breadth of the river, one of the most prominent reasons for their abandonment when first considered. The space occupied by the piers as being executed, is only seven per cent. This is a most important feature in the relative merits of the two modes of construction. Our present dams are generally about 5 to 6 feet above summer water level, and cover an area corresponding nearly with that described; latterly we have constructed them similar to those, filling the external barrier with stones, and the inner with clay, necessary to render them water tight. The force of the current is necessarily increased, and the natural consequences, owing to the fragile nature of the deposits forming the bed of the river, is to undermine rapidly the part exposed to the action of the waters, thus rendering them more insecure every day, and requiring an immense amount of expensive labour for their protection. I mention these facts which our experience has brought to light, as an additional reason why we should not resort to such an objectionable mode of construction. As to their cost, assuming the existing dams to serve the purpose as far as they go, we should have to raise them to the height of 25 feet above their present level, and add as much to their length up stream, as the necessary slope at the end would require. These ponderous erections would measure about 350 feet in circumference, and from their foundations to the top would measure 40 feet, 25 feet above the present dams. The wall thus formed of timber and stone, would be about 20 feet in thickness; the cubic contents of this mass above the level of the present dams, would be 200,000 feet, and the masonry saved thereby would be exactly 20,000 feet, which is all that is required to form the stone cutwater or ice-breaker attached to the pier. I believe no man capable of instituting a comparison, and with these facts before him, will for one moment hesitate in giving the preference to the ice-breakers as now being executed; their more permanent efficiency, founded in every instance upon the solid rock, placed beyond the reach of any influence exerted by the currents, and their incomparable pre-eminence in relation to the space they occupy, together with their immunity from accidents (not requiring repairs of any kind), a light in which the other mode can never be regarded, and, lastly though not least, their evident economy in the first cost, place them immeasurably in the scale of merit beyond the temporary mode suggested as the substitute, on grounds which I think I have made clear, are altogether untenable."

The following, is a brief description of the form and construction of a pier, as matured by Mr. Ross. The requirement of the tube being 16 feet in line of the bridge by 21 feet transversely, the dimension of the piers, excepting the two centre ones, were established at 33 feet in line of the river by 16 feet in width, at the under side of the superstructure. The up-stream side of the shaft descends with a batter of 3″ in 10 feet, to a point in all cases 30 feet above summer water, forming the top or saddle of the ice breaker. To form the ice-breaker, the masonry at this point is extended horizontally up stream, about 10 feet, to prevent ice coming in contact with the shaft, should it even reach that height, and from thence descends with a slope of 1 to 1 to a point 6 feet under summer water level, or 36 feet from the bottom of the shaft, presenting an angular or wedge face to the current. At this point an off-set of one foot is made, and thence descending in a vertical line to the rock, still preserving the same angular shape. The down-stream end of the pier is brought down to within 28½ feet of summer level, with a batter of 3″ in 10 feet, where an offset takes place of 1 foot, thence descending to summer water level with a batter 4½″ in 10 feet, thence to a point 6 feet under summer level with a batter of 1 foot in 5 feet, where an offset of 1 foot takes place, thence vertically to the rock. The sides of the pier leave the top with a batter of 3″ in 10 feet to summer level, thence to 6 feet under the summer level with a batter in 1′ in 5′, where the offset of 1 foot occurs, thence plumb to the rock. The dimensions of the pier are thus increased from 33′ x 16′ at the top to 92′ x $22\frac{1}{2}$′ at the foundation. The two planes containing the wedge portion of the ice-breaker are dressed smooth, while the remaining sides of the pier are left in their rough or quarry state, with the exception of the angles, which have a margin draft of 6 inches. The two centre piers are 33′ x 24′ at tube level, and increase proportionally in dimensions as they approach the foundation. The courses of masonry comprising the piers run from 3′.10″ to 1′.6″, the individual stones of which range from 6 to 17 tons. Those in the cut-water are fastened together by strong iron cramps 12″ x 5″ x $\frac{1}{2}$ thick, through which bolts $1\frac{1}{2}$″ diameter and provided with a slit on the base for the introduction of an iron wedge, are passed six inches into the course below when the bolt reaches the bottom of the hole prepared for it in the lower course, the wedge is forced up into the slip, thus dividing the iron and forcing it against the solid walls of its prison, from whence it is impossible ever to be withdrawn. The whole mass of the cut-water is thus converted into one huge block. We think any person who compares the two arrangements for guarding against danger from ice, will be convinced from the clear and powerful style in which Mr. Ross deals with the subject, that his views are correct, and that he has arranged the material comprising the pier, in the most perfect manner possible, for the service it is required to perform. An important feature in the character of the bridge is the formidable looking abutment at each end, and which give so massive an appearance to the whole structure. They are 290 feet long by 92 feet in width at the rock foundation, and carried up to a height of 36 feet above summer water level, for the reception of the ends of the adjoining tubes, which have a bearing of eight feet on them. At this level the dimensions are reduced to about 242 feet x 34 feet, from the different slopes and batters. A parapet is then carried up on all sides to a height of 29′.3″, terminating in a heavy projecting cornice, with flat lintels 16 feet in width, over the land and tube entrance, at each end of the abutment, and, being in the Egyptian style of architecture, the effect produced is extremely grand and impressive, conveying the idea to the spectator, of enormous solidity and strength. These abutments are not in reality what they appear to be, a solid mass of masonry, but hollow, each having eight openings or cells 48 feet in length and 24 ft. in width, separated by cross walls five feet thick, with the top arched and corbelled over four feet under rail level. The flank wall on the down-stream side, rising nearly perpendicular, is seven feet in thickness, and tied to the cross walls, while that on the up-stream side slopes from its foundation upwards to an angle of about 46 degrees. Its thickness is 12 feet, and it rests against the cross walls before alluded to. It presents a smooth surface to facilitate the operations of the ice, on which account its form has been determined; and to insure greater resistance to the pressure of the ice, the cells are partially filled with earth, stones, and gravel so that one solid mass is obtained. The great length given those abutments, is in view of the rapidity of the current and the floating ice sweeping around their outer ends, after striking the upper side of the embankments, and which nothing but the most massive masonry can resist. The section determined by Mr. Ross for the earth embankment leading from the abutment to the shore, is peculiarly well adapted for meeting the shove of ice. The upper side exposed to it is formed into a hollow shelving face; the lower portion or foot of the slope has a straight incline of 3 to 1, extending to the bed of the river; while the centre part is a circular curve of 60 feet radius, running in a tangent to the top, with an inclination of 1¼ to 1.

The large floes of ice, in sliding up, cannot pass this curved section, but break and fall back. The down-stream side which is not exposed to the direct action of floating ice, has a slope of $1\frac{1}{2}$ to 1. The faces of the slopes on each side, are protected by a riprap wall of broken stones, from 3 to 6 feet deep, and surmounted by a cut-stone coping 3 feet wide and one foot thick, running on each side, the entire length of the embankments, and terminating at the end in two massive Egyptian pilasters, built in rock-face ashlar.

The embankments as completed are 28 feet in width at rail-level.

CHAPTER VII.

ROBERT STEPHENSON.

The superstructure, as designed by Mr. Stephenson, consists of 25 tubes, or, rather, as one continuous tube extends over two spans, of 12 double tubes, and the large central one over the channel. They are of the uniform width of 16 feet throughout, for the accommodation of a single line of railway, but differing in height as they approach the centre. Thus, the depth of the tubes over the first two spans is 18′. 6″, the next two 19 feet, and so on, every coupled pair gaining an additional six inches, to the centre one, which is established at 22 feet in depth, as the proper proportion obtaining for a beam 330 feet long. These side-spans being all the same length, the increase in height does not arise from any requirement of additional strength, but simply to prevent the appearance of too great a break being visible in the top line of the tubes, and, by graduating the difference in height between the ends and centre, to give greater facilities for the roof required in the protection of the tubes from moisture and consequent oxidation, and presenting at the same time a straight and continuous outline on top.

These tubes, being detached, are not designed upon the principle of continuous beams, for practical reasons, including the circumstance of the steep gradient on each side of the central span, and the great disturbance which would be caused by the accumulated expansion and contraction of such a continuous system of iron work, in a climate where the extremes of temperature are so widely apart. The arrangement introduced of coupling but two together, with an intermediate space of 8 inches between them and the neighbouring tubes, divides this movement and retains it within certain specified limits.

A double tube, covering two openings, is securely bolted to the masonry of the pier in the centre, on which it has a solid bearing of 16 feet by 19 feet, and provided with a free bearing on each of the two contiguous piers of $7\frac{1}{2}$ feet, resting at each end on 14 expansion rollers 6″ in diameter and 3 feet in length, seven on each side of the tube, retained in place by a wrought-iron frame, allowing the rollers to traverse on a plained cast-iron bed-plate $7\frac{1}{2}$ feet long $3\frac{1}{2}$ feet wide and 3 inches thick, bolted to the masonry. A similar plate covers the rollers, and is secured to the bottom of the tube. The tube is thus free to expand or contract each way from the bearing-pier in the centre.

Creosoted tamarack timber, covered with felt, is introduced between the iron and the stone, in every case, to give the junction of these hard materials a certain amount of elasticity.

The tube proper is composed entirely of wrought iron, in the form of boiler plate, ranging from $\frac{4}{16}$ to $\frac{12}{16}$ of an inch in thickness, with the joints and angles stiffened and strengthened by the addition of Tee and Angle irons. The secret of success in this mode of construction, lies in arranging those different thicknesses where the strains or weights call for additional strength or otherwise.

At the time Mr. Stephenson commenced his experiments with the models, prior to the building of the Britannia Bridge, he found the results obtained, differed so widely from those indicated by the formulæ for determining them, that but little reliance could be placed on any deductions arrived at from their use. He consequently was under the necessity of prolonging the experiments to a much greater length than at first anticipated, but with a success which led to most important results in this branch of statics.

These discrepancies arose to a certain extent, from the ability of wrought iron to sustain a compressive strain, not having been estimated sufficiently high, as well as the diversities existing among scientific men, relative to the character and extent of the different strains existing in rectangular beams.

It is not our purpose to enlarge upon this subject farther than to state, that in a hollow beam supported at each end, and sustaining a weight, the upper surface in the centre, is exposed to a strain of compression, diminishing to the ends, while for the lower surface at the same points, the conditions are reversed, becoming tensile,—the sides acting as struts or braces to prevent those two opposite strains approaching each other. In a beam of this description, therefore, the excess of strength, must, on the top and bottom, be in the centre, and diminish as the ends are approached; while on the sides, the conditions are again reversed, the centre requiring the minimum of strength necessary for connecting the top and bottom, with an increase as the ends or bearings are reached.

Another consideration to be observed, in so far as the economic distribution of material is concerned, arises from the inability of wrought iron to sustain the same amount of compression as tension, reversing the characteristics of cast iron, and which has been established, from the experiments alluded to, as being in the proportion of 4 to 5,—or, in other words, a sectional inch of iron in the top of the tube, can practically sustain but four tons, while the same area in the bottom, may receive as high as five tons without injury.

The following table will shew the general distribution of material in the different parts of the tube, as arranged by

Mr. Stephenson, starting in all cases from the centre of the spans:—

TOP PLATES.

From Centre.	L'ngth of Division.	Sectional Area. Plates.	Sectional Area. Strips, Tee and Angle Irons.	Total Area.	Thickness of Plate.
	′ ″				
1	11.00	125	92$\frac{1}{16}$	217$\frac{1}{16}$	$\frac{5}{8}$″
2	11.00	125	86$\frac{7}{16}$	211$\frac{7}{16}$	$\frac{5}{8}$″
3	11.00	114$\frac{3}{8}$	86$\frac{7}{16}$	200$\frac{10}{16}$	$\frac{9}{16}$
4	11.00	107$\frac{1}{16}$	84$\frac{11}{16}$	191$\frac{12}{16}$	$\frac{1}{2}$
5	11.00	87$\frac{1}{2}$	84$\frac{11}{16}$	172$\frac{3}{16}$	$\frac{7}{16}$
6	11.00	75	77$\frac{5}{16}$	152$\frac{5}{16}$	$\frac{6}{16}$
7	11.00	56$\frac{11}{16}$	77$\frac{5}{16}$	134	$\frac{5}{16}$
8	11.00	53$\frac{1}{4}$	55$\frac{1}{4}$	108$\frac{1}{2}$	$\frac{4}{16}$
9	11.00	50	55$\frac{1}{4}$	105$\frac{1}{4}$	"
10	11.00	50	48	98	"
11	11.00	1	"	"	"
Bearing.	8.00				
	129.00				

BOTTOM PLATES.

1	19.6	137.50	63.75	201.25	$\frac{3}{8}$—$\frac{5}{16}$	
2	14.0	137.50	57.75	195.25	"— "	
3	14.0	125.00	57.75	182.75	"— "	Double.
4	14.0	112.50	54.25	166.75	$\frac{5}{16}$—$\frac{4}{16}$	
5	14.0	87.50	57.50	145	$\frac{4}{16}$—$\frac{3}{16}$	
6	14.0	85.00	33.00	118	$\frac{5}{16}$	
7	14.0	50.00	42.00	92	$\frac{4}{16}$	
8	17.6	50.00	42.00	92	$\frac{4}{16}$	
Bearing.	8	50.00	42.00	92	$\frac{4}{16}$	
	129.0					

SIDE PLATES.

Beginning at the centre, and strengthened by Tee bars inside and out, placed at distances of 3′, 6″,—

The first space of 35 feet from the centre is formed of $\frac{1}{4}$ inch plate.
The second space of 45½ feet " " " $\frac{5}{16}$ " "
The third " 35 " " " " $\frac{6}{16}$ " "
The remaining space " " " " $\frac{8}{16}$ " "

The sides of the tubes at the bearing ends, are likewise greatly stiffened by lateral bracing.

Keelsons, 10 inches in depth, are placed transversely at distances of 7 feet and secured to the side Tee bars by gussets, for the support of the longitudinal timbers carrying the rail.

The top of the tube is also supported by keelsons at the same distances apart, and the whole tube rendered rigid, by stiffening gussets and double covers over every joint.

The wrought iron in a single tube 258 feet in length, including its bearings over the piers, weighs about a ton to the running foot, or 258 tons in all.

The central tube, in consequence of its increased length, is somewhat different in its arrangement; the bottom and top being proportionally stronger,—the first with an additional thickness of plates, and the last, with longitudinal keelsons 10″ high, taking the place of the ordinary longitudinal Tee bars, as existing on the side tubes; the side plates are 2½ feet, instead of 3½ feet wide, with a proportionally larger number of side Tee bars. The whole tube is disconnected from the others, being bolted to pier No. 12, and resting on rollers on No. 13 pier.

Windows are introduced into the sides of the tubes near the line of neutral axis, and serve to light up the inside. Iron brackets are placed on the piers where not occupied by the tubes, and slope back to the top of the tubes, but are entirely disconnected from it. They serve to give a finished appearance, and likewise prevent the snow and rain blowing in through the openings left for expansion and contraction.

