THE IRON AGE

Paper Read before the San Francisco Chapter,

AMERICAN INSTITUTE OF ARCHITECTS,

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BY G. H. SANDERS, F. A. I. A.

Gentlemen, Fellows and Associates of the San Francisco Chapter of the A. I. A.:

Poem and Legend, Fable and Myth glow with the lustre of the Golden Age, and every nation with a history, written or unwritten, has a background of romance which owes its brightness to the same luminous source.

The writings of the poets and moralists of Greece and Rome, through which the threads of authentic history have come down to us, draw their inspiration from a far-away time, which, like the lingering afterglow of a glorious summer's day, tells of an era when the world was young, and mankind lived in simplicity and innocence, and enjoyed a happy immunity from the incumbrances and inconveniences of the, perhaps, overwrought civilization of their and our day.

Both Hesiod and Ovid describe not only a golden, but a silver, a bronze and an iron age, the former interposing the heroic age between the bronze and the iron. The first four are also mentioned as forming constituent parts of the great image of Nebuchadnezzar's vision as recorded in Daniel—one of the Prophetical books of the Hebrew Scriptures. The mythology of the ancients, as well as the clay records of Assyria, are replete with allusions, more or less definite, to the same wondrous epoch, as well as to the increasing degeneracy of the succeeding ages.

But authentic or fabulous as these may be, in the Genetic record alone do we find a coherent, if only figurative, account of a condition of things which could rationally afford an adequate foundation for the all-pervading idea of the golden age. We shall return to the subject in our concluding remarks, and will for the present merely state that, of the four ages above recognized, the last has been commonly conceded to be the peculiar heritage of men of the present day.

THE AGE OF IRON.

But it is not the "Iron Age," of which we wish now to speak so much as the "Age of Iron," a much more definite and easily apprehended, if less comprehensive idea, than that indicated by the former term, which, indeed, may be taken to include the whole range of the philosophy, sciences, arts and morals—nay, even the religion of the times, with all their respective concomitants and accessories which together make up the life of the man of the nineteenth century.

But putting aside for the present the uncertain traditions, as well as the myths and allegories of the days of old, the scientific explorer of our times has collected, classified and arranged, in orderly sequence, the evidences of at least three ages, neither fabulous nor figurative, which have prevailed in former times. These are known as the stone, the bronze, and our own iron age, from the material which was most generally employed during the respective periods in the ordinary implements of utility and defense, all the stages of which may be practically existing amongst various barbarous nations of our own day and generation.

This brings us face to face with our subject proper, and the chief element of its title, viz.: Iron.

This is a substance of such world-wide utility that it is apt to appear impossible to dispense with it. This, however, is disapproved by the history of past times as well as by the known condition of many peoples and tribes of the present day, though their position and status, indeed, may be said to be measured by the degree of their knowledge and appreciation of this significant material.

