PROGRESS OF ENGINEERING SCIENCE.

[Concluded from page 53.]

Among the various contrivances which have been introduced to assist in rendering the great ocean available as a highway to the nations, none are more beautiful than the lighthouses that crown the headlands of every maritime county, or point out the dangers of the mid-ocean. Those that are erected on the shore, too often, it is true, partake of the absurdities of modern shore-going architecture in general. There are Grecian and Gothic lighthouses, and even Egyptian towers, that would fain cheat us into the belief that they belong to long past ages; but even then we forget these absurdities in contemplating the beauty and perfection of their photogenic arrangements. These have occupied the attention of some of the ablest scientific men of modern times, and they now send their rays through the darkness with a space-penetrating power that a few years ago would have been deemed impossible, and vary or alternate them with a steadiness and precision that has given confidence to thousands, and saved many a storm-tossed vessel from destruction.

To Smeaton is due the honor of having fixed the form of the best class of these structures; and even now the Eddystone remains a model which has hardly been surpassed. Nothing could exceed the patient ingenuity with which that great engineer mortised his tall tower to the wave-worn rock, and then dovetailed the whole together, so as to make rock and tower practically one stone, and that of the very best form form for resisting, or rather for deadening, the action of the waves. The Bell Rock of the elder Stevenson, which succeeded this, is taller, and even more graceful, but its foundation was larger, and the difficulties far less. The Skerryvore lighthouse of the younger Stevenson surpasses both, whether in beauty of construction or grace of form, and would excite equal admiration for skill in overcoming difficulties, were it not that it is the third of its class, and the work was lightened by the experience previously gained.

It is to be regretted that these structures are generally placed so far at sea that they are very little seen, for they are, taken altogether, perhaps the most perfect specimens of modern architecture which exist. Tall and graceful as the minaret of an Eastern mosque, they possess far more solidity and beauty of construction; and, in addition to this, their form is as appropriate to the purposes for which it was designed as anything ever done by the Greeks, and consequently meets the requirements of good architecture quite as much as a column of the Parthenon.

In early times nations were content—as they are in most parts of the East now—with such loads as could be carried on the backs of beasts of burden. Long strings of camels or mules, or droves of bullocks, wandering over the half-cultivated plains, sufficed for all the rude wants of the Phoenician epoch. The Romans, living in a more closely cultivated country and with a more extended empire than had previously been known, seem to have been the first to think of employing wheeled carriages for purposes of transport, and consequently the first who deemed it necessary to make permanent roads or to build bridges.

In those days, however, the mechanical branch of the profession was so immeasurably behind that which we now designate as civil engineering, that the professors of the latter were content to effect by brute force what we now accomplish by infinite scientific contrivance. They drove their roads straight as an arrow up hill and down dale, and paved them with blocks of stone, that not only must have enormously increased the friction, but must have tended to destroy any wagon not provided with springs, and have required a Roman's power of endurance to survive a journey long upon them.

In order to understand this, it is necessary to bear in mind that the resistance to a load drawn along a road is made up of two parts, friction and weight. No human ingenuity has yet succeeded in taking one ounce off the weight, though by distributing it over a very long surface, by means of low gradients, it may to a certain extent be rendered practically innocuous. All our skill has been applied to the task of getting rid of friction, and on our railroads we have so far succeeded as to diminish the relative importance of these two elements to an extent never before dreamt of. An active horse, for instance, will draw a cart, weighing a tun, with tolerable ease along a well-made level road; and when he comes to such an incline as shall require a tractive force equal to what would draw two tuns on a level, he can double his power for a short distance, and overcome it. The same horse, however, will draw ten, or even thirty tuns along a perfectly level railway; but a very slight incline will double this, or require the exertion of ten to twenty times greater force to lift the train up the incline than what is required to move it on the level, and no horse could even, for a few yards, accomplish this. Indeed, up some such inclines as the locomotive now climbs he would require to put forth the power of 100 horses to lift the train while the friction remains constant at 1-horse power. With the Romans, all this was reversed. Clumsy mechanical arrangements made friction the element to be overcome; so much so, that it is difficult for us to understand how a four-wheeled plaustrum, without a perch, was ever coaxed round a curve—how it turned nobody knows—and with the rude wheels keyed on to the axles, as was generally the case in baggage wagons, and without grease, the friction must have been so enormous that a slight addition to the lifting power required by a steep incline must have been of comparatively little consequence. Where pack saddles are used this is even more apparent; the load a horse can carry on its back is so small in proportion to its tractive power, that the steepness of the road is of comparatively little consequence.