It was originally intended to cover the top of the tubes with a curved corrugated iron roof, to protect them from the weather. This design was subsequently abandoned and the present sloping angular one substituted, composed of grooved and tongued boards, covered with the best quality of tin. This tin is not put on in the usual manner, but, by an ingenious arrangement, each sheet is allowed to expand and contract at pleasure, without the danger of destroying the fastenings which attach it to the timber underneath, as in the ordinary method made use of, and thus insures its continual efficiency.

A foot-walk 26 inches in width extends along the top of the roof, the whole length of the tubes, for the convenience of the *employées* connected with the work; a track is also provided for the painting-travellers.

The foregoing description will convey a general idea of the structure as designed by Messrs. Stephenson and Ross, and, in assigning each gentleman the individual credit due for this magnificent result of their joint labours, we find it a difficult matter to discriminate correctly. The iron work, in all its features and minutest detail, may be looked upon as the product of the genius of the first; for it was he who originated, matured, and successfully applied the system at Bangor, and at the Menai Straits, and under whose immediate direction it has arrived at the state of perfection we now see in the Victoria Bridge. Valuable assistance was, no doubt, rendered by the second, in determining the proper spans for its reception, and for the successful manner in which it was carried out under his immediate superintendence; while, on the other hand, the origination and development of the equally important remaining section of the bridge, in all its admirable details of piers, abutments, approaches, &c., must be referred to Mr. Ross, although, no doubt, thoroughly examined and modified in some respects by Mr. Stephenson. The estimated cost may be put down under the heads of

First.—Approaches and abutments............$1,000,000
Second.—Masonry in piers between abutments..$4,000,000
Third.—Wrought-iron tubular superstructure..$2,000,000

Total......$7,000,000

This sum was afterwards reduced to $6,000,000, but subsequently, in consequence of a bonus of $300,000, given the contractors for completing it one year in advance of the time specified, the ultimate cost of the structure came to about $6,300,000.

CHAPTER VIII.

MESSRS. STEPHENSON'S AND ROSS'S CONTROVERSY IN DEFENCE OF THE DESIGN.

A DESIGN of this extensive character could scarcely escape criticism, and we accordingly find, shortly after its maturity, many professional gentlemen, running tilts against its rocky towers and iron sides, with lances tipped with envy and malice, but in most cases profoundly ignorant of the objects against which they were directing their furious charges. For the information of the reader, we will notice a few of the most prominent of these attacks, before concluding the history of the design :—

At the period of the introduction of the Tubular System and for some time after, there existed great diversity of opinion amongst engineers and savans, regarding the correctness of the principle established by Mr. Stephenson, in the arrangement of the iron, especially in the sides of the tube; some even going so far as to declare it to be a wasteful expenditure of material for the attainment of a given strength; in short, that in the scale of comparative merit, it stood at the very lowest point; while on the other hand its advocates stoutly maintained the reverse, or that, except in particular cases, while it is not a more costly method of construction, it was the most efficacious one that had hithertofore been devised for large spans. Various arrangements of material for beams had been suggested, and brought into use in lieu of the tube as matured by Stephenson, to two of which we will refer, premising that they were regarded generally by that gentleman's opponents, as the most successful rival combinations yet effected, and that by their adoption for the Victoria Bridge a saving of 70 per cent. in superstructure would be made. Other engineers argued there would be a vast reduction in the masonry proposed for the bridge, as well as in the item of superstructure, by the introduction of the suspension principle, admitting as it did of greatly increased spans, and thereby diminish the number of piers required in the proposed tubular arrangement.

In the somewhat better discussion, which then took place, Mr. Stephenson's attention was directed principally to the defence of his favourite system, as opposed to the rival beams above alluded to, while Mr. Ross had the honor of taking up the gauntlet in behalf of the solid roadway, in opposition to the proposed series of suspension spans, recommended for the Victoria Bridge.

Our attention will now be directed to the first gentleman's arguments, but, from the necessity of condensation, their force will be greatly diminished.

The three systems of beams under consideration may be described as follows :—

First.—The tubular girder, or what is sometimes called the box girder, when employed for small spans, with which may also be named the single ribbed girder ; the whole belonging to the class known as boiler-plate girder.

Second.—The trellis girder, which is simply a substitution of iron bars, for the wood in the trellis bridges, which have been so successfully employed in the United States, where wood is cheap and iron dear.

Third.—The single triangle girder, recently called "Warren" from a patent having been obtained for it by a gentleman of that name.

In those three different systems of beams, there exists no difference of opinion amongst engineers, as to the ruling principle in the estimate of strength. Primarily and essentially the ultimate strength is considered to exist in the top and bottom—the former being exposed to a compressive force, and the latter to a force of tension from the action of a load—therefore if the different denominations of girders possess the same spans and depths, with a like load to sustain, the amount of effective material in the top and bottom must be equal in each class.

The dispute then comes down to the most economical and advantageous manner of connecting the bottom to the top, all other conditions being common to each system.

In the tubular system this connection is made by the use of continuous boiler plates, rivetted together and stiffened by vertical Tee bars.

In the second class, or trellis girder, it is accomplished by bars of iron forming struts and tiers, more or less numerous, intersecting each other and rivetted at the intersection.

The third class, or Warren's system, has the connection between the top and bottom effected with bars, not intersecting, but forming a series of equilateral triangles, being struts and tiers alternately.

The reader has now before him the three rival systems of beams, upon which this part of the discussion hinged.

In taking up the consideration of the statement, that 70 per cent. of material would be saved by the use of the third class in place of the first or tubular, Mr. Stephenson proceeded to shew that the dimensions of his proposed tubes for the Victoria Bridge were 242 feet in span, 16 feet in width, with an average depth of 19 feet, dimensions and proportions which would obtain, in either of the other systems, if applied to this locality. The weight of a tube of this size was known to be about a ton to the running foot, or 242 tons in all. This material had been distribued with a view to the ultimate practical strain of 4 tons compression in the top and 5 tons tension in the bottom, to each inch of sectional area, arising from a total weight of 514 tons, including the weight of the tube, sleepers, rails, and a rolling load of one ton to the lineal foot of superstructure.

The same amount of material being required in the top and bottom of the rival beam, to resist under the same conditions an equal amount of strain, the alleged difference of 70 per cent. in the total weight, must therefore exist and be sought for in the material making up the sides. To see how far this is in accordance with the actual state of the case, the following analysis is made of the arrangement proposed for distribution:

Top of Tube............	76 Tons.	
Bottom of do............	82 "	158
Sides		84
	Total	242 Tons.

From this it is evident that both sides bear a proportion to the total weight of only about 29 per cent. What then becomes of the assertion that the difference in material in the sides of the rival systems, is equal to seventy per cent. of the whole weight?

To make the contrast in point of efficiency and economy still more striking, Mr. Stephenson proceeded to institute comparisons between one of the Victoria tubes and an open beam on the Warren or triangular principle, lately built by Mr. Cubitt, on the Great Northern Railway, upon which all possible skill and science had been brought to bear, in order to reduce the total weight and cost to a minimum. This comparison is of great value from the similarity of spans and depth of beams, thus:

Victoria Bridge span 242 feet, weight, including bearings, 275 tons for a length of 257 feet; Newark Bridge span, 240½ feet, weight, including bearings, 292 tons for a length of 254 feet: shewing a balance of 17 tons in favour of the Victoria tube, and rendered still more striking from the fact of the Newark Dyke bridge being only 13 feet wide, while the Victoria tube is 16 feet, having a wider-gauge railway passing through it.

The deflection on the Newark bridge, when tested by a strain of 6¾ tons to the inch sectional area, was seven inches in the middle, or 4⅜ inches with a load reduced to one ton to the running foot. The Victoria tube yielded only ⅞ of an inch, with an equal amount of rolling weight. Comment on these results is unnecessary.

Greater difficulty was experienced in arriving at a relative comparison with class No. 2, (held by some to be the most economical,) from the circumstance of there being no structure in existence possessing the same dimensions as the tubes. The nearest approach to these conditions existed in the Boyne trellis bridge of three spans, with the centre one 264 feet in length, and 22½ feet in height. This bridge is built for a double line of way, with a width of 24 feet. Its total weight, including the beam itself, platform, rails, and a rolling load of two tons per foot, amounts to 980 tons, uniformly distributed. The superstructure is constructed upon the principle of continuous beams, a term which signifies that it is not allowed to take a natural deflection due to its span, but being tied over the piers to the other girders, the effective central span is shortened to 174 feet; in fact, this principle changes the three spans into five spans. Now the effective area given for compression in this centre span is 113½ inches, which gives a strain for the 174 feet span of nearly 6 tons to the inch in comparison.

The reasons for not constructing the Victoria tubes on this continuous principle, have already been given, and would operate equally against the principle being applied to the trellis beam, were it introduced into the bridge in place of the tubular system. But since the discussion rests on the merits of the sides, let the Boyne bridge be supposed to have sufficient area on the top to resist four tons per inch, (the proper practical strain), and let the spans be not continuous, an imperative condition in its application to the Victoria bridge, it will be found by calculation, that the area required at the top will be 364 inches instead of 113½, and the weight of the span would be found by calculation to come but little short of 600 tons, (whereas it is now 386 tons on the continuous principle,) and if we suppose the Victoria tube to carry a double line of way, and 24 feet wide, with a depth of 22½ feet, even if we double the size and quantity, the whole amount of weight will be certainly very little more than 500 tons for the span, giving a difference in favour of the tubular system over the trellis beam of nearly 100 tons for each span, in its application to the Victoria Bridge. In addition to those satisfactory comparisons, Mr. Stephenson shews beneficial results arising from the continuity and solidity of the sides, in resisting horizontal and many other strains, independently of the top and bottom, by which the stiffness is very much increased.

With such a preponderance of evidence in favour of the tubular system, it is a subject of astonishment that diversity of opinion could exist, or that a controversy would be carried on by gentlemen to whom one would suppose these facts were palpable, even before they were introduced into the discussion by Mr. Stephenson, but who from the clear, able, and popular style of treating the somewhat intricate subject, brought it within the scope of the most ordinary reader, while, at the same time, the gentlemanly consideration shewn in the treatment of the arguments brought forward by his professional brethren, and courtesy exhibited while in the act of demolishing their strongholds, will ever render his written articles on the subject models of professional controversy.

Having glanced at the triumphant manner in which Mr. Stephenson emerged from his branch of the conflict, we now turn to the combatant in another field, and trace, in the words of a despatch to his associate engineer, the successful result which attended his part of the discussion relative to the suspension principle.

"I find, from various sources, that considerable pains have been taken to produce an impression in England in favour of a suspension bridge, in place of that we are engaged in constructing across the St. Lawrence at this place. This idea no doubt has arisen from the success of the Niagara suspension bridge lately finished by Mr. Roebling, and now in use by the Great Western Railway company, as the connecting link between their lines on each side the Niagara river, about two miles below the great 'Falls,' the situation and particulars of which you will no doubt have some recollection. I visited the spot lately, and found Mr. Roebling there, who gave me every facility I could desire for my object. Of his last report on the completion of the work, he also gave me a copy, which you will receive with this. I have marked the points which contain the substance of his statements. I also enclose an engraved sketch of the structure. Mr. Roebling has succeeded in accomplishing all he had undertaken, viz: safely to pass over railway trains at a speed not exceeding 5 miles an hour. This speed, however, is not practised, the time occupied in passing over 800 feet is three minutes, which is equal to 3 miles an hour. The deflection is found to vary from 5 to 9 inches, depending on the extent of the load, and the largest load yet passed over is 326 tons of 2000 lbs. each, which caused a depression of 10 inches."

"A precaution has been taken to diminish the span from 800 to 700 feet, by building up underneath the platform at each end, about 40 feet in length, intervening between the towers and the face of the precipice, upon which they stand, and struts have also been added extending 10 feet further."

"The points involved in the consideration of this subject are, first, sufficiency; and second, cost. These are in this particular case soon disposed of. First, we have a structure which we dare not use at a higher speed than 3 miles an hour; in crossing the St. Lawrence at Montreal, we should thus occupy three-quarters of an hour, and, allowing reasonable time for the trains clearing and getting well out of each other's way, I consider that 20 trains in the 24 hours are the utmost we could accomplish. When our connection is complete across the St. Lawrence, there will be lines (now existing, having their termini on the south shore) which with our own line will require four or five times the accommodation. This is no exaggeration. Over the bridge in question, opened only a few weeks, and the roads yet incomplete on either side, there are between 30 and 40 trains passing daily. The mixed application of timber and iron in connection with wire, renders it impossible to put up so large a work to answer the purpose required at Montreal; we must therefore construct it entirely of iron, omitting all perishable materials; and we are thus brought to consider the question of cost. In doing which as regards the Victoria Bridge, I find that dividing it under three heads, it stands as follows:

First.—The approaches and abutments, which together extend to 3000 feet in length, amount in the estimate to......................	$1,000,000
Second.—The masonry forming the piers which occupy the intervening space of 7000 feet between the abutments, including all dams and appliances for their erection	4,000,000
Third.—The wrought-iron tubular superstructure, 7000 feet in length, which amounts to..	2,000,000
(About $285·70 per lineal foot) making a total of.	$7,000,000

"By substituting a suspension bridge, the case would stand thus: The approaches and abutments extending 3000 feet in length, being common to both, more especially as they are now in an advanced state, may be stated as about $1,000,000.

"The masonry of the Victoria Bridge piers ranges from 40 to 72 feet in height, averaging 56 feet, and there are 24 in number. The number required for a suspension bridge, admitting of spans of about 700 feet, would be 10, and these would extend to an average height of 125 feet. These 10 piers, with the proportions due to their height and stability, would contain as much (probably more) masonry as is contained in the 24 piers designed for the Victoria Bridge, and the only item of saving which would arise between these would be the lesser number of dams that would be required for the suspension piers, but this I beg to say is more than doubly balanced by the excess in masonry, and the additional cost entailed in the construction at so greatly increased a height."

"Next as to the superstructure, which in the Victoria Bridge costs $285·70 per lineal foot. Mr. Roebling in his report states the cost of his bridge to have been $400,000. Estimating his towers and anchor masonry at $100,000, which I believe is more than their due, we have $300,000 left for the superstructure, which for a length of 800 feet is equal to $375, giving an increase of $89·30 per foot over the tubes, of which we have 7000 feet in length."

"By this data we show an excess of nearly 10 per cent. in the suspension as compared with the tubular principle, for the particular locality with which we have to deal; besides having a structure perishable in itself, on account of the nature of the material, and to construct them entirely of iron would involve an increase in the cost which no circumstances connected with our local or any other consideration at Montreal would justify. We attain our ends by a much more economical structure, and, what is of still greater consequence, a more permanent one; and as Mr. Roebling says no suspension bridge is safe without the appliances of iron stays from below, no stays of the kind referred to could be used in the Victoria Bridge, both on account of the navigation and the ice, either of which coming in contact with them would instantly destroy them. No security would be left against the storms and hurricanes so frequently occurring in this part of the world."

"No one, however, capable of forming a judgment upon the subject, will doubt for one moment the propriety of adopting the suspended mode of structure for the particular place and object it is designed to serve at Niagara. A gorge 800 feet in width and 240 feet in depth with a foaming cataract racing at a speed from 20 to 30 miles an hour underneath, points out at once that the design is most eligible, and Mr. Roebling has succeeded in perfecting a work capable of passing over 10 or 12 trains an hour, if it should be required to do so. The end is obtained by means the most applicable to the circumstances; these means however are only applicable where they can be used with economy as in this instance."