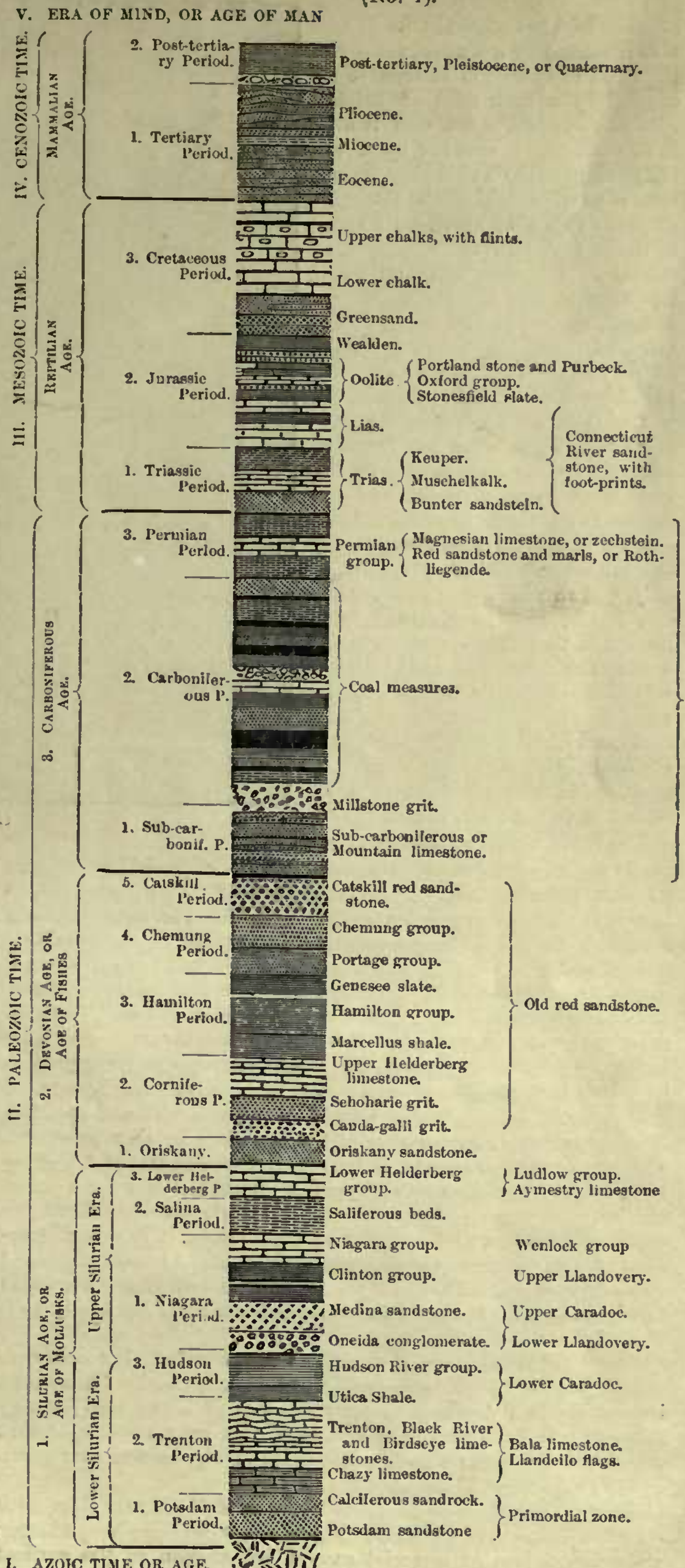
To fully comprehend the true position of iron in the scale of life, we must glance at its position in the scale of creation. Accepting as such the accompanying Geological section of the shell or crust of the earth, we will ask your attention to a brief examination of its component parts and the manner of their formation—the accompanying section (1) (from Geological Section in Webster's Dictionary), which is generally taken to represent a total thickness of about thirty miles, is just about the 330th part of the diameter of the earth, or about the comparative thickness of an ordinary egg shell.

The entire internal body of the earth has been supposed to be a molten mass, and to properly understand this we must begin at the beginning, and the beginning, in this case, is

"NEBULÆ."

In No. 2 we have a representation of the great nebula in Orion. The latter is one of the most conspicuous constellations visible in the southern heavens during the latter half of the year, and the

(No. 1).



nebula is distinguishable by the naked eye, and constitutes the sword-hilt of the figure. The nebula itself is one of the most extraordinary objects to be seen in the heavens, and is, in fact, one of the "show" objects of the astronomers. It is notable on account of its vast extent as compared with most of the other nebulæ, as well as its wonderful complexity and apparent confusion of parts. It was one of the first objects examined by Lord Rosse in his great six-foot reflector, and great was his joy and astonishment to find the vast cloudy masses resolve themselves into myriads of stars! Some others of the nebulæ are not as yet resolvable when seen through the telescope. The spectroscope, however, is the instrument especially relied on in investigations of this kind. This curious instrument has the power of distinguishing the chemical properties of substances by the light emitted by them in an incandescent or highly-heated condition. In this way the light of various mineral salts, gases and other terrestrial substances have been compared with the sun, the fixed stars, and even the *nebulæ*! Thus the "spectrum," as it is called, from its shadowy character, becomes a sort of *scale* or *gauge* for the qualitative analysis of all the rest of the universe; and it is everywhere found to be similar, if not altogether uniform, in properties.