Long before great bridges were erected, it had occurred to engineers that iron might probably be employed in building bridges. As early as 1775, Mr. Pritchard built one at Colebrook Dale, 100 feet span, and in 1795 Thomas Wilson erected one at Sunderland, 237 feet clear span, with only 260 tuns of metal, while the center arch of Southwark Bridge, only 3 feet more in width, contains 1,665 tuns. Hitherto these two have not been surpassed by any arches of the same kind; but Telford proposed to replace old London Bridge with one of a single arch, 600 feet span, and afterward begged to be allowed to span the Menai Strait with one of nearly the same extent. More recently Mr. Page proposed to cross the Thames, just above the Tower, with a single arch of 750 feet clear span, to carry two lines of rails and a roadway 24 feet wide, besides footways. Bold as the project may appear, still Mr. Page's experience and admitted knowledge of the subject are such that no one doubts its feasibility. From various causes none of these great schemes have been carried out, though there seems no reason to doubt that they might have been executed with success. As the resistance to pressure in cast-iron is as nearly as may be ten times that of stone, there seems at first sight no reason why an arch of iron, 1,000 feet span, should not be made as easily with the same weight of material as one of 100 feet of stone; and as blocks can be cast with more precision than they can be hewn, and fitted with flanges and other constructive expedients, even the most gigantic arches ought to be far easier to build in this material. The one element of uncertainty is the contraction and expansion of the metal from heat; but there seems little cause to fear it.

On the Continent, where scientific knowledge is generally in advance of practical skill, they have carried this principle to excess, by using wire, which is iron in its most perfect form, for tenacity. This has reduced the weight of the bridge so much relatively to the load, as to render the undulation excessive, and frequently to lead to the most frightful accidents. Still the bridge over the Sarine at Friburg has stood for thirty years, with very slight repairs, though its span is 870 feet, while that of the Menai Strait is only 570, and the bridge which recently crossed the Thames at Hungerford Market, which is our largest and typical example of the class in England, was only 676½.

The boldest and grandest application of this principle is the bridge constructed for railway traffic by Mr. Roebling, just below the Falls of Niagara. So rapid has been the progress of engineering science, that if any one had proposed, twenty years ago, to throw a railway bridge over a chasm 800 feet wide, and 245 feet above such a foaming torrent as that of the Niagara, he would have been looked on as a madman. Yet this has now been accomplished, and by very simple means. The bridge consists of a rectangular tube 20 feet deep by 26 feet wide, or rather two floors 18 feet apart—the upper carrying the railway, the lower the roadway for ordinary traffic. These are connected together by a series of wooden posts, braced together by diagonal iron tie-rods. By bracketing out from the rocks, the free length of the tube is reduced to 700 feet, and is then suspended from towers 821 feet apart from center to center by four wire cables of 10-inch. section, and each containing 3,640 separate wires. These are further assisted by numerous braces radiating from the towers, and a multitude of ingenious minor contrivances.

When a train weighing more than 300 tuns passes over the bridge, the deflection is said to be only 10 inches; and certain it is that, so far, it has answered all the purposes for which it was intended; but nevertheless it seems too frail and fairy-like a structure for the rough usage of railway traffic, and trains are not allowed to move across it at a higher velocity than a man can walk. With great care and continuous repairs it may do its work for years to come, but it may any day deposit its load in the boiling flood beneath, and so again separate the provinces it has so boldly united. Indeed, taking it altogether, there can be little doubt that the tubular girder proposed by Robert Stephenson for the same purpose would have been a better piece of engineering. It would have cost more in the first instance, for if the published accounts are to be believed, the suspension bridge cost only £100 per foot forward; but the durability of the tube would have been practically unlimited, its safety undoubted, and an occasional coat of paint all the repair it would have required.