With the views of Mr. Ross as above set forth, Mr. Stephenson entirely concurred, and, after reviewing and exemplifying them to a greater length, ended with an eloquent eulogium upon the skill and science displayed by Mr. Roebling in overcoming the striking engineering difficulties by which he had been surrounded at Niagara, evidently proud and happy in having met, in mechanical science, with a noble spirit kindred to his own.

A sketch of the early history of the Victoria Bridge has now been given, including descriptions of the designs submitted by various engineers; and as to some the necessity for this course may not be evident, but regarded as taking up too much space and time, with what, to the general reader, may be looked upon as a dry and unprofitable dissertation, we can only say, that as more than one claimant has appeared for the honor of first proposing the work, it has been the desire of the writer to give each his just due; and should any injustice have been done in assigning to one that credit to which another is entitled, to place the subject fully in detail, in all its parts, before the world, so as to admit of a correct opinion being arrived at through the medium of a free press and contemporary discussion, as it is to such sources the future historian of Canada must refer for material, when he alludes to the great work. In concluding our remarks on this branch of the subject, the following comparative synopsis of the different plans proposed is given.

Names of Engineers.	Description of Structure.	Total length.	Greatest headway above water.	Least headway above water.	No. of spans.	Length of span over channel.	Length of remaining spans.	Length of solid approach.	Length of super-structure.	Estimated cost of Bridge.	REMARKS.
										$	
Mr. Morton..............	Stone and wood...	11,540	...	...	...	...	...	...	...	...	¼ of a mile above foot of Nun's island.
Mr. Gay, "Upper," ...	Stone and wood...	14,960	...	...	...	...	...	...	...	613,321	Head of Nun's island.
Mr. Gay "Lower,"....	Stone and wood...	12,540	25	22	56	draw 60	200	...	11,200	525,693	Foot of Nun's island.
Mr. T. C. Keefer.......	Stone, iron & wood	10,000	100	45	23	400	250	3060	6,940	1,600,000	Point St. Charles to St. Lambert.
Mr. T. C. Keefer.......	Stone and iron....	10,000	100	45	23	400	250	3060	6,940	3,600,000	Do. Do. Do.
Stephenson & Ross...	Stone and iron....	9,184	60	36	25	330	242	abuts 2600	6594	6,300,000	Do. ½ a mile above.

CHAPTER IX.

JAMES HODGES.

We have now arrived at the period when the designs so elaborately matured on paper, were to receive material embodiment,—when, after the engineer had exhausted all his science, skill, and ability, in the office, in pointing out the method of encountering Nature's difficulties, and unable to proceed farther, he had now to retire, and allow others to come on the scene, for the purpose of carrying out his results in iron and stone; to boldly meet, grapple with, and successfully subdue the heretofore unconquerable river, saying practically, Thus far shall thy forces extend, but no farther.

The railway development in England had originated men, who, to the shrewdness of contractors, united the scientific ability of engineers, and to whom that and many other countries, are indebted for the successful and energetic manner in which their private and public works were executed; but towering high above all those was the celebrated firm of Peto, Brassey, & Betts, with whom an agreement had been entered into for the construction of the Grand Trunk Railway, including of course the Victoria Bridge.

These eminent gentlemen, with a world-wide reputation as contractors, have also established their names as household words wherever railways have extended their civilizing influences; for the sun cannot shine in any quarter of the globe without reflecting back its rays from monuments of their enterprise, energy, and skill. In the prosecution of works, many of which may well be termed national, they have trained up a staff of engineers, adapted to the peculiar services required of them, and, in their combined characters as practical mechanics and theoretical men have produced results which will render the nineteenth century the wonder of all time.

Well did Robert Stephenson remark, when speaking of this system, that having such men as Peto, Brassey, and Betts, as contractors, with James Hodges for their engineer, nothing was left for his mind to dwell on but the poetical department of the profession.

This gentleman had been in the employment of the firm for many years, and justly in possession of a larger degree of their confidence than any other member of the staff. He had, in behalf of the company, carried through some of the most extensive works in England. The great Northern railway, and the celebrated Lowestoft Harbour, owed their successful completion to his energetic character, while the chalk-cliffs of Dover, those natural bulwarks of the "sea, girt isle," had trembled to their very foundations under the powerful forces he brought to bear against their solid walls. With the reverberations of that huge blast still ringing in his ears, he had retired in the prime of manhood to the seclusion of private life, in the enjoyment of a well-earned competency, leaving the active pursuits of the profession he had loved and honoured so well, to other and younger men. This retirement was to be of brief duration. The Canadian contract had been taken by the firm he had served with such ability and faithfulness. In the enormous staff of eminent men under their control at the time, there were none to whom they could with confidence entrust this gigantic and untried work, and but one individual in England who in their opinion was fitted to conduct it. That man we need scarcely say was James Hodges, a name now dear to many Canadians, and who, at the earnest request of his late employers, left the quiet shade of that honoured retreat in Surrey, to engage in a conflict with the most formidable material adversary ever encountered by man.

In attempting to delineate the character of our late revered chief, we could dwell on the theme as one filled with the most pleasing reminiscences. The kind and cordial personal confidence he ever solicited in the intercourse with his staff; the pleasure and gratification always exhibited when bringing his vast and varied mechanical abilities into play in assisting them out of the numerous difficulties ever at hand; the high principles and rigid integrity by which he was actuated, and ever strove to inculcate by precept and example; the simple manly and straight-forward style which characterised his daily walk and conversation; his kind and feeling heart for the multitude under his control, in providing ministers of the Gospel, school-teachers, and medical men, for their spiritual, moral, and physical well being, stamped him as one of the most philanthropic men of the day; while among the thousands by whom he was surrounded, there beat not a heart more tender and sympathising than his on the occurrence of any of those fatal or serious accidents to life or limb, which always accompany the prosecution of so great a work, but in this instance reduced to a minimum by the effective and careful provision provided in every department.

An intercourse extending over a period of five years, gave the writer an opportunity of becoming acquainted with the numerous acts of kindness and charity, now no doubt forgotten by the donor, but enshrined in the hearts of the recipients. Of the universal feelings of respect and attachment, as well as the unqualified admiration for his scientific and mechanical ability, which pervaded all classes in Canada, we will not personally dwell on, but exhibit him as described from other and widely distant points of view.

A writer in one of the leading journals of the Province, in the course of a lucid and able article on the Victoria Bridge works, thus speaks of him: "These figures convey some idea of the forethought and practical combinations which are necessary to carry out a design profitably to a contractor, and there are two ways of doing this. There is the harsh overbearing inconsiderate selfishness, which extends no thoughts to others, and views "the hands" in the cold material view of wringing from their labour all the profit which could be gained, without a thought of their comfort and happiness; and there is the zenith of this low view of the matter, and it has to be said to Mr. Hodge's credit, that the latter is the principle by which he has been guided. He has not contented himself with only looking to the interest of the firm which he represents, but he has carried on the work like a gentleman. There have been trying times during the last five years, as any one may readily conceive, and Mr. Hodges may not have spared others, indeed it was not possible to do so, but he never spared himself. Where there was difficulty and danger, there he was to be found, and no man has been asked to go where he would not have had to follow. Disappointments and accidents and temporary failures form chapters in the history of all such undertakings, when they are written, but generally the world never hears of them. They come and cost anxiety and pass away, and re-appear again to be triumphed over periodically, to be met with only to create renewed energy."

At a public dinner given to the late employées of the Victoria Bridge, after Mr. Hodges' departure from the country, one of the most distinguished engineers in America spoke as follows: "It is my firm conviction, gentlemen, that the contractors never, in any of their great enterprises, displayed more wisdom and sagacity, or greater ability to cope with great difficulties, than in selecting Mr. Hodges for the arduous work of placing the Victoria Bridge where it now stands, as firm as the rock it rests upon. It is not enough to say, gentlemen, that no better man could have been found for the place. I go farther and assert, that in any community, however large, of intelligent and able men, it would have been a difficult matter, a very difficult matter indeed, to have picked out a man so eminently fitted in all the various qualifications it required, as Mr. Hodges has proved himself to be for conducting the great work to a successful completion; and, gentlemen, it was not only in his dealings with the St. Lawrence that he proved himself a man of resource and a skilled and patient workman, but, better still, in his dealings between man and man he has proved himself to be that which the poet has termed 'the noblest work of God, an honest man.'

"It is but negative praise, gentlemen, to say that a man has no enemies; of Mr. Hodges it is but simple truth to say that in every man with whom he had dealings during his sojourn amongst us here in Canada, he secured a friend."

Another engineer, a late member of Mr. Hodges' staff, and a Canadian, during the course of his speech, in replying to the toast "Success to the Victoria Bridge," thus alluded to his late chief: "Some few years since, the idea of such a structure spanning our noble St. Lawrence, would have been laughed at, and to people acquainted with the force of the current, and the millions of tons of ice to be hurled against this barrier, the scheme seemed perfectly ridiculous; but there were others who thought differently, men of unrivalled genius pointed out the way by which the obstacles could be surmounted, and soon found others willing and ready to furnish the "sinews of war," to aid them in the untried conflict with the mighty river, and that that confidence was not misplaced, this auspicious and happy meeting to celebrate its success abundantly testifies. You will remember this gigantic work was commenced in the year 1854, to be completed in 1861, in the short space of eight years, a time not to be measured by the usual span in this rigorous climate, but each season to be compressed as it were into a few short fleeting summer months. You will also please bear in mind that two of these years were nearly lost, owing to monetary difficulties during the Crimean war, when works in all other parts of the world were either paralyzed or stopped. I ask you, then, in the face of all this, with the bridge open for traffic in the year 1859, nearly 18 months before the time specified by the most sanguine, if its construction has not been a success,—an achievement, gentlemen, owing in great measure to the indomitable energy and ability of Mr. James Hodges, ably seconded by yourselves, individually and collectively? You will perhaps allow me to pay more than a passing tribute to this gentleman, notwithstanding that he has been so highly eulogised on this and other similar occasions. We young Canadian engineers owe him a debt which nothing can cancel, one which will be transmitted to our children and children's children, for the ready and helping hand he extended in placing us in positions to be associated with this, our country's greatest work; and now that the bands which united us to him for the last five years are severed, never again to be reunited, we would like if it were possible, this evening, for an expression of our gratitude to be wafted on the wings of the winds across the broad Atlantic, to his honoured retreat in Surrey, telling him that the high and honorable precepts he both taught and practised in our midst, will never be forgotten, but be forever cherished in memory, enabling us as far as possible in our future career, to follow in his footsteps. Gentlemen, I have seen him in moments of disaster, and in hours of success, at times when he was forced to bow to powerful and ruthless adversaries, and when gazing with the calmness of a Christian philosopher upon the destruction of the works of months, in a few minutes, prepare resolutely again to enter the arena of conflict, and eventually emerge victoriously. You have all lately seen him in the full flush of triumph, with the victor's garlands encircling his brow, the crash of triumphant music and the ringing cheers of a thousand spectators in his ears;—at a moment like this, when conscious superiority and pride would have been pardonable if ever, and yet, with a modesty unparalleled, have heard him disclaiming all credit, and in eloquent terms pointing to you as the men who did all, thereby shewing the truth of the maxim, that 'genius and ability are always allied with modesty.'"

His Lordship the Bishop of Montreal, in the course of an eloquent address, on the occasion of the first passenger train passing through, thus alluded to him: "He, the Bishop, was there because he wished to pay the tribute of his personal respect to Mr. Hodges, to testify his high sense of that gentleman's integrity, and of the Christian principle with which he had provided for the education and spiritual supervision of all the people connected with the work. He looked on this gentleman's example, as one which all employers should follow. They had no right to congregate large bodies of people without making provision for their spiritual wants. Mr. Hodges, with the approbation of his principals, had acted so as to secure this great blessing for the people employed by him, and, though this mighty work would meet with the fate described by the great poet,

'The cloud capp'd towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea all which it inherits, shall dissolve,
And, like the baseless fabric of a vision,
Leave not a wreck behind,'

yet the integrity of character, high moral principles, and Christian philanthropy which had actuated Mr. Hodges would remain on record for all eternity."

The following extract is also given from a speech delivered on the same occasion by the engineer who had been sent out from England on behalf of the Grand Trunk Railway Company, to examine the bridge :

"He, the speaker, only repeated what he had heard from Mr. Stephenson and Mr. Ross, that much of the success of this undertaking had been owing to the skill, energy, and unfailing resources in difficulties of Mr. Hodges. The speaker had examined closely and critically every part of the work. No iron tubes were ever put together over which passengers might more safely pass; no masonry was ever heaped stone on stone with greater art, or with more precaution to secure solidity and durability."

And lastly, Mr. Ross, in the delivery of a powerful address on the subject of the numerous difficulties encountered during the construction, and in referring to the cordial co-operation received at all times from the parties concerned, spoke in the following manner of the contractor's agent :—"Having always present to my mind, that golden rule, which I trust will ever be found to characterise my proceedings, 'to do to others as you would be done by,' my task has been an easy one, my occupation in so far at least as pertained to the duties peculiar to my own calling a plaything. Yet it would be too much to expect that works of such magnitude, with varied subjects of consideration, together with the more than ordinary conflicting elements of a rigorous climate, could go on to the end without some drawback to a uniform progress. I however never yet found the talented agent invested with the responsibility of carrying out this great trust on behalf of his employers, to be wanting. The resources of his mind were at all times equal to the exigency of the case, and, so far from feeling any degree of reproach inseparable (if any exist) from all concerned, the result has ever been one of unmingled gratulation."

The foregoing extracts are a few of the many which might be given to show the high position he occupied in public opinion in Canada during the time of his sojourn, but, in connexion with those expressions of respect and admiration, we cannot refrain from noticing a fact not referred to by any of the speakers, and which no doubt was driven from their memories at the time by the magnitude of the work more immediately before their observation; we refer to the construction of the Grand Trunk Railway, simultaneously with the Victoria Bridge.

The whole of this extensive enterprise as far west as Toronto, was within the general surperintendence of Mr. Hodges, with a section of it amounting to nearly 320 miles under his constant and personal surveillance.

Many of the mechanical structures on the line were of a magnitude second only to the Victoria Bridge, and required the same watchful care and skilful resources on the part of the chief, as did the great work itself.

In fact every branch of the work, from the erection of locomotives and rolling stock, down to the simple box culverts along the line, received from this ubiquitous man the most rigid examinations, at very short intervals of time, and not the least was the management of the monetary department for the whole extent of the line. So successfully was it carried on, that from the commencement to the end of the work, every contractor, tradesman, mechanic, and labourer, had his money to the day it was due. This universality of business talent, so rarely combined in the same mind, with great mechanical resources, can only be appreciated by those who have to do extensively with each distinct department.

We do not say he was without zealous and able assistants; but this we do assert, that he was the main motive power, laying down the laws by which they were to be governed, and creating the discipline by which they were to be guided, with admirable skill and management.

CHAPTER X.

COFFER DAMS.