The spectrum is a luminous band of prismatically-colored light. When this is caused by a beam of sunlight, the band or spectrum is seen to be crossed by a multitude of bright, colored and dark lines and bands. When the light emitted by a variety of metallic substances, gases, etc., is examined, the lines they produce are found to agree with some of those found in the spectrum of the sun. The same is found when the light of the fixed stars is examined, as well as the nebulæ, and terrestrial substances are found in all of them! The nebulæ are also found to differ among themselves, just as the stars do, but in a different way. Thus, some are found to exhibit only the lines caused by the two great gases, nitrogen and hydrogen; and these have been hitherto found unresolvable into stars by the telescope. Others show bands only, and these *are* resolvable. Others, again, show both bands and lines, and therefore appear to be of a mixed or compound order, and in which the original gaseous elements, which appear to constitute the original mass of all nebula, would seem to be in process of conversion or resolution in the other cases completed or not yet commenced.

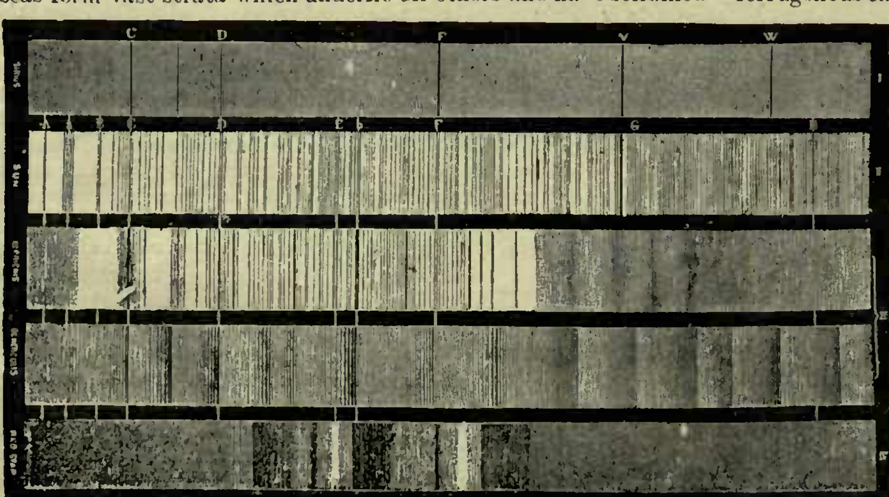
GREAT NEBULA IN ORION. (No. 2.)

The latest accepted theory in regard to these mysterious accumulations of ærial substances appears to be that, as these vast masses of "drift" are caught here and there in the eddies arising from the inevitable friction resulting from ethereal motion, aggregations of condensation naturally occur, and in the vast sweep of inconceivable ages, under the influence of all-pervading Law, universes of harmoniously balanced solar, planetary and lunar systems, with all their necessary and appropriate accompaniments, come into being. The diagonal of centrifugal and centripetal forces which have arisen in the case of each initial eddy, establishes a center of gravitational energy, which becomes in time a sun, and the sun, in the progressive evolution of being, becomes in turn an earth, and by successive condensations and depositions of the fiery gases in the form of more and more solid materials, an orb, capable of receiving and sustaining life, slowly emerges from the womb of creation, and a world of life is born. The first raindrop which reaches the cooled surface of a new-born world marks an epoch. The last that ever falls on the same earth marks another. Between them lies the history of the life of that world!

The condensation and deposition of material at first ethereal, then gaseous, then aqueous, necessarily include phenomena impossible to describe because incapable of being seen by any other faculty than that of imagination. It can only be said that what does occur must have taken place in the case of our earth in the order here represented. (No. 1).