Perhaps, after all, there is nothing better than the simple tubular girder, which was evolved out of the first experiments, and used with such success in carrying the Holyhead Railway across the Menai Strait. The first and most obvious proposal for this bridge was one of cast-iron in compression, which would have been the cheapest and most architectural mode of effecting the object; but the Admiralty interfered, and insisted that a clear headway of 100 feet above high water should be maintained throughout. To meet this difficulty a tube suspended by chains was then suggested, nearly similar in principle to the one recently erected at Niagara; but as the investigation proceeded, it was found that the chains might be dispensed with, if a tube of sufficient rigidity could be constructed to carry any railway train across the greatest opening, which here was 460 feet clear. So complete were the investigations, and so careful the execution of the whole work, that subsequent experience has added little to the knowledge then attained; and, besides being the first, it is, considering the difficulties of the execution, one of the most perfect works of its class. In extent, and in some respects, for cleverness of execution, even this bridge is surpassed by that across the St. Lawrence, at Montreal, which, though only a single tube, is 6,592 feet long; but the center span is only 330 feet, and the remaining 24 openings average 242 feet. The great engineering difficulty was the erection of such a structure on so rapid a river, frozen at times, and at the breaking up of the ice bringing down great bergs, which threaten to overwhelm everything. All these difficulties have been successfully surmounted, and the bridge promises to be as stable as it is efficient.

The Bhore Ghat incline, which has just been completed on the line from Bombay to Central India, is 15¾ miles in length, and the height surmounted is 1,831 feet, so that the average is 1 in 48, or about the same as the Semmering; but for one mile and a half it is 1 in 37, and for eight miles 1 in 40. The amount of tunneling, bridging, and embanking on the Indian line is such that the cost was £1,100,000, or upwards of £68,000 per mile.

The Americans work some inclines with a steeper gradient than even these, but never so long or of so permanent a character. But it is now proposed to cross the Simplon by a railway, and before long Innspruck will be connected with Verona, so that it can hardly be said that any mountain chain which has been traversed by roads is inaccessible to the steam horse. Even the Himalayas might be so traversed; and if a hundred years hence some unborn Brunel be called upon to make designs for the Lahore and Lanak Junction Railway, and find himself forced to tunnel through the ridge, it will not be that the engine could not climb a pass even 18,000 feet above the level of the sea, but that the perennial snows of those regions would form so unsuitable and so unsatisfactory a foundation for his permanent way.

Not only is it easy to converse with every important place in England, but messages can be sent to every capital in Europe, and answers received in an incredibly short space of time. Once it was possible to communicate with America, and it probably will be so again before the year 1864 changes its index. Already the Atlantic Telegraph Company have received tenders from eight different firms, any one of which is competent to the task, and some of these tenders are so favorable that one of them will, no doubt, be accepted; if so, London and New York may be within speaking distance again before twelve months are over, and this time with every chance of their connection being permanent, so great has been the improvement in the manufacture of submarine cables, and so extensive the experience of the mode of laying them. While this is being debated, a cable has left England which is destined to unite Calcutta with London, and which, in all probability, will accomplish this object ere long. But communication with any point on the North American coast must embrace also New Orleans and the whole of that continent. Our communication with Calcutta extends by an easy link to Singapore, and from Singapore to Canton and Batavia; and from the latter place there is no difficulty in reaching the Australian continent. It may thus be that before many years are over we may see recorded in the morning's *Times* events that happened at Sydney, or Shanghai, or San Francisco, on the previous day. Surely this is a wonder and a triumph of scientific skill if anything ever was; and surely the men who do these things are giants!

AMERICAN DENTISTRY—PROCESS OF SETTING TEETH ON INDIA-RUBBER PLATES.

While in conversation recently with a small knot of intelligent persons, the subject of artificial teeth and dentistry engaged our attention, when one of the party related a case, in connection with himself, which evinced the superior skill of American dentists. He stated that while he was residing in Glasgow, Scotland, for a few months during the summer of 1861, he went to a dentist in that city for the purpose of having three artificial teeth secured in his upper jaw. While they were being fitted he informed the operator that he was about to return to the United States, when the dentist said, "Well, these very teeth came from America. We get all our artificial teeth from Philadelphia." The three teeth were supplied, and although apparently neatly fitted, our friend never felt easy while he used them; and soon after he arrived in New York they were removed and their places supplied by an American dentist with a new plate and teeth, which have never given him the least trouble.