In making arrangements for carrying out the work, in devising coffer-dams, machinery, and all the thousand and one skilful appliances to be made use of in its prosecution, no assistance was rendered by Messrs. Stephenson and Ross, as both gentlemen considered it entirely within the province of the contractors, or rather their representative, Mr. Hodges, to adopt such means as they might consider most economical to themselves, so long as the soundness and stability of the work were in no way affected.

With Mr. Hodges therefore rests the entire credit of the origination and successful applications of the numerous ingenious inventions and adaptations in the carrying out of this work.

The most important consideration at the commencement of operations, was the method to be employed in placing the foundation of the piers and abutments in place, and at the same time to combine great strength, efficiency, and economy. In a river exposed to such extreme changes, strength of current and depth of water, with the peculiar deposit existing on its rocky bed to be removed, it was evident that the methods generally in use for foundations, such as the diving-bell, or by means of concrete confined in "caissons," would be utterly futile, and therefore not to be entertained.

The idea that first suggested itself to Mr. Hodges, in connection with the building of the piers, was the construction of large floating coffer-dams, so arranged as to present the least resistance to the current, and furnished with an inner well or opening sufficiently large to admit of the pier being built, after the water and deposit were removed, and capable, on the completion of the masonry, of serving a similar purpose with additional ones.

Three structures of this description were built, and undoubtedly were the most economical, speedy, and effective system of coffer daming made use of. By means of the first two built, No. 1 and 2 piers were erected ; and had it been possible to remove them to winter quarters a few days sooner, many other piers would have owed their existence to them. The third one, however, built three piers most successfully, and was only taken to pieces on the completion of the Bridge. The circumstances which operated most against the entire use of floating dams arose from their being able to build but one pier each, in the season, besides not being adapted to meet the force of the ice, and consequently, did any unforesen difficulty with the foundation arise, by which the masonry could not be commenced or completed the same year, as in the case of Nos. 3, 4, 5, 6, 8, 9, 14, and 15 piers, the entire structure would be destroyed by the ice. A second system had to be introduced to obviate such contingencies, being sufficiently strong to remain intact during the winter, and in readiness for next season's operations.

A third system, being a combination of the other two, was also devised.

Before giving a description of the manner in which those three distinct and widely differing systems were brought into successful operation, the following result of their work is given:

No. 1, or floating coffer dam, was used in the erection of piers 1, 2, 7, 17, and 18.

No. 2, or solid crib coffer dam: Piers 3, 4, 5, 6, 8, 9, 10, 11, 14, 15, 16, 19, 20, 21, 22, 23, 24 and the two abutments.

No. 3, or combined system: Piers 12 and 13.

No. 1 *System.*—The floating coffer dam was built in two pieces or distinct pontoons. The sides were parallel, and the upper end made up of two minor sides approaching each other at an acute angle.

The height of this structure was about 16 feet, and the sides 20 feet wide, closley corked and rendered water tight. The second or tail piece was built rectangular, 16 by 20 feet, and long enough to fit in between the sides of the other, at the lower end,—both of them being a strongly built and braced as possible, to enable them to resist the enormous pressure to which they would be exposed, when the water was pumped out of the area they enclosed. When required for use, the main pontoon was taken by steamboats and towed to the site of the pier, and, having been brought to its required position, strong piles were slipped down through guides, into the bed of the river, thoroughly driven home, by pile engines, and served to keep the dam stationary.

Sluice gates were then opened, allowing the water to flow into the pontoon, which, with additional weight placed on the deck, caused it to sink within a few feet of the bed of the river, the piles playing freely in their guides and allowing this subsidence to take place. When the required depth was reached, strong iron bolts secured the piles to the main body of the dam, and with an additional weight on the deck, rendered the whole mass now resting on the numerous pile legs, stationary and firm.

Sheet piling reaching to the bed of the river, was then placed on the outside, where exposed to the current, and prevented it sweeping underneath the dam.

The second section was afterwards towed up, put in place at the foot of the first, and sunk in a similar manner.

An area of perfectly still water, about 130 feet in length, by 54 feet in width, was thus obtained in a few days, for subsequent operations.

In this space a second frame, following the inner contour of the pontoon, was prepared, made up of timbers 12 inches square resting vertically on each other, with the sides stiffened by cross braces or struts, to prevent them approaching each other, when exposed to the pressure, and framed on the bottom to sink the irregularities of the bed of the river. The building was then continued till it rested on the bottom and brought up level with the deck of the outer coffer dam. The dimensions of this inner dam were such as to leave a space on all sides, between it, and the inside of the outer dam of about six feet in width, for a puddle chamber. Sheet piling was then driven in the entire length of this chamber so obtained, on both sides of it, and, after the gravel and loose stones were removed from its bottom, so far as practicable, by dredging, the "puddle" was introduced, consisting of thick clay, rendered impenetrable to water by tamping or beating it down.

The dam was then ready for pumping.

No. 2 system, the area of still water was obtained by inclosing the space, with the ordinary crib work of the country, framed to suit the bottom, upon which it had a solid bearing, and raised four feet above summer water, presenting when finished a rectangular figure 173 feet in length by 88 feet in width on the outside, with an enclosed area of still water 52 feet in width by 125 feet in length. The sides and lower end of this crib-work, were 18 feet in width, and the upper end 30 feet.

These cribs were built of open work, that is to say, spaces of 6 inches intervened between the side timbers, with dovetailed cross-ties at every 10 feet, and strongly bolted together with iron rag-bolts, and wooden tre-nails. The floor for the reception of the stones, was placed about

2 feet under summer level, excepting in the head of the dam, where it was about 6 feet, and the entire crib-work filled with stones to the height of four feet above that level. Six feet of the upper angle of the head of the dam were taken off with an inclination of 1 to 1 and planked over, furnishing a sloped surface for the ice to slide on.

In the event of the dam having to remain in during the winter, it was sometimes planked over, on its upper surface, so as to afford no points for the ice to catch on; in other instances, it was left unprotected with equal success.

The inner dam was arranged precisely as that described for the floating dam, and with its puddle chamber dredged out, and filled with clay, was also ready for pumping.

No. 3 system. A combination of the two preceding systems, was made use of in this mode so as to obstruct the main channel of the river as little as possible, and at the same time to restore it to the navigation with the least possible delay. To accomplish this, as well as to ensure the certain completion of the large piers, Nos. 12 and 13, during the season, Mr. Hodges had four rectangular pontoons constructed during the preceding winter, for the sides of the two dams.

The upper ends were composed of detached cribs, with aprons between them to break the current, while the lower sides were made up of continuous cribs. The pontoons were sunk and held in place in the same manner as the floating dam.

The area of still water produced by this method, yielded the necessary facilities for sinking the internal crib-work, similar in all respects to the arrangements described for the other two systems, and, after being sheet-piled and puddled, was ready for pumping.

The two abutments were built in spaces surrounded by two lines of crib-work, each nine feet wide, with a puddle chamber 4 feet in width intervening.

CHAPTER XI.

PUMPING.

THE respective coffer dams having been brought to this point, the anxious time for discovering their efficiency had arrived, with the commencement of the pumping, not that the labour was great in removing the water, but the application of the test to show if the dams were tight, or if the water would not force its way up through the beds of quicksand and boulders, as fast as the pumps could remove it, naturally created anxiety. Nothing could be better than the two different descriptions of pumps used. Those introduced by Mr. Hodges consisted of two cast-iron cylinders about 18 inches in diameter each, and placed vertically side by side, with their piston-rods connected by means of a bell-crank, working them alternately, by the gearing connected with the engine. Water-tight flexible suction-hose, was connected to the bottom of the cylinder pipe, and thence conveyed into the well, sunk to the rock, into which all surface water was conducted. The pumps were therefore on the suction and forcing principle combined, and threw an enormous stream of water when under full headway. An objection to their use, was the bulk and weight with the concussion or jar transmitted to the dam, frequently causing the sheet piles to start and a break-in to follow. Before the damage could be repaired, much trouble had to be encountered in moving the machinery, to admit of the piles being replaced or driven home. Apart from those considerations, they were equally efficient with the centrifugal forcing pump introduced by Mr. Chaffey, throwing an equal volume of water, if not greater, with less power required to drive them, and were used by Mr. Hodges in pumping out eleven coffer-dams and the north abutment.

The centrifugal or forcing pump, introduced by Mr. Chaffey, and adopted by Mr. John O. Hodges, pumped out 13 coffer-dams and the south abutment. This pump consisted of a circular cast or wrought iron shell, from 15 inches to 2 feet in diameter, according to the power required, and from 6 to 9 inches in depth. From the side of this circular box, a pipe of sheet iron, 7 inches in diameter, was carried sufficiently high to admit of the water flowing in a trough over the top of the coffer dam; the pump and pipe were held in place by a light iron or wooden frame, 2 feet square, from the pump to a few feet above the top of the dams, and serving also to support the vertical shaft, passing down into the pump, and provided with a couple of wings or vanes attached to and revolving with it in the circular shell above described. The water flowing into this receptacle through appertures in its bottom, was seized by the rapidly revolving vanes and forced with great velocity up the 7″ pipe, from whence it was conveyed into the river.

The whole apparatus was extremely portable, but required very high speed to do its work effectively, and without careful protection and watching, was liable to be entirely stopped by chips of wood or other small obstructions being drawn into it, in which case, it was necessary to lift the whole affair out of the water, before the obstacle could be removed. When working with its usual speed, it threw out from 800 to 1000 gallons a minute, lowering the water in the inner area of the dam at the rate of 2 feet an hour, and occupying from three to ten hours in entirely emptying it. When this was done, a well, usually four feet square, was sunk through the deposit, a foot into the rock below, and the pump moved and lowered into it. Drains were then made leading into this well, and the surface water arising from springs or leakage, conducted by them to the pump.

The exact area to be occupied by the pier was then marked out by Mr. Hodges, and as many excavators put to work as the space would allow, and continued by relays night and day. If the dam proved sound, the work proceeded rapidly; but if the foundation was bad, a break would fill the entire cavity in a few moments, the men forsaking their tools, and, squirrel-like, running up the ladders provided for their escape. An examination of the break would perhaps shew one entire side of the dam deprived of its puddle, with the sheet-piles floating about in all directions, making it necessary to re-drive them all, and procure additional puddle to replace that swept into the dam. This being accomplished, and the pumping resumed, the same anxious hours were to intervene before the bottom would again become visible, but now covered with the late puddle, converted into soft mud. On the excavation being recommenced, and probably before the late accumulation had been removed, another alarm would drive the men up pell mell, closely followed by the rising muddy water. On this occasion, the break may have taken place in an entirely different direction, and where least expected. A second delay of course takes place, until the damage is repaired, when, on the work being resumed, and every thing going on favourably for a day or two, a stratum of quicksand is struck, in the very centre of the dam, far from the sheet piles, and in a moment, the gushing, boiling, heaving sand and water rushes up, filling the vacant chamber as quickly as before.

This time, however, the cure is much more difficult and protracted. The sheet-piling and the puddle on top are unchanged, and present no indications by which a discovery can be made, of the quarter in which the connection between the inside and the outside of the dam exists. The pumps have to be kept running at full speed, withou sensibly diminishing the level, and the process of pile-driving renewed in full vigor, until the subterranean channel of connection is reached and cut off. To do this, the piles have now increased from 3″ plank to timbers 12 inches square, and shod with heavy wrought-iron shoes, enabling them to be forced down through the solid crust, existing above the quicksand, into the hard bed lying underneath, and, after long and weary labour the pumps at length begin to make an impression on the inner level, gradually reducing it again to the bed of the river.

Another, and if anything, still more severe trial, was met with, as in the case of No. 8 and No. 9, where portions of the coffer-dam, rested on large piles of round boulders, heaped upon each other to a considerable height, and not discoverable until a diver went down into the still water, enclosed by the dam, to ascertain why the pumps made no impression on the level. The ordinary sheet-piles and the puddle of course, had not penetrated through this mass of stones, which furnished innumerable interstices or sieve-like openings, allowing the current from the outside to rush in as fast as removed by pumping. Very extensive pile-driving follows, or else the puddle is dredged out of the chamber, and the stones removed by the difficult and laborious process of divers going down and attaching grappling-irons to each individual stone, to be then removed by powerful appliances from above. An idea of the difficulty attending this part of the operation, may be had from the fact that the stones so removed, ranged from 3 to 15 tons in weight, (with one individual stone as high as 30 tons,) and in many instances, with the coffer-dam resting partly on them, rendering the removal an almost impossibility.

In other dams no such trouble was met with, and the pumping effected without difficulty; an average however of the 24 piers, was about three total interruptions for each.

CHAPTER XII.

TRAVELLER STAGING, AND TRAVELLERS.

ON the completion of the coffer dam, and during the time of pumping and excavating, the staging for the masonry travellers was being put up; but as there was some difference in the arrangement made use of by Mr. Hodges and Mr. Chaffey, each system will be described.

In the mode made use of by the first gentleman the hoisting, conveying, and setting, were accomplished by means of travellers. Two of those machines were elevated on staging, raised about 36 feet above summer level. This staging was composed of bents on each side of the coffer dam, supporting two longitudinal caps or timbers, on which the rails were laid for the travellers to traverse on, and extended from the upper end of the pier to the lower end of the coffer dam, and projected sufficiently far over to admit of one of the travellers going out beyond the coffer dam, directly above the deck of the barge containing the stones. The extreme ends of the plates were connected together by timbers, which served to stiffen them, and at the same time prevent the travellers going overboard. The rails were laid on those caps to a guage of 36 feet, for the travellers to work on, and without obstruction from one end to the other, the whole staging being held in place, and stiffened by braces and struts from the dam, externally to the upright bents supporting the cap-timbers for the railway.

For the erection of the shaft of the pier, a scaffold about 40 feet in length, and raised to the necessary height, was put up, the bents supporting it being on the outside of the lower race, and necessitated a traveller 40 feet span, to admit the lower travellers passing the framework.

The traveller was provided with gearing by which it could be worked by manual labour, the entire length of the staging, and also with a strong double-purchase "jennie" or smaller traveller working laterally on it. To the hoisting drum of this "jennie," driven by smaller pinions from a crank movement, was attached the leading chain in a system of blocks or pulleys, connecting with the "lewis" or iron fastening in the stone to be lifted. This fastening was of a very simple and effective character. What was called the single lewis, consisted of a short piece of iron about 9 inches long and an inch round, with the upper end terminating in a strong ring four inches in diameter, into which was inserted the hook belonging to the lifting-block before mentioned. The remaining end of the lewis, terminated on one side in a flat bevelled face, with the end somewhat larger than the centre. Before lifting a stone, the lewis was introduced into a hole previously drilled, about 4 inches deep, slightly larger than the section of the iron, and held by the hand, so that its end did not approach the bottom of the hole within half an inch. In this position a small steel wedge, flat on one side and circular on the other, was firmly driven between the bevelled face and the side of the hole. The stone was then ready for hoisting.

From the two reversed bevelled faces of iron coming in contact, it is evident, the more force or weight applied in endeavouring to remove the lewis, the firmer would its connection with the stone be made, and in this manner carried the weight with it to the place required. To be withdrawn, a slight tap with a hammer on the upper end of the lewis, forced it to the bottom of the hole, and loosened the small wedge. Both were then removed by the hand.