First: The igneous or primary rocks of the Azoic Age with only the outer rim of which we can ever become acquainted; then depositions of material caused by erosion in the earliest seas form vast strata which underlie all others and have solidified into the rocks of the second or Palezoic series, succeeded by the Mesozoic and Cenozoic times or ages, and finally by the present time or age, known as the age of mind, or of man.

The second or Palezoic series of times or ages are divided into three great epochs, viz.: The Silurian age, or age of Mollusks; the Devonian age, or age of fishes, and the carboniferous age, or age of plants; while the Mesozic corresponds to the single age of reptiles, and the Cenozoic to the Mammalian age. All these enormous periods are divided and subdivided again and again, so that every strata has its place in the vast whole in such a way as to be readily recognizable, if not by its intrinsic characteristics, it may still be identified by those of its neighbors above and below. But of the whole, it is with the upper third of the second or Palezoic time, called the Carboniferous age, that we have to do. The included strata are known as the coal measures, and contains as well most of the workable beds of iron ore. Associated with the coal measures also are vast strata of limestones, including the sub-carboniferous or mountain limestones, and superimposed beds of magnesian limestones—the former indispensable as fluxes, and the latter, recently found to be equally valuable as a means of purifying the ore from the phosphorous and sulphur often contained in the coal used in the process of converting the iron into steel. The iron ores, also, which are principally worked, have themselves been largely the result of plant growth, as by the process of absorption of metallic vapors from the atmosphere by the vegetation, and the setting free of the mineral thus held in combination by the decay of root fibres, etc, the oxidized metal has been carried down and caught in the subjacent sandstones and clay-stone rocks, and so has formed the ferrugenous earths and beds known as Iron stone, Haemetite, etc.



TYPES OF STELLAR SPECERA. (No. 3).

We thus see in the very center of the scale, associated with tho great belt of the coal measures, evidences of a time or age of extraordinary plant growth and of conditions of solar, aqueous and atmospherical phenomena unprecedented in the life of our planet; a time or age of light and heat storage, and of strength and energy storage, and of such other peculiar and suggestive combinations as to justify to some extent the claims of these same code measures as the real bona fide iron age after all; or at least it would appear that by the, shall we not say, Providential provisions of the law of natural selection, all the necessary elements have been brought together for the development of this present existing wonderful age or time, which all are ready to recognize as the "Age of Iron."

The qualities of cast and wrought iron and steel are so well known as scarcely to need mention, except for the sake of reference hereafter.

Fusibility, density and inflexibility in the case of cast iron, and malleability, ductility and elasticity in the case of wrought iron or steel generally cover their respective characteristics and constitute their valuable properties. Transverse strength and resistance to crushing in the case of cast iron, and of shearing in the case of wrought iron as well as the still more valuable capacity to resist tensile strains in the case of the latter substance, are in every way enhanced in cast and wrought steel, and still other valuable properties in what is known as malleable cast iron. The Bessemer and other processes of converting pig iron into steel, or, still better, directly from the ore, by forcing a blast of atmospheric air through the molten mass of metal in a crucible, has added so enormously to the availability of steel as a lighter, stronger, and more reliable substitute for ordinary iron, for almost all purposes for which the latter has hitherto been used, as almost to constitute as great a possible development in manufactures and means of ultimating great enterprises. as the invention of the steam engine itself.

THE APPLICATION OF IRON.

But passing from this phase of the subject to the application of iron in the arts of construction, we will note its progress as an agent in the accomplishment of some of the great enterprises of the century.