American dentists stand at the head of their profession, and in the preparation of teeth and plates our artists are unrivalled. Formerly all artificial teeth were secured on plates of gold, but within the past four years that remarkable substance, "hard india-rubber," has taken the place of the metal in many cases, and its use for this purpose is extending. When gold is at such a high premium, the employment of a cheap, suitable substitute in dentistry is of no small benefit to the community. The artificial gums and plates of hard india-rubber in which sets of teeth are now made by dentists are very beautiful. They are of a light cinnamon color, and are hard, light and smooth as polished glass. Much skill and a considerable amount of science are involved in the manufacture of such rubber plates with sets of teeth. The whole of the operations and processes in connection with their manufacture have been shown and explained to us, at our request, by William C. Horne, a young and skillful dentist, of Fourth street, Brooklyn, E. D., and we will describe the method of taking the impressions, and fitting, making and finishing the plates ready to be applied to the mouth of a patient. We may, however, explain that what are called "temporary sets" of teeth are very often made and applied to patients before sets intended for permanent use are made; but our intention is simply to describe the manufacture of full "permanent sets:"—

After the patient's natural teeth have all been extracted, and the gums have become sound and properly set, the first task of the dentist who is to provide a set of artificial teeth is to take a cast of the gums and the roof of the mouth. Two instruments called "impression cups," are used for this purpose. They are composed of metal: the one for the upper jaw being formed like the hollow part of a horse's hoof, is designed for taking an impression of the upper jaw and the roof of the mouth; while the other one, for the lower jaw, is formed simply with a semicircular channel to take the impression of the lower gums. Some plaster of Paris in a soft state is put into the upper impression cup, which is placed in the mouth and pressed against the upper jaw. The plaster soon takes a set and becomes hard; when this is effected the cup is withdrawn. The plaster now contains the negative cast of the upper gums and the roof of the mouth. The lower cup is now charged with plastic bees-wax (which adheres to it), then it is laid over the lower gums in the mouth, and receives its impression at once. Plaster of Paris is perhaps the best substance for taking an accurate cast, but as the lower impression cup has to be inverted, wax is more convenient to use for taking an impression of the lower gums.

The impressions taken of the gums are next varnished and oiled for the purpose of taking positive casts from them, called "the model," to represent the natural gums. These are made by taking casts in plaster from the molds in the impression cups. After the models are taken, to obtain the size and form of the gums and roof of the mouth, the next object is to get the thickness of the plate for the teeth. This is called the "trial plate," and is made either with plastic gutta percha or bees-wax, which is carefully built on by the dentist with his fingers and a proper instrument, upon the model, to the hight judged according to the length of the patient's teeth and the natural position of the jaws. This part of the process must be performed in a very skillful manner.

The trial plates are now taken from the model and tried upon the patient. A true perpendicular line is then drawn through the center, toward the chin, of both jaws, and marked on the plates, and a cross mark is also made at each side on the plates, where the jaws come in contact. After this these test plates are taken and put upon the models, which are then placed in an instrument called "the articulator." In form it is almost like two shallow cups, secured by a joint, to represent the upper and lower jaws of the face. The articulator has three movements regulated by screws. One movement is up and down, the second lateral, and the third back and forth. The object and use of the articulator is to get the true position of the patient's jaws, and the natural distance between the teeth. Considerable judgment must be exercised in its use, as in order to secure the capacity for eating with artificial teeth, they must be set somewhat closer than natural teeth. The length of time between the period when the teeth were extracted and the new set fitted, must be taken into consideration.

The next operation is to select the teeth for the set, and they must be of such a size as will suit the patient's mouth and cast of countenance. Elderly persons should not desire what are called "white, pretty teeth," as these are only suitable for young persons. Artificial teeth for permanent rubber sets are prepared by dentists, in blocks of three for the sides and in blocks of two teeth for the front. For temporary sets and for gold plates, the blocks are of single teeth. A full description of the manufacture of artificial teeth was published on page 341, Vol. II, SCIENTIFIC AMERICAN (current series). Those for rubber sets have metallic pins on their base with heads upon them.