The double lewis, for heavier stones, consisted of two short pieces of iron about 9″ in length, with an iron ring through one end of each. To be used, two holes were drilled into the top bed of the stone, approaching each other at an angle, and the lewis introduced, coupled together by a strong chain about 3 feet in length, passing through the rings. To this chain the hook of the lifting block was attached and the stone conveyed to its required position. Various other modifications were introduced by Mr. Hodges and made use of, but the two described will serve to give the reader an idea of the simple manner in which the enormous masses of rock were handled.

Each traveller was usually provided with four men to work it, and, as everything underneath was distinctly visible, they had no difficulty in conveying the material to the exact spot required by the masons engaged in setting the masonry.

When the level of the pier approached the upper side of the coffer dam, and from thence required the stone to be hoisted, by far the slowest part of the process, if performed by manual labour, the assistance of steam was introduced, and expedited the work in a remarkable degree. At this period, the pump being no longer required, the engine which had driven it was appropriated for the purpose, being connected by means of a belt with a small pully placed on the top of the scaffold so arranged as to connect with the drum of the hoisting-jennie. By this arrangement the stone could be run up to a height of 60 feet, or less if required, in a very short space of time, when the jennie being detached from its motive power, two men were able to work the traveller rapidly to the place required, and lower the stone quickly, or the reverse if necessary. This steam hoist was first introduced by Mr. Chaffey.

Mr. Chaffey, in the erection of his piers, used a very different method, quite as effective, and in some respects more so, consisting of a compound derrick or crane, worked either by horse or steam power, and may be described as follows. The main part consisted of a mast or square stick of timber, about 80 feet in length, placed on end and terminating in an iron pivot, resting in a cast iron socket, secured to a platform prepared near the side of the masonry and supported on the coffer dam. This mast was retained in its vertical position by two wooden guys or pieces of timber, with bent plates of iron, bolted to their upper ends, passing over a pivot or gudgeon of strong iron in the upper end of the mast, with their lower ends firmly secured to the sides of the coffer dam, and placed at such an angle with each other, as to retain the mast in its upright position in all stages of its future operations. Thus arranged, and with the horizontal arms afterwards added, it possessed a rotatory motion, within the limits of nearly 270 degrees of the entire circle.

At a height of about three feet above the pier, when completed, the arms for supporting the travelling jennie were bolted to the mast. They were in two pieces, about 8″ x 14″, placed on each side of it, and so arranged that the longer arm possessed sufficient length to take the extreme ends of the pier in its horizontal sweep; the shorter arm was made to clear the guy-timbers, and served for the truss-rods introduced to stiffen the mast.

The long arm carried the rails on which the jennie traversed, and was provided with a clear space between its two sides, from the mast to its outer end, at which point they were bolted together. Sufficient room was thus left for the blocks and chains from the jennie to work in. The long arm was supported and strengthened by heavy tie-rods or suspension-bars, passing from each of the side-pieces, at short intervals, to the top of the mast, and secured to the pivot before alluded to. From this point back tie-rods ran to the outer end of the shorter arm, and thence to the pivot at the foot of the mast, forming a powerful truss to support it when exposed to the enormous leverage of a stone weighing ten tons, suspended from the extreme end of its long arm.

The chains from the jennie, for both hoisting its load and giving it a lateral motion, passed from it over friction pulleys, placed at the intersection of the arms with the mast, then and to its foot, through which they passed by a peculiar arrangement, and thence, under friction pulleys, were conveyed horizontally to the respective drums, connected with the machine giving them motion. A circular segment, about 6 feet in diameter, was firmly bolted to the foot of the mast, around which a chain passed to a third drum.

The most novel feature in the whole affair was the ingenious arrangement of wheels within wheels, all existing in the compass of 8 feet by 4 feet, and by whose aid an intelligent boy, without moving from his position, could bring three of the six different movements into play, either separately or at the same time. Thus, the jennie being at the outer end of the long arm, with its "fall" of chains and blocks attached to a stone, say of six tons weight, lying on the deck of a barge at the lower end of the coffer dam, and ready for hoisting, on the signal of "all right" being given by the lewis boy, a system of clutches and beaks was brought into action and with the power applied, the stone was snatched from the deck, as if it were a pebble, and rapidly elevated. A second motion in the mean time carried it towards the mast, while at the same time the whole derrick was swinging around its arms and jennie to the upper end of the pier, or wherever the stone was required; which point reached, a motion of the hand from the foreman mason, on the top of the pier, conveyed the signal to the boy below, who stopped the three motions instantly by detaching the machine from the motive power, and by the powerful breaks applied by the touch of the boy's hand the ponderous stone was held swinging in the air, until the mortar was spread for its bed by active masons. A second signal, readily understood, brought the necessary movements into being, and placed the stone in the exact position required, when a tap of the hammer on the lewis head, severs its connection with its late load. A third wave of the hand reversed the three motions, by bringing other three into life, and in a moment or two the lewis and blocks were on the deck of the barge for a second stone, occupying but little more time than the reader has spent in its perusal. This derrick, with the steam traveller erected by Mr. Chaffey at St. Lambert, described in an after part of this article, form two of the most remarkable and successful applications of power during the entire progress of the work.

CHAPTER XIII.

MASONRY.

EITHER of the described systems having been brought into working condition, the excavation to the rock accomplished, a large quantity of stones, together with cement and sand, on hand, blacksmith shop and proper accommodation for the men provided on each coffer dam the rock swept perfectly clean, and the precise lines of the pier foundation marked on it, the first large quoin or corner stone was lowered down to its long home ; others quickly follow, and soon complete a level course throughout the entire foundation, the stones of the heavy ashlar or outside masonry forming headers and stretchers alternately, while the backing or inside work is made up of blocks scarcely less formidable.

The cross timbers which prevented the inner dam collapsing, were cut singly, as met with, and the ends wedged tightly against the intervening masonry, with the level of summer water reached, and all danger from breaks at an end, the pumping was stopped and the dam allowed to fill with water. Cement mortar, in the proportion of 2 parts sand to 1 of lime, was used for both ashlar and backing throughout the entire foundation up to the level of surface water, from which point the backing was laid in common mortar, made of the best well-burnt fresh lime in the proportion of 1 sand to 1 lime. The ashlar throughout the pier from foundation-stone to coping, was laid in hydraulic cement, with all vertical or end joints "grouted," that is cement mortar in the proportion of 1 part sand to 1 part cement, reduced by water to the consistency of a liquid paste, and in that condition poured into the joints, filling every cavity thoroughly. The external joints were then pointed in cement mortar in the same proportions as used for the grout.

The mode of securing the upper face or cut water of the pier with bolts and cramps, has already been described, in referring to Mr. Ross's design.

The construction of the piers was in many instances urged forward day and night, by successive relays of masons, from the lateness of the season, owing to the great length of time previously occupied in the preparation of coffer dams, pumping, excavating, &c. During the night large bon-fires were lighted on different parts of the coffer dams and piers, creating a lurid glare, in the midst of the surrounding darkness, but rendering everything distinct and visible on the work.

The masonry of the parapets on each abutment was built by means of large Wellington cranes, 35 feet in height by 53 feet in span, encompassing the entire walls, and sufficiently strong to elevate stones weighing ten tons with safety.

On the entrance-lintels of those parapets, above the roadway, the following inscription in large letters is cut into the stone:

ERECTED, A.D. MDCCCLIX.

ROBERT STEPHENSON AND ALEXANDER M. ROSS,

ENGINEERS.

While the lintels at the other end or over the tube entrance, bears this:

BUILT

BY

JAMES HODGES,

FOR

SIR SAMUEL MORTON PETO, BART.,

THOMAS BRASSEY, AND EDWARD LADD BETTS,

CONTRACTORS.

CHAPTER XIV.

TUBE SCAFFOLDS.

Various considerations induced Mr. Hodges to adopt the plan of building the tubes in place, instead of following the method used by Mr. Stephenson at the Menai Straits, a considerable portion of the river being obstructed by shoals, and even in deep water large detached boulders, brought by ice, frequently lifted their heads within a short distance of the surface. The numerous rafts constantly descending during the summer season, and the necessity of continuing the tube operations in the winter when the surface of the river was covered by ice, as well as its great width, were some of the reasons which operated against building the tubes on shore and floating them out on pontoons.

In designing the most efficient scaffolds for this purpose many things had to be kept in view. Those spans near the shore, when built in summer, and generally beyond the reach of descending rafts, required the minimum of strength and precautionary measures, apart from the necessary requirements for sustaining the great weight of the tube. This class may be termed *No.* 1 or *Summer Scaffold. Class No.* 2, consisted of those built during summer, in the direct channels taken by heavy rafts, and consequently required an excess of strength over and above the tube requirements, to enable them successfully to resist the impact of those enormous flows of timber when cast against them by the swift current. *Class No.* 3.— This mode required a vast amount of additional weight and stability above either of the other two, to meet the terrific and almost irresitible winter forces of moving fields of ice.

Before describing either of those distinct classes, we will give a statement of the work accomplished by each.

Class No. 1 or Summer Scaffold, Tubes 2, 3, 4, 5, 6, 16, 20, 21, 22, 23, and 24.

Class No. 2 or Truss Summer Scaffold, Tubes 1, 9, 10, 11, 14, 15, 16, 17, and 18.

Class No. 3 or Winter Scaffold, Tubes 7, 8, 13, 19, and 25.

In the erection of Class No. 1, three wooden cribs 57 feet long by 20 feet wide were sunk in the opening between two piers, dividing it into equal spaces, and raised four feet above summer water. The floor containing the stone filling was placed at that level and the cribs filled up; leaving three spaces a foot wide each, the full width of the crib, one in the centre line of the bridge, and one on each side at the distance of 11 feet from the centre. Through those openings hard-wood piles shod with iron, were driven down into the bed of the river as far as practicable, and cut off on top to the same level. On the piles so arranged oak timbers were placed as cills, and pine timber bents or posts erected, on the top of which oak caps were placed to receive the longitudinal stringers running the entire distance between the masonry of the two piers. Those chords or stringers were each made up of two timbers 14″ x 14″, and additionally stiffened over the intervals between the wooden cribs, by diagonal braces or struts, starting from the cills on the piles, and meeting under the chords. The superstructure under the floor was therefore made up of three distinct ribs or series of bents on each crib and strongly connected together by cross girths and diagonal braces.

Floor timbers 12″ x 12″ and 35 feet long were then placed on the top of the chords at distances of four feet centres and planked over. The top of the scaffold as thus constructed was three feet under the bottom line of the tube, which was supported at certain intervals on wooden packings and oak wedges, giving ample room between the scaffolds and tube for men to work. A traveller race for the Wellington cranes to be used in the erection of the tubes, was then made, and consisted of two timbers 242 feet long, one on each side of the tube, resting on short posts from the floor timbers, and giving a guage of 26 feet, the width of the cranes. These cranes were about 22 feet in height, and encompassed the entire section of the tube except the bottom.

In the erection of this class of scaffold, scows were sometimes substituted for the cribs by Mr. Hodges, in which case piles were driven down through guides in their sides and supported the weight of the superstructure and tube; the purpose of the scows and cribs being merely to hold the piles in a vertical position and afford them protection. In other instances where the sides of the old coffer dams admitted it, but one scow or crib was sunk in the centre, and the remaining bents erected from the piles driven down through the crib work of the coffer dams, the general style of the superstructure continuing the same.

Class No. 2.—In this mode of scaffolding an entirely different arrangement was introduced. A single crib, 80 feet long by 30 feet wide, was sunk in the centre of the opening and carried up a height of 10 feet above summer level; the floor was near the surface of the water, and entirely filled with stones to yield the weight necessary for its protection when struck by rafts.

The cross ties were so arranged the entire height of the crib as to furnish two chambers 2 feet in width, and at the distance of 13 feet each side of the centre line of the bridge. Those ties retained in place the hard-wood piles driven down into the bed of the river, and afterwards cut off to receive the hard-wood cills. The cills supported the upright posts carrying the truss superstructure, and formed two distinct ribs, fastened together by cross-girths and side-struts to furnish additional stiffness. Stringers 14″ x 14″ were carried on the top of the bents the entire length of the span, and additionally supported from underneath by braces running out from the feet of the upright posts to the underside of the stringers over the sub-spans, and also by braces from the sides of the piers in the same manner. Floor timbers were then placed across those sub-chords, at distances of 12 feet, and planked over. The structure at this stage of its progress was converted into a platform upon which the lower chords of the truss were put together, and built on the "Howe" principle, with a depth of 20 feet; the bottom and top chords were 14″ x 24″ each, made up of three ribs 8″ x 14″, the side braces 8″ x 8″ with the counter ones 8″ x 10″, and a run of 16 feet; the truss side-rods were double of $1\frac{7}{8}$ round iron; the width between the side-ribs of the truss was 24 feet. The floor was made up of timbers 14″ x 14″ resting on the lower chords, at distances of 3′ centres and 35 feet in length, with every fourth one 60 feet long to admit of braces, being bolted to the ends and carried up to the top chord of the truss. The floor, when planked over, was about 3 feet under the bottom of the tube, and, with packing and wedges in place, and the Wellington crane placed on the track, prepared for it on the upper chords, the time had arrived for commencing the tube.

The two scaffolds bordering on either side of the centre one, four in all, were provided with two cribs 80′ x 22′ in place of one as in other instances. This was necessary from the swift current running at least 10 miles an hour, with the great depth of about 20 feet of water, rendering it almost impossible to sink the wider single cribs; otherwise the general arrangements of the superstructure and truss were the same.

Class No. 3.—In this design a crib 80 feet long and 30 wide was sunk in the centre and carried up to the bottom of the truss or 6 feet from the tube. The upper end was sloped up from the bottom, with an inclination of 1 to 1, to a height of about 30 feet above summer level, at which point the dimensions of the crib were reduced to 40 feet in length by 28 feet in width—from this level a margin of 12 feet was left from the front edge of the slope, and the shaft of the crib, 28 feet by 28 feet, continued up. The margin so retained was planked over and formed the saddle of the ice-breaker, being adapted for throwing off the ice if it should succeed in coming over the top of the slope, and prevent it striking the square face of the shaft.

The slope or ice-breaker was sheeted with 4″ hardwood planks, resting with a solid bearing on the strong timber-work underneath. The first floor was 3 feet under summer level, the second one 7 feet above, the third 10 feet above the last, and filled with stones to the top of the ice breaker.

The timber work of the crib was as strongly put together as possible, with close joints, rag-bolts of iron, and oak treenails, the cross and longitudinal ties dovetailed into the sides and treenailed at each intersection, with the stones carefully packed around the ties and underneath the slope of the ice breaker. The external face of the crib was made quite smooth so as to offer no obstruction to the ice. The face of the ice breaker, instead of being flat or angular, like the stone pier cut water, was rounded off to give facilities for the ice slipping off as it forced its way up the incline.

Two rows of hard-wood piles, the extreme width of the crib, were driven into the bed of the river, and held in place by ties on each side. At the level of 6 feet above summer water, they were cut off and an oak cill placed on top. The upright timbers or posts upon which the superstructure rested, started from those cills, and were held firmly in place by cross ties and the stone filling. The superstructure consisted of a truss built on the Howe principle, as described for Class No. 2. In this position the scaffold received the full shove of ice; before the tube was commenced and after the close of the river, braces were carried up from the sides of the crib and piers to the under part of the lower chord, stiffening it materially. The Tube was then started.