When James Watts was chided by his parents for wasting his time watching the action of steam on the tea kettle lid, they little knew the tremendous revolution in the condition of the world that the boy was destined to bring about—neither more nor less than the virtual inception of the age of iron, and thereby the amelioration of the condition, and, shall we not say final civilization of the habitable world, in a way unattainable by any other means. The invention of the steam engine has led to the extension of manufactures; the conquest of the ocean by the construction of vessels of steel, rivalling in dimensions the famous Ark of old; the extension of the land by the drainage of vast areas of bog, marsh, fen, and lake; the cutting of canals, and the connection of oceans by water-ways like great rivers; the covering of continents with net works of steel rails; the prospective belting of the world by means of telegraphic cables; the conversion of our streets into checkerboards of cable cars, our business houses into "cloud capped towers" indestructable by fire; and the spanning of great rivers and arms of the sea by enormous structures in the form of bridges, before which the mightiest works of the ancients fade into dolls' houses, and the very loftiest of which we have any positive knowledge, are dwarfed into pigmies in the presence of the Eiffel tower.

BRIDGES.

LONDON OLD BRIDGE. (No. 4.)

The first illustrations to which we will ask your attention are a number of bridges. These useful structures have, in all ages, taxed the ingenuity of engineers to construct, and may be said to have been a most important means of education, in enabling him to surmount difficulties and achieve success in almost every direction in which his energies have been exerted. The first structure we have here represented is Old London Bridge. This is a striking example of the cumbrous obstructiveness not unusual in the methods of the past. It was begun in 1178, by Peter of Cole Church, and was thirty-three years in building Often covered with large and picturesque masses of wooden buildings which were as often destroyed by fire—the main structure appears to have remained until the beginning of this century, essentially as it was built. The next illustration, which is New London Bridge, was designed by Mr. George Rennie, and built by his brother, Sir John. This a beautiful structure; having spans of 152 feet, and twenty-nine foot rise of arch, replaced the old bridge which was removed to make way for it.

LONDON NEW BRIDGE. (No. 5.)

Waterloo Bridge was erected in 1817, and is of a similar character to the preceding, being constructed of stone in many arches, of less span, but in a wider part of the river. See next illustration.

But the next example is altogether different in material, if not in form. Until recent years, stone, brick or timber was the material almost always employed in the construction of bridges; but late in the last century cast iron began to be employed, and the specimen here shown—Southwark Bridge over the Thames, 240 foot in span of arch, is not regarded as a success, in view of the material used, as it is unnecessarily heavy and expensive.

WATERLOO BRIDGE. (No. 6.)

The next specimen here shown, the Menai Suspension Bridge, (No. 8.) indicates a great advance in the right direction. The use of chains or links and wire cables on the suspension principle began to be quite usual before this structure was commenced by Telford in 1819. It is 570 feet span, and has a versed sine of forty-three feet for the curve of the Catenary.

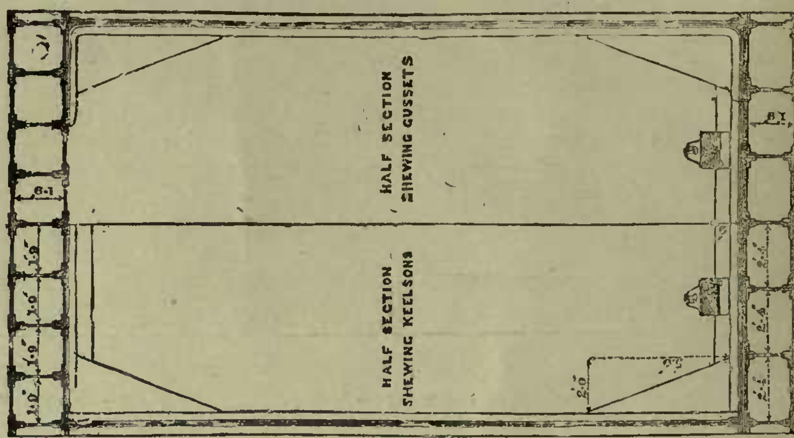
This form of bridge, however, was not at this time found suitable for railways. The objection raised on account of vibration has been obviated by the principle introduced in the next example, known as the Britannia Tubular Bridge, (No. 9) designed and built by Robert Stephenson in 1845. It shows a

SOUTHWARK BRIDGE. (No. 7.)