After a suitable number for a set has been selected they are placed on the trial or test plates of wax, and the joints are ground to make good junctions, both the upper and lower sets being prepared at the same time. When accurately arranged the teeth are secured in position on the trial plate with soft wax, then they are tried in the mouth of the patient to obtain perfect articulation, which being effected, they are next secured upon the model with soft wax. It will be understood that the plaster model represents the gums of the patient, and the rubber plates with the teeth in them are to be fitted upon the models of the upper and lower gums. The upper plate extends back upon the roof of the mouth, otherwise the two plates for a set are similar. A description of one, however, will suffice for both, as the operations involved are alike.

The wax of the trial plate upon the model is now made quite smooth to obtain a smooth cast from it of what is called the "counterpart," or the back section of the mold. This cast secures the perfect form and thickness of the india-rubber which is to be applied to take the place of the trial plate, and it is also necessary for keeping it in perfect shape while being vulcanized. The model, with the test plate of wax and the artificial teeth set on it, is now placed in a small iron flask, provided with adjustable screws, and soft plaster of Paris is now poured into the flask, which, when set, forms a cast of the counterpart of the trial plate and model. The space between the plaster counterpart and the plaster model is occupied with the wax trial plate, which forms the measure of the india-rubber to be supplied, and the wax must be removed to give place to it. The flask is next subjected to a gentle heat, opened, and the wax trial plate carefully removed, leaving the teeth and the space occupied by it to be packed with the india-rubber. This article, designed for dentistry, is prepared by the Goodyear Rubber Company, and comes in thin square sheets of a bright red color, said to be effected with the oxide of gold. When exposed to a moderate temperature, the rubber becomes sufficiently plastic to be packed in the mold in the flask, around the base of the teeth, occupying the place of the wax trial plate. It had been found that unless rubber plates had been made very thick, some of them were liable to crack at the bottom of the channels fitting on the gums. To obviate this evil and secure strong and thin plates, Mr. Horne fits a continuous small plate of gold upon the whole ridge of the model, and fastens it with small gold loops, securing it firmly in the rubber. The model and rubber being now packed around the teeth in the flask, the "counterpart" is placed upon it and gently screwed down until the proper thickness and form of the trial plate is produced on the rubber, holding the teeth in it perfectly, and occupying the place of the removed wax. During this operation of screwing down the flask it is kept warm, so that the rubber is maintained in a plastic condition, and any surplus of it is forced out by the pressure of the counterpart upon it, through small vents provided in the flask.

The rubber plates being perfectly molded and the teeth secured in it in the flask, it is ready for what is called the "vulcanizing process." This consists in subjecting the rubber to an elevated temperature in a moist atmosphere, when it undergoes a complete chemical change, becoming hard, inelastic and very permanent in its character. To effect this, the flask containing the prepared rubber plate is put into a small, portable, metallic oven, containing some water, the lid of which is firmly screwed down and a thermometer secured in it to indicate the temperature. The oven is heated either with a gas jet flame or an alcohol lamp, and when the temperature rises to 320° Fah. this heat is maintained for about one and a half hours. The water in the oven generates steam and the rubber is subjected to a moist heat and considerable pressure. As thermometers differ slightly, different dentists may vulcanize with a slightly lower or higher temperature than that specified. While the rubber is heated in the flask, the mold in which it is confined keeps it in perfect shape. The flask is next taken out of the oven and cooled with water, then unscrewed and the vulcanized plate removed with the teeth set perfectly in it. It will be understood that the plate for each set is vulcanized in a separate flask. The plate has now to undergo the finishing operations, and is first filed and scraped with fine tools; it is then ready for rubbing down and polishing. It is next subjected to the action of a hard revolving brush wheel and ground pumice stone; then to the action of a similar wheel and rotten stone powder, and finally to a softer brush wheel and fine whitening. When finished, such india-rubber plates are hard and smooth as polished glass, and are then ready to be placed permanently in the patient's mouth. The artificial teeth appear to be as firmly secured in the rubber as if they had grown in it, and the operations connected with india-rubber dentistry are certainly scientific and ingenious. Gold plates are all soldered to teeth with a blow-pipe, and the metal is swaged in a die. As the rubber is molded in casts of the patient's gums, such plates are more accurate than those of swaged metal. They are also about one half lighter, and many persons prefer them to gold, as they feel more like the natural gums and the roof of the mouth.

We have thus described the method of manufacturing india-rubber plates with sets of artificial teeth.