The scaffold for the centre opening, differed somewhat from the foregoing. There the increased span required two supporting cribs; and the height being sufficiently great above any danger from ice, allowed Mr. Hodges to bring the superstructure of the scaffold entirely underneath the tube bottom, and, for additional strength, to introduce a third longitudinal rib. All were strongly cross-braced and connected together. The run of the side-braces of the truss was reduced from 16 feet to 12 feet.

In the erection of all those scaffolds, scows with lifting derricks, driven either by horses or steam power, were employed, and by this means pieces of timber 60 feet long and 14″ square were taken from the water and raised 60 feet high, with the same facility as the stones of the piers, by the traveller and the steam crane previously described.

The entire scow was made up of two smaller ones, or pontoons 60 feet long by 10 feet wide and about 4 feet deep, with the lower angles of the ends taken off. They were placed side by side, with an intervening space of 10 feet between the adjoining sides, and decked over. The mast stood at the upper end over the centre space between the two scows, and was held in place by two wooden guys, running from the top to the outer angles of the lower end of the vessel. A moveable jib-boom or arm was attached to the mast some distance from the top and connected at its extreme end, with the top of the mast allowing it to be raised or lowered at pleasure, or as required by the height of the scaffold.

A series of blocks and ropes, constituting the lifting arrangement, was attached to the outer end of the boom, with the leading rope conveyed down the mast, and thence to the drum of the motive power. The whole mast had likewise a rotatory motion, enabling the stick, after being lifted to the proper height, to be deposited on the scaffold anywhere within the range of the arm. By this arrangement a large truss-scaffold could be put up or taken down in a remarkably short space of time. The scows, from their peculiar shape and light draught of water, were eminently well designed for being moved about or moored in strong currents, and were first introduced on the work by Mr. Chaffey, with horse power for working them, and afterwards adopted by Mr. Hodges, who substituted steam power.

CHAPTER XV.

TUBES.

The plates and iron work for the tubes were nearly all prepared in England, punched, marked, and ready for putting together, before coming to Canada. Thus each individual plate, strip, cover, kelson, gusset, tee and angle iron, had the number of tube, thickness, and mark corresponding with similar ones in the detailed drawings of each tube, sent out with the iron, and enabled every piece to be identified at a glance and placed in its proper position in the work. This was a most important point, as the plates differed from each other in the small gradations of $\frac{1}{16}$ of an inch in thickness, and would otherwise have rendered it a difficult and tedious work to carry out the correct arrangement in the distribution of the different thicknesses of plates, and probably would have resulted in errors.

Prior to the commencement of the iron work, extensive temporary shops were put up at Point St. Charles and St. Lamberts and provided with the necessary powerful machinery for manufacturing rivets, cutting and punching boiler-plate, from an inch in thickness downwards, making screw-bolts, drilling and turning, as well as machinery by which large sections of the sides of the tubes were rivetted together by steam power, and so conveyed to the tube in course of erection. Accommodation was likewise provided for a large number of smiths, and during the two years occupied with the iron work those unpretending looking shops were alive with labour and energy, admirably governed in all the numerous branches and details.

On the completion of the scaffold, the packings and wedges were arranged accurately to levels furnished by the engineer in charge, at distances of 20 feet along the tube, by which a camber of $4\frac{1}{2}$ inches was given its bottom, to allow about 2 inches for subsidence of the scaffold, and compression of the packing, during construction, and to possess at least $2\frac{1}{2}$ inches when completed, and prior to the wedges being struck. The bearing-plates for the friction-rollers were then bolted to the bed of the masonry with 3″ creosoted tamarac plank enveloped in felt, intervening, supporting the 14 friction expansion-rollers, and frames with the cover-plates similar to those beneath, placed over them, and bolted to the end bottom-plates of the tube. Similar timbers were likewise introduced between those covers and the tube, as well as in the recess left in the next or bearing pier. Every thing was now in readiness for the rapid progress of the work. The respective plates as marked and corresponding with those on the plan, were brought forward and bolted together in place, and in the course of a week the entire plating of the bottom was completed.

Portable forges for heating rivets where then brought on to the scaffold, attended by a set of rivetters each. The set was constituted of two rivetters and a holder-up, all men, with two boys, one for working the forge, and the other for carrying the rivet to the place required, and introducing it into the hole from underneath. The holder-up then brought a heavy hammer against its head to retain it in its place, while the two rivetters on the upper side proceeded with two small hand-hammers to bring its upper end into the required shape for the head of the rivet; which being done, both dropped the small hammers, one seizing a steel concave cup, which he held on the head lately fashioned roughly into shape, and the other a heavy sledge-hammer, with which he struck the cup a succession of vigorous blows, forcing the still red-hot rivet into all parts of the hole, and leaving the end smooth, round, and regular. A steel drift, or round pin tapering to a point was then placed in the next hole and forced into it by several heavy blows, causing the holes of the different plates lying in each other to correspond exactly. The drift was then knocked back by the holder-up underneath,and a second red-hot rivet introduced, to meet with the same treatment as its predecessor, and so on throughout. In an after part of the work, while the top and sides were being rivetted, the holder-up stood on a light scaffold elevated some distance from the fires; but such was the skill acquired by the little boys in the science and laws of projectiles, that with the small tongs they sent the red-hot messengers through the smoky atmosphere, with the most unerring aim, to that part of the narrow scaffold occupied by the holders-up, who seized them with similar tongs, and placed them in the holes previously drifted, and brought the weight to bear against their heads.—But to return to the bottom. Four or five sets of rivetters in the course of a few days prepared it for the reception of the side-plates. These plates were rivetted with the machines at the shops in large sections composed of 6 small plates and four T bars over their junctions, put on trollies or small cars, and, by means of the small shunting or pony engine, were brought immediately to the place required. From the trollies they were lifted on end and swung into place by the Wellington cranes before referred to, and fastened to the bottom keelsons with side gussets. A second one was then put up on the other side of the tube, and secured in like manner, as well as connected by the top keelsons and gussets; others soon followed, and in a few days the greater part of the sides were in place. After the centre space of ½-inch plates, amounting to about 70 feet,was completed,the top plates, and the longitudinal angle and T bars were put on and the rivetters started, the sides requiring them only at the top, bottom, and every third vertical T bar. The plating being completed and eight or ten sets of rivetters at work, the noise, din, darkness, and confusion, rendered the interior of the tube a perfect pandemonium to a person visiting it for the first time, and as he carefully felt his way along, before becoming accustomed to the darkness ; falling occasionally over keelsons and other obstacles in his path, trembling with fear lest some of the fiery rivets should come in contact with his face, in their swift passage through the air to their respective destinations ; with the smoky blazing fires surrounded by active little imps covered with soot and dirt; together with the drum-like reverberations of the hollow tube, as if a thousand demons were exercising their combined agility and strength in producing the greatest amount of tip tap tapping on its sides and top for his especial benefit, he would have had some difficulty in bringing himself to believe he was not a resident in Pluto's dark dominion, instead of a visitor to the celebrated Victoria Bridge. But as the idea of being an inhabitant of earth gained ground, and while cogitating upon all the wonders surrounding him, with thoughts reverting occasionally to the probable dam age sustained by his hearing faculties, these doubts were for the time dissipated by a succession of shrill, sharp whistles in the immediate vicinity, and on turning quickly to learn their import, discerned through the dim, hazy light, the powerful but puffing little engine rapidly approaching with its loaded cars the place he occupied. This ocular demonstration that his ears were still all right, gave renewed energy to his bodily movements; but in the agile semi-rotatory evolution attempted, with a view to prevent any damage either to the engine or himself, by a collision, a not sufficient heed to his footsteps brought that delicate and sensitive part of his person known as the "shin" into immediate and forcible contact with the hard edge of a keelson bar, and landed its proprietor at full length, face downward, on the bottom of the tube, at the same moment the energetic little locomotive swept past. While afterwards reflecting on the erratic movements described, and congratulating himself on being in possession of all his usual faculties, a sharp stinging pain in the lower extremity brought to mind the damage sustained by his "understanding," and furnished additional food for reflection, as he limped out of the darkness into broad daylight.

The plating of the tubes was usually let to the platers by the ton, while the rivetters, including the holders-up and boys, were allowed a certain sum each per diem. A day's work required the putting in of a certain number of rivets, and any over that to be counted as extra time.

Some gangs have been known to make 4 days in about 16 hours, working time, putting in 700 rivets, when 180 constituted the number required. Generally, however, they did not average over 1½ days each when working.

Each rivet after being put in was tested by the inspector, and if loose or too small, was cut out by the parties who put it in, and replaced by another. On the completion of the rivetting, and after being thoroughly examined by Mr. Hodges and the inspector appointed by Messrs. Stephenson and Ross, levels were taken to determine the ordinates of the camber then existing, at distances of 20 feet along the bottom of the tube, prior to the wedges being struck from underneath.

This operation usually lasted three hours; and when accomplished, the tube was on its natural bearing. Levels then taken at the same points, indicated a permanent camber from ¼ to ¾ of an inch in the centre. This arose from the plates in the sides being punched for a straight

Before concluding this subject, we may mention that observations on the state of the atmosphere were taken three times each day, and its consequent effect upon a single tube ascertained. From the information thus obtained, it appears that a beam of iron 260 feet in length is subject to a movement of 3 inches in a climate possessing the extremes of temperature like that of Canada. With the sun shining on the top and side, an increase of one inch in the camber takes place, with a horizontal camber in the centre of about $\frac{1}{2}$ an inch.

Observations twice a day, extending over a period of six years, were taken of the temperature of the water and level of the river St. Lawrence, at each end of the bridge.

CHAPTER XVI.

STAFF, ETC.

The following interesting particulars of the Victoria Bridge, and the materials used in its construction are given:

First stone No. 1 Pier laid 20th July, 1854.
First passenger train passed 17th December, 1859.
Total length of Bridge, 9184 feet lineal.
No. of Spans 25; 24 of 242 feet; one of 330 feet.
Height from surface of water to underside of centre tube 60 ft.
Height from bed of river to top of centre tube 108 feet.
Greatest depth of water 22 feet.
General rapidity of Current 7 miles an hour.
Cubic feet of Masonry 3,000,000.
Cubic feet of timber, in temporary work, 2,250,000.
Cubic yards of clay used in puddling dams, 146,000.
Tons of iron in tubes, say 8250.
Number of rivets, 2,500,000.
Acres of painting on Tubes, one coat 30, or for the four coats 120 acres.
Force employed in construction during Summer of 1858, the working season extending from the middle of May to the middle of November.

Steamboats, 6, Horse-power, 450,..	} 12,000 Tons.	
Barges, 72, ...		
Manned by	500	sailors.
In Stone Quarries, ...	450	men.
On Works, Artizans, &c....	2090	do.
Total	3040	men.

Horses, 142. Locomotives, 4.

The whole of this force was handled by Mr. Hodges for his Principals, Sir S. Morton Peto, Bart., Thomas Brassey, and Edward Ladd Betts, Esquires, with the following Staff :—

ENGINEER DEPARTMENT.

James Hodges, Esquire, Senior Agent and Chief Engineer for Contractors.

John Duncan, Assistant Engineer.

Charles Legge, Assistant Engineer.

Oliver Gooding, Assistant Engineer.

Alexander G. Fowler, Draughtsman and General Superintendent.

H. H. Killaly Jun., Draughtsman.

J. W. Woodford, Mechanical Engineer.

John Melville, Assistant do.

J. Dunbar, Mechanical Draughtsman.

Simon Foote, Inspector of Tube-work.

L. Kirkup, Jun., do. do.

W. R. Bell, do. do.

John McNeil, Foreman of Carpenters.

Alexander Sutherland, Inspector of Masonry.

J. Akenhead, do. do.

George Pyke, Inspector of Painting.

Edward Bromley, do. do.

Robert Wildbore, Foreman of Labourers.

John Baily, do. do.

John Kay, Time-keeper.

George Penk, do.

George Perkins, Superintendent of Sailors.

OFFICE BRANCH.

W. C. Spiller, Chief Accountant.

David Aikman, Accountant and Store-keeper.

Thomas Cole, Paymaster.

J. Blakeney, Accountant.

Samuel Goulder, Clerk.

C. L. Wilkison, Clerk.

J. Morrison, Assistant Store-keeper.

STEAMBOAT DEPARTMENT.

Capt. D. Ross Kerr, General Superintendent.
W. C. Dutton, Clerk and Accountant.
Capt. Sclater, Steamer "Beaver."
Capt. Davis, " "Muskrat."
Capt. Ryan.
Capt. Dutton.
Capt. Duncan.

MEDICAL STAFF.

Dr. Godfrey.
Dr. McDonnell.
Dr. David,
Dr. Howard.

Rev. Mr. Elligood, Chaplain.
Frederick Brown, Schoolmaster.

BENJAMIN CHAFFEY'S CONTRACT.

J. W. Woodford, Assistant.
Milton Sessions, General Superintendent.
H. Reynolds, Accountant and Paymaster.
C. H. Pyke, do. do.
R. Dufort, Sub-Contractor for Masonry.
Reed & Co., do. do.
Fisk and Hodgson, Sub-Contractors for Stone.
John Morris, Sub-Contractor.
David Irwin, do. Crib-work.
Joseph Kirkbride, Foreman Carpenter.
William Kirkbride, do. do.
Duncan McDonald, do. do.
Edward Williams, do. do.
Hugh Cameron, do. of Labourers.
Mr. Proctor, Veterinary Surgeon.

JOHN O. HODGES' CONTRACT.

J. W. Wilstead, Sub-Contractor for Scaffold.
William Bissant, do. for Masonry.

George Matthews, Sub-Contractor.
Andrew Stark, Foreman.

James Hodkinson's Contract.

Samuel Ratcliff, Principal Foreman.
Edward Coulton, Principal Foreman.
White & Co., Sub-Contractors.
Duckworth & Clark, Sub-Contractors.
George Pierson, Foreman.
Edward Hughes, Paymaster and Accountant.

Jacques Normand's Contract.

S. Bonneville, Foreman.
J. Normand, Jr., "

Wm. Newcomb's Contract.

Mr. Turnbull, Assistant.
D. Wilson, General Foreman.
J. Turner, Foreman.

General Contracts.

Patrick White,	Contractor,	solid approaches.
Thomas Dillon,	"	roof of tubes.
Louis Dronen,	"	"
J. W. Wilstead,	"	"
G. Thompson,	"	"
U. J. Martineau,	"	tinning roof.
Thomas Fennel,	"	removing old coffer-dams.

Brown & Watson's Contract.

D. Wilson, Foreman.

Robert Stephenson, } Esquires, Associated Chief Engineers of
Alexander M. Ross, } the Victoria Bridge.

Francis Thompson, Esquire, Architect.

Mr. L. Kirkup, Sen., Inspector of Tube Work.

CHAPTER XVII.

PROGRESS MADE, 1854.

THE following summary is given of the progress made from year to year, during the construction of the Victoria Bridge:

1854.—During this year but little was done beyond the necessary preparations, in opening quarries, preparing machinery, steamboats, barges, and the requisite appliances for carrying on the work. The north approach was commenced, and the coffer dam for the abutment constructed. Two floating coffer dams were built; and an observatory about 70 feet in height erected at Point St. Charles, for the reception of a large transit-instrument, to be used in establishing the centre line of the bridge; a smaller one was also put at St. Lambert. The most important work accomplished, was the opening up of two quarries, one at Pointe Claire, on the line of the Grand Trunk Road, fifteen miles above Montreal, and the second at Isle Lemotte, in Lake Champlain, at the distance of 60 miles from the south end of the bridge. The stone yielded by those quarries belongs to the first in the series of the lower silurian, and is known by the geological term of chazy, resting immediately on the calciferous sand-rock and the Potsdam sandstone, and yielding courses from four feet to one foot in thickness.

From Pointe Claire, the store was transported either in barges through the Lachine Canal, and thence directly to the work, or put on stone cars built expressly for the service, of immense strength, and so conveyed to Point St. Charles stone-field, where they were deposited until required.

At the Lake Champlain Quarry, owned by Messrs. Fisk

& Hodgson, the mode of transit was somewhat different, this quarry being directly on the border of the lake. The stones after being prepared were shipped on schooners and barges and towed by steamers to St. Johns on the Richelieu River, there transferred to the Montreal and Champlain Railway cars, and transported a distance of 20 miles to the south approach of the bridge and deposited in the stone-field until required in construction.

During the winter of 1853 and 1854, the first steps were taken by Mr. Hodges in laying off the distances between abutments and piers on the centre line. This work was done on the ice, the respective distances being carefully measured with standard rods; and on the centre of the pier being found, "guides" were framed, so that a long iron rod could be lifted and let fall in one place, forcing a bolt, of iron about three feet in length, into the bed of the river. To this bolt was fastened a chain sufficiently long to admit of a wooden buoy being attached to it, and sunk through the ice. The following summer, the buoys and chains were easily discovered, and served to mark out the correct position required for the coffer dam; and the bolt, the exact centre of the pier after the dam was pumped out. During the succeeding winters, the operation was repeated, and the bolts afterwards found within a few inches of each other in every case.

We have referred to the commencement of the north solid approach, and have now to chronicle its destruction in the winter of 1854 and 1855, by the great height to which the waters rose at that time. Although Mr. Hodges had made every exertion to carry the embankment to such a level as would guard against this danger, and in the opinion of many had done so, yet the shortness of the season for doing it, and the increased height of the water above an average, resulted in its entire annihilation in a few moments of time.

CHAPTER XVIII.

PROGRESS MADE, 1855.

THE working season of 1855 did not result in any very great amount of progress, in so far as the bridge was concerned, being a time of great monetary depression owing to the Crimean war. The energies of the contractors were devoted more to the completion of the line westward to Kingston, which was opened for traffic in the autumn of this year. Several important works in connection with the bridge, were, however, accomplished. The north embankment was again started, and by the end of the season had attained a height of about 20 feet above summer water. The foundation of the north abutment was put in and raised to a height of eight feet above summer water, and its extreme end to a height of 20 feet above the same level, corresponding with the embankment. Piers No. 1 and 2 were built by means of the floating coffer dams before alluded to, but not completed in time to allow of the dams being removed and taken to their winter quarters, before the navigation closed. Those ponderous vessels, put together as strongly as iron and wood would allow, were crushed into pieces by the ice as if they had been built of card paper, and hurled against the cut-waters of the two piers they had aided in building. This was probably the severest test those structures will ever be exposed to, as they are the smallest, and consequently possess less material, than any of their brethren, and at the time had not the additional weight of the superstructure. It is needless to remark, that the test was triumphantly borne, without the slightest mark or wound to tell the tale.

Solid coffer dams, built of timber, and raised four feet above summer water, with the upper ends sloped off for ice-breakers, were put in for piers 3, 4, 5 and 6, on the Point St. Charles end of the bridge; the latter two by Brown & Watson, builders belonging to Montreal. These gentlemen succeeded in removing about 3000 tons of boulders, sand, and mud from the foundation of No. 5 pier, and in getting the masonry up to summer water by the end of the season. No. 6 dam was likewise pumped dry, but the time did not admit of any masonry being commenced.

The greatest difficulties were encountered in the foundation of No. 3, from the peculiar formation of the bed of the river occupied by the dam. At one end there was a depth of four feet, and at the other nine feet of hard-pan, boulders and quick-sand, to be removed before coming to the rock. The consequence was frequent "breaks" of the water, causing a stoppage of the excavation, and rendered it necessary to postpone its completion to another year; this pier proved the most troublesome of the 24. No. 4 dam was pumped out, but with the remaining three stood over for the next season. A third floating coffer dam was prepared and in readiness for No. 7 pier the following year.

On the south side of the river, some progress was made; and in connection with it we have now more particularly to mention the name of Benjamin Chaffey, to whom Mr. Hodges had given a contract for the erection of the south abutment, and two neighbouring piers. This gentleman had long previously been engaged on the public works of Canada, as a contractor, during which time he acquired the reputation of being a most skilful mechanic, and, what was of still greater consequence, won universal confidence and esteem, for the probity which always characterized his dealings with others, rendering him emphatically "the noblest work of God," and who, during the whole course of his extensive connection with the works of the Victoria Bridge, added, if such a thing were possible, to the previous high character sustained, and, by the ingenuity and skill he brought to bear in the erection of nearly one half of the masonry, coffer dams, and tube staging, of the entire bridge, contributed most essentially to its successful completion, at the same time acquiring the unqualified confidence and esteem of both Mr. Hodges and Mr. Ross, as well as the admiration of all who witnessed the ingenious machinery he invented to aid in the prosecution of his work.

On receiving this contract, his attention was first directed to the source whence the stones were to be furnished, and, after extensive research, decided on the Lake Champlain quarry to which allusion has been made. This quarry had been worked for some years previously, but principally for common building purposes, when a stone of one ton in weight was considered a maximum, with the machinery, for working it on a corresponding scale. A leap from one ton to 20 tons, involved serious consideration to the appliances at the time existing in the quarry. Mr. Chaffey was therefore under the necessity of inaugurating a new system before closing with the proprietors for the requisite supply of stones, and in the course of a few days put them in a position by which they were enabled, by the use of his remarkable contrivances with the aid of a horse, or two men, to lift and transport blocks of 20 tons, with greater facility than before they were able, with double that force, to move a single ton. This being accomplished, his attention was directed to the requirements existing at St. Johns and St. Lambert. At the former place it was only necessary to remove the stones from the boats to the cars; but at the latter place other considerations were involved: a stock of material amounting to at least 10,000 tons, was to be accumulated and placed in such position in the stone-field, prior to the commencement of the masonry, as to admit of each distinct course being kept separate, and readily accessible when required. To effect this a steam traveller 66 feet in length, placed on a ghanty-frame raised 20 feet from the ground, and extending about 600 feet in length, was constructed. The boiler and engine were attached to the "jennie," and traversed laterally along the traveller, being provided at the same time with gearing to admit of a motion being communicated to the traveller, driving it from one end of the staging to the other. With this machinery, worked by one intelligent boy, a train of cars loaded with the heaviest blocks of stone, could be moved on the railway track, underneath, backwards, and forwards, as required, and the stones taken up and deposited together, according to the courses they were intended for. We have frequently seen this extraordinary automaton at work, with three of its six distinct movements in motion at one time. Thus, a ponderous block of limestone weighing perhaps eight tons, would be taken from a car, and while in the process of being elevated to the height necessary for placing it on the top of a pile, some distance farther on, and at the side of the field, the lateral motion was carrying it sideways and the whole machine moving in the direction of the pile at the rate of four miles an hour; which point reached and the stone safely deposited, the three motions were instantaneously reversed, and the traveller brought back to the car for a second load, to be conveyed perhaps this time in an entirely different direction. A greater or more efficient labour-saving machine for work of this description, was probably never invented, and reflects the highest degree of credit on its projector, and his able assistant, Mr. Woodford, although but one of the many ingenious applications of power made by those gentlemen, as has already been seen.

In the prosecution of his contract this season, Mr. Chaffey succeeded in constructing the coffer dam for the south abutment, and producing the masonry to a length of 3 feet above summer water. A much greater deposit of sand, gravel, and large boulders, had to be cleared out before reaching the rock, amounting to 8 feet in depth, more than was anticipated from previous examinations and soundings.

The coffer dam being at a distance of about 800 feet from the shore, a tramway supported on wooden cribs was built, on which a track connecting with the stone-field and Champlain Railway was laid, and the cars brought down to the abutment. This had all to be taken up before the close of navigation, to prevent the ice carrying it away, and to be in readiness for next summer's operations.

The head of the coffer dam for No. 24 pier was put in place, provided with a sloped ice-breaker, and this closed the season's operations on the river.

CHAPTER XIX.

PROGRESS MADE, 1856.

THE spring of 1856 opened with brighter prospects, and a vastly increased amount of work was the result.

After the closing of the river in the winter of 1855 and 1856, and on the weather becoming more moderate, Mr. Hodges instituted a complete examination of the bed of the river, with a view to become thoroughly acquainted with its conformation on the sites to be occupied by the remaining coffer dams. Soundings were taken accurately at distances of about 25 feet and extended several hundred feet from each centre line of the piers. He was then in a position to frame the bottom of the dams to suit the irregularities of the bed of the river.

During the following season, in the spring, the water again rose to an extraordinary height, and succeeded in forcing its way over the end of the north embankment, although raised to a height of twenty feet the year before. A few moments more would have resulted in its entire destruction; but owing to the quantities of stone, earth and timber thrown into the gap, the wash was held in check, and, the water subsiding a few inches, resulted in its preservation. A few days after the complete subsidence of the river, the coffer dams of the previous year were found intact, but with many of the upper timbers ground down half their thickness, by the abrasion of the ice floating over. Operations on an energetic and extensive scale were at once commenced; the north abutment, with its numerous travellers, started, as well as the clay-trains for raising the embankment.

A determined battle now ensued between Mr. Hodges and the almost unconquerable No. 3 dam, but resulted eventually in a complete victory, after a desperate struggle. No. 4 was likewise subdued and completed. Messrs. Brown & Watson prosecuted Nos. 5 and 6 with such vigour as enabled them to finish the masonry, and have everything cleared away before the close of navigation.

The large floating coffer dam built the previous season was launched in the spring, towed out to No. 7, sunk in place and proved an entire success, enabling the pier to be built in deeper water, and in far less time than any previous one. After the completion of the pier, the dam was towed to Boucherville and placed in winter quarters, to be in readiness for the second pier. The abutment and the embankment were not quite completed, but raised far above any danger from ice in winter.

On the south side of the river, Mr. Chaffey's work had by the end of the summer loomed up into view.

In the early part of the season, the tramway leading from the shore to the abutment, had been replaced and continued out to the second pier or No. 23; the staging from the abutment was put up, with the necessary travellers, and the masonry of the structure vigorously urged on. By an ingenious and effective method, the hoisting was accomplished by steam. A shaft running along the top of the staging, the entire length of the abutment, was driven by an engine on the coffer dam, giving motion to the hoisting-drum of each "jennie" and elevating the stones in a tenth part of the time required by manual labour. When the stone arrived at the proper height, the "jennie" was detached from the motive power and travelled to the place required for setting the stone. By this simple contrivance Mr. Chaffey was enabled to complete the abutment in a far shorter time, than would otherwise have been required, at a much less cost, and forms the first instance on the work of the application of steam in building the masonry.

Coffer dams of crib-work were put in for piers 24 and 23 and the masonry entirely completed. The first was built with two compound derricks, worked by horse power, and the last by the ordinary traveller with a "steam hoist." The cutting and setting of the masonry thus far was performed by the Messrs. Read of St. Catharines, to whom Mr. Chaffey had given the sub-contract; the cribbing by Mr. David Irvin. The taking up of the tramway concluded the season's operations.

The amount of work performed this year was most satisfactory, and attended with no mishap.

CHAPTER XX.

PROGRESS MADE, 1857.

The work on the river commenced this spring on the level of the water permitting. Solid crib-dams were put in for piers No. 8 and 9, by Mr. Normand, sub-contractor, and the floating-dam towed up from Boucherville and sunk in place for pier No. 18. This position, being about 1300 feet from the nearest built pier, was determined trigonometrically from the south shore. The chain attached to the iron anchors driven into the bed of the river, were fished up and the correct position verified. Somewhat greater difficulty was encountered with this pier, than its mate No. 7, on account of the greatly increased depth of hard-pan, and boulders lying over the rock. These troubles were easily surmounted, and enabled the masonry of the pier to be completed early in the season, when the coffer-dam was taken back to winter quarters for the next year's operations.

In pumping out No. 8 and No. 9, it was found an almost impossible task to reach the bed of the river. An enormous quantity of boulder-stones formed the deposits, on which the upper ends of the dams rested, rendering it next to impossible to cut off the connection between the inside and outside by sheet-filling and puddle. The consequence was, that with all the pumping power possible to be applied, very little headway could be gained against the seive-like interstices of the boulders. Dogged perseverance in pumping and pile-driving at last enabled Mr. Hodges to see the bottom of No. 9, and after removing an immense quantity of material above the rock, notwithstanding several "breaks in" of water, and consequent delays before being resumed, he had the satisfaction of seeing this pier rising its head nine feet above the water, when the time came in December for abandoning it. No. 8 was if any thing still worse than its neighbour just alluded to, and yielded but a brief glance of the terrible work in store for next year, furnishing anything but agreeable thoughts for the mind to dwell on during the long winter months which must intervene before it would again reappear in view from beneath the cold ice waters of the St. Lawrence. The masonry of the north abutment was completed, and tube No. 1 built in place, forming the first link in the iron chain for connecting the two shores. The contract for the tube-work of the entire bridge was given to Mr. James Hodkinson.

Mr. Hodkinson, up to this period, had been in the employment of Mr. Hodges, superintending the construction of the ironwork for the entire rolling stock built by him for the Grand Trunk Railway, and was essentially an "iron man." Many locomotives had been fitted up by him, as well as the splendid machine shops for the Grand Trunk at Point St. Charles. A better man therefore, as being thoroughly conversant with iron work in all its details, could scarcely have been chosen for this important and extensive contract, which he prosecuted in a manner never before excelled, either for speed or quality of work. 13 tubes, including the large one, amounting in all to about 3474 lineal feet, in one year, more especially as much of the time was lost from not having scaffolds in readiness, stamps the wisdom displayed by Mr. Hodges in the selection of this gentleman for the performance of the work, although no doubt greatly indebted to his intelligent and energetic assistants, Messrs. Ratcliffe and Colton.

The north embankment was also nearly completed.

From the successful manner in which Mr. Chaffey executed his former contract, Mr. Hodges extended it to four additional piers, a winter scaffold for tube No. 25, and a portion of the south embankment, all to be completed during the season. To do so it was neccessary again to extend the tramroad from the shore to pier No. 19, a distance of about 2400 feet in water ranging from 3 to 9 feet in depth, with a current of 6 miles an hour. This connection with the shore enabled the material to be brought to each pier by means of cars, as the shoals existing in the neighbourhood rendered it impossible to bring steamers or barges to the place.

The four coffer dams of crib-work were commenced as soon as the points were reached by the tramway, and completed in time to allow the masonry to be finished in the early part of December. The contract for all this crib-work was sublet to Mr. David Irvin, and the cutting and setting of the masonry to Mr. Raphael Dufort, a builder belonging to Montreal, both of whom carried on their work in a very energetic and satisfactory manner.

The great irregularities existing in the bottom of the river were never more evident than in the foundation of No. 19 pier. At the upper end there was a depth of 12 feet of hardpan, so compact as to return a vertical face for that height, while at the foot of the pier, about 90 feet distant, the material changed to mud and stones, with only a depth of 2 feet to the same level of rock. The four piers were erected by the two compound derricks, each building two piers, during the few weeks between the completion of the coffer dams and the close of navigation, an achievement not surpassed on the bridge previously nor afterwards. They were driven during the commencement by horses, and subsequently by the pumping engine, proving as effective on the river as their coadjutor the steam traveller on the land.

A winter wooden scaffold, sufficiently strong to resist the force of the ice, was erected for No. 25 tube, and the embankment carried out from the shore to the abutment, to a height of 16 feet above summer level.

The season by this time had so far advanced as to render it impossible to save the whole of the tramway; a matter of no great consequence, not being again required, as the water beyond No. 19 was of sufficient depth for navigable purposes. Every thing of importance on both sides of the river, having been removed to land, a few hours after witnessed the ice in interminable fields sweeping over the late busy scenes of energetic and well-directed labour.

CHAPTER XXI.

PROGRESS MADE, 1858.

The winter scaffold between the south abutment and No. 24 pier being completed in the early part of January, tube No. 25 was commenced, and finished the day previous to the spring shove. This scaffold was the first wooden structure exposed to the full force of the ice and stood the test remarkably well.

A different system for constructing the coffer dams was resolved on, from the circumstance of so much of the summer being over before they were in readiness for the masonry, as well as the great strength of the current, in the centre of the river, where they were now required. Mr. Hodges determined on sinking the cribs forming the upper ends of the dams, through the ice, and building them sufficiently high to be above summer water in spring. Mr. Chaffey was accordingly instructed to proceed with those for piers 14, 15 and 16, and Mr. John O. Hodges, to whom the contract had been given, with the ones for piers 12 and 13, on each side of the main channel. The two gentlemen at once commenced building the cribs in the strongest possible manner, and sinking them in place. They were generally 92 feet in length by 30 feet in width, with an average height of 18 feet. Six feet of the upper angle were taken off with a slope of 1 to 1, and planked over to furnish an ice-breaker. Each crib had about 9 feet in depth of field stones, with numerous hard-wood piles shod with iron driven down between the cross ties into the bed of the river. The upper surface of those cribs would be about 15 feet under the level of the water in the spring during the shove of the ice, and abundantly strong, it was thought, to resist any amount of impact from submerged ice. A most important step was thus taken towards the subsequent progress of the work on the departure of the ice, and with it a *point d'appui* for the commencement of operations in still water, when spring would come. A few days however served to dispel those fond anticipations of progress made, and realizing the words of the poet,—

> "The best laid schemes of mice and men gang aft' aglee."

The terrific movement had commenced, with nothing visible but millions upon millions of tons of ice crushing past the sentinel-like piers, with their giant heads far above, relieved occasionally by a large stick of timber, wand like, hurled into the air, as the only evidence of the presence of the large and supposed immovable cribs known to exist underneath this awful commotion.

On the subsidence of the water, some of the cribs were found three hundred feet down the river from the places where they were sunk, while others were from 30 to 100 feet, occupying the sites of the masonry, and presenting a truly pitiable condition.

Instead of a step in the right direction, it turned out to be the reverse, as not much progress could be made until these obstructions were removed. This operation, owing to the difficulty of getting the stones out of them, by divers and otherwise, occupied the greater part of the summer. A second step taken by Mr. Hodges, during the winter, produced the most satisfactory and beneficial results. Four pontoons, 160 feet long, 20 feet wide, and 10 feet deep, were built for the sides of the dams belonging to piers 12 and 13, and which so expedited the work, notwithstanding the late casualty, as to admit of both mammoth piers being completed, as well as No. 10 pier, with an ordinary coffer dam. The winter scaffold for the large span was also well advanced.

In conducting this vast amount of work to so successful a termination, in the face of all those difficulties and discouragements, being the largest piers, in the deepest water and strongest current, in the centre of the raft channel, and with a treacherous quicksand foundation for some of the dams, Mr. John O. Hodges performed a larger amount of work under those peculiar circumstances, than was ever before accomplished on the bridge, or probably in the world.

Pier No. 9, left from previous year, was finished, and the struggle resumed with No. 8 and waged with undaunted vigour on both sides, ending however in favour of Mr. Hodges. The now venerable and somewhat shaky old floating coffer dam, was once more towed up from Boucherville, and sunk for No. 17 pier, exhibiting in its old age the same virtues which characterized its youth, in building its third pier in less time than any of the remaining 23.

Mr. Chaffey succeeded, after removing the obstructive cribs, in completing the three coffer dams, the whole of the masonry belonging to pier 16, and in bringing that of 15 and 14 some distance above the water. During the season he also erected five summer scaffolds and the crib for a winter one. Three summer scaffolds were also put up by Mr. Walter Wardle, on the north side, two by Mr. Hodges as well as a winter one, and the crib for a second one sunk. These summer scaffolds, on both sides of the river, were also taken down after the tubes were built, and conveyed to the shore.

Mr. Hodkinson was enabled to put up eleven tubes on the scaffolds so constructed.

This year, opening with disaster closed with the most triumphant success, 7 piers were built and two brought out of danger; 11 tubes were completed by Mr. Hodkinson, and as many scaffolds put up and taken down, with four winter ones well on to completion; the embankment leading to the south abutment, was brought nearly to its ultimate height, and therefore out of danger; everything auguring favourably for the entire completion in the year 1859.

CHAPTER XXII.

PROGRESS MADE, 1859.

THE last year of construction had now arrived, and with its close is destined to be memorable in the annals of time, as having furnished this triumphant result of the labour of man, for the admiration of all generations to come. A year in the time of completion had been curtailed for a "consideration," far from equivalent to the increased cost, resulting in the additional exertions requisite for bringing it to pass; the dark hours of night had to be appropriated for work otherwise requiring the bright sun light of day; many additional men were required for forcing the work forward at this railway speed, and under such circumstances greatly enhanced the cost. The contract sum was swallowed up, together with the bonus; large drafts on the private resources of the gentlemen composing the firm, were required to bring the thing to pass. But they were men who faltered not; the country required the use of the bridge by the close of 1859, and was not disappointed.

At the close of the year 1858, we stated, everything augured favourably for the next season's completion. A vast amount of work had, however, to be accomplished, and any unforseen mishap or accident might operate seriously against it. 13 tubes, including the large one, many of them still in England, had to be erected, with all the scaffolds, which were now rendered a difficult and hazardous undertaking by reason of the almost mill-race current in 20 feet of water, and the extraordinary strength required to guard against danger of rafts, when occasionally as many as three would be hurled up against one scaffold at the same time.

Pier No. 11 was to be built entire, and two others completed; the parapet walls of both abutments were to be put up and the permanent way through the tubes, and the roof constructed; the embankments finished and protected with stone rip rap wall. All the old crib coffer dams were to be torn up and destroyed, a work in itself nearly as troublesome as in the first place putting them in. All these and many other works were to be completed before the end of the season.

Mr. Hodges, nothing daunted, set himself about the accomplishment of this difficult task, strong in the faith that if the thing were possible for any men in the world, those he had surrounding him were the ones to do it. In the programme issued, Mr. Chaffey was to complete his two piers, build the parapet walls of the south abutment, and the six remaining scaffolds to the centre, complete the protection of the south embankment, and remove all coffer dams, scaffolds, and other obstructions in the river between the south shore and No. 13 pier.

Mr. John O. Hodges was to open the ball with the completion of the enormous scaffold for the large tube, and the erection of the coffer dam for No. 11, together with the pier; Mr. Hodkinson to have his attention fully occupied with the 13 tubes yet remaining to be built. While, in addition to the general planning, directing, superintending the entire work given those gentlemen to execute, Mr. Hodges himself was to undertake the erection of the six scaffolds between the north shore and pier No. 12 and the parapet walls of the north abutment; the removal of all scaffolds, coffer dams; the construction of the permanent way through the entire length of the bridge, as well as the roof and painting; the protection by rip rap wall of the north approach, and many works of less magnitude, but equally important and necessary for the successful opening of the bridge. We do not propose enlarging upon this season's operations to any further extent than to say, that it was owing to the indomitable energy displayed by Mr. Hodges, as well as to the equally energetic sub-contractors engaged in the work, that the public are indebted for the carrying out of the programme.

By the 15th day of November the entire work had so far advanced as to admit of the small shunting engine in use on the bridge, crossing over to St. Lambert, conveying Mr. Hodges and a part of his staff, being the first instance east of the Niagara Falls of a locomotive driving itself across the St. Lawrence.

During the afternoon of the same day, Mr. Blackwell, Vice-President of the Grand Trunk Railway, with a party of friends, passed over *en route* for England, in a car drawn by the same engine.

The state of the work at the time not admitting of general traffic, the bridge was closed to the public, and the work yet remaining to be accomplished, vigorously urged on, night and day, until the evening of the 12th December, when the first freight train to Portland passed over.

The week following 292 cars, heavily laden with freight, made the transit, also during the night, as in the course of the day the track was required by the contractors.

CHAPTER XXIII.

TEST OF TUBES.

On the 15th of December, preparations were completed for a final test of the strength of the tubes; singularly enough at the same time, with the close of navigation, when vast fields of ice, under nature's superintendence, were hurling their solid masses against the masonry of the piers and testing their efficiency and strength by over one million tons a minute. Any force or weight man could bring into comparison with this, would be puny in the extreme.

Yet notwithstanding the inability of competing with nature's test, a load had been obtained such as seldom before was seen for a like purpose. A train of platform cars 520 feet in length, extending over two tubes, was loaded, almost to the breaking limit of the cars, with large blocks of stones, and in readiness for the experiment.

Prior to this a steel wire was extended the entire length of the tubes for the purpose of measuring the deflection, and strained by heavy weights as tightly as possible over pulleys at every bearing of the tube. This wire formed the datum from which all movements were to be measured on slips of card attached to vertical staves at various points along the tubes.

During the two days occupied with the test the public were rigorously excluded, none being admitted by Mr. Hodges to witness the experiment but Mr. Keefer, Deputy Commissioner of Public Works, Canada, the engineers belonging to his staff, with Mr. Ross, and the two engineers from England. At each slip of paper one of his assistants was placed and provided with a lamp and a pencil by which to make the necessary marks.

The loaded train was then taken hold of by two of the most powerful engines belonging to the Grand Trunk and, with extreme difficulty from the great weight, brought into the first two tubes, beyond which all their united efforts failed to draw it. A third engine having been obtained, the three were barely able to force the load along to the centre of the bridge; when night coming on, the test of the remaining portion of the bridge was deferred until the following day.

Early next morning, the interesting experiment was resumed, and concluded during the day.

In giving the result of the fearful ordeal to which the tubes were subjected, we will only note the deflection on a pair of the side tubes, the others being similar, and the central one.

When the train covered the first tube, the deflection in the centre amounted to $\frac{7}{8}$ of an inch, and the adjoining one, to which it was coupled, was lifted in the middle $\frac{3}{8}$ of an inch. The load then being placed over both tubes, the deflection was the same in each, or $\frac{3}{4}$ of an inch in the middle; and on being entirely removed, both tubes resumed their original level.

The large centre span, entirely disconnected from the other tubes, on being covered with the load throughout its entire length, deflected in the centre only $1\frac{7}{8}$ inches, and came back to its previous level on the load being removed.

All these results were considered highly satisfactory, as being considerably within the calculated deflection for such a load according to formulæ well known and generally made use of.

Nothing exemplified more strongly the confidence felt by Mr. Hodges in the strength of the work, than the severe test to which he exposed it. The writer well remembers the "peculiar feelings" he experienced when standing at the marking-post assigned him, surrounded at the same time by an Egyptian darkness, dense enough to be felt, arising from the condensed steam and the smoke of the engine, and totally obscuring the light of a glass lamp two feet distant. To thus stand closely pressed up against the side of the tube, with eyes and lamp brought within a few inches of the datum-line intently watching its movements, and leaving but sufficient room for the slipping, groaning, puffing but invisible engines and their heavily loaded cars to pass, with but a quarter of an inch of boiler-plate between time and eternity; or when mentally reasoned back to safety and security, and while listening, during the stoppage of the train, to the surging, cracking, crashing ice far below, as it swept past, to have those feelings of personal security dissipated in a moment by the thought of an over-loaded car breaking down and burying the deflection-observer beneath its weight, was surely reason enough for the existence of the "peculiar feelings" alluded to.

CHAPTER XXIV.

CONCLUSION.

ON Saturday, the 17th day of December, invitations were issued by Mr. Hodges to a large number of the citizens of Montreal to attend an informal opening of the bridge for general traffic, to which about one thousand ladies and gentlemen responded.

The excursion train containing this great number of people, was drawn by two engines and occupied 7½ minutes in passing through the tubes; high speed under the circumstances not being necessary. After proceeding six or seven miles down the line, the train returned, and, on emerging from the bridge on the Montreal end, the excursionists left the cars and partook of a champagne dejeuner on the north abutment, provided by the host; when the usual amount of speechifying took place.

On the following Monday the bridge was handed over to the Company, and has ever since been in use.

We have now completed a very imperfect sketch of this great undertaking, from the time the project was first launched into existence, by the Hon. John Young, up to the period when the embodiment of the idea in stone and iron enabled a thousand souls to be wafted with the speed of the wind across the great river, high above its conflicting and angry elements, at a time also when all communication for freight purposes with the south side of the river was interrupted, and even for passengers to cross in canoes during the day was a work of danger and extreme suffering from exposure and cold, when, by the means now in use, during the silent watches of the night when the citizens of

Montreal were buried in repose, thousands of tons of freight glided swiftly and silently over the running ice, and, by the great connecting link brought into use, caused a pulsation to be felt in all the veins and arteries of commerce throughout the land.

In speaking of its future success, who can estimate it, being intimately connected with the prosperity of Canada! We have endeavoured to sketch this, in dwelling on the country's rapid progress in material wealth, during the past few years, and may well form sanguine anticipations of its future; indeed, but few minds are capable of estimating the enormous increase of population and wealth yet to be in our Western World, when Canada will extend to the confines of the Pacific Ocean and be covered with a net work of railways all converging to this point of crossing the St Lawrence. Then, and not till then, must be left—to the yet unborn millions,—the rendering of the verdict as to the full measure of success which will attend the Victoria Bridge.

A few months more and the Prince of Wales will behold for the first time, our noble Province, the brightest jewel in his future diadem; and as he gazes on the wondrous structure which is destined to carry the name of his revered parent and sovereign down to the latest time, may we not anticipate a thrill of pride and joy in the contemplation of the splendid future yet in store for his Western Empire; and will not thousands unite with him in wishing God-speed to the march of this young Northern Giant in the van of enterprise, liberty and happiness on the western continent, emulating the noble example of its mother in the eastern world!