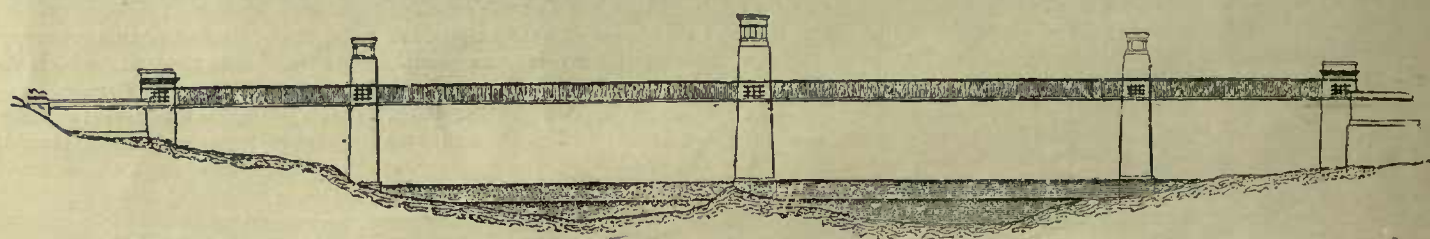
complete revolution in the construction of bridges, which has led to vast results. This bridge consists of two independent wrought iron tubular beams 1511 feet long, each 15 feet wide and 23 feet high at ends, and 30 feet in center. The central pier is 230 feet high, and the two center spans are 460 feet each. The land spans on each side are 230 feet each in length. The top and bottom flanges of these immense girder tubes are cellular in construction, and the floor and ceiling are strengthened by keelsons and gussets, and the side plates are strengthened by T irons inside and out. See sec. (No. 11) This bridge, however, in this peculiar form has only once been repeated in the Victoria Bridge over the River St. Lawrence, in Canada which is 7,000 feet in length, and whose spans are almost equal to those of the Britannia Bridge. The mode of construction, the methods of floating the tubes into position and raising them into their places by hydraulic pressure, and the final triumphant success of both these undertakings, together with the interesting incidents and imminent risks to which both were subject, owing to the dangerous conditions attending their construction, has almost the interest of a romance, and has raised both these enterprises, together with the name of their designer, into a prominence which can never be lost. Nevertheless, it is certain that they are never likely to be

MENAI SUSPENSION BRIDGE. (No. 8)

repeated, since more economical and advantageous forms of construction have arisen from the principle which they inaugurated, one type of which is the high level bridge at Newcastle. (No. 12) This is a combination known as the bow string girder, an open tube carried on a cast iron arch and wrought iron tie (see plan and elevation) presenting an appearance of great lightness and beauty both being more economical, and avoiding the disadvantages of the close tunnel form so objectionable in such long structures as the Britannia and Victoria Bridges, which shut out light and air, and the fine scenery which such situations usually present; but even this form of the tubular bridge is unnecessarily expensive, and the experiment is not likely to be again made. It was simply a combination of the *truss* with the *arch* and *tube*, both of which latter are wholly dispensed with in the next

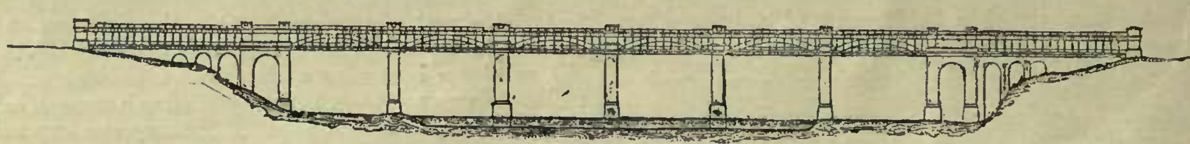


BRITANIA BRIDGE. (No. 10)
(Cros Section of Tubular Girder.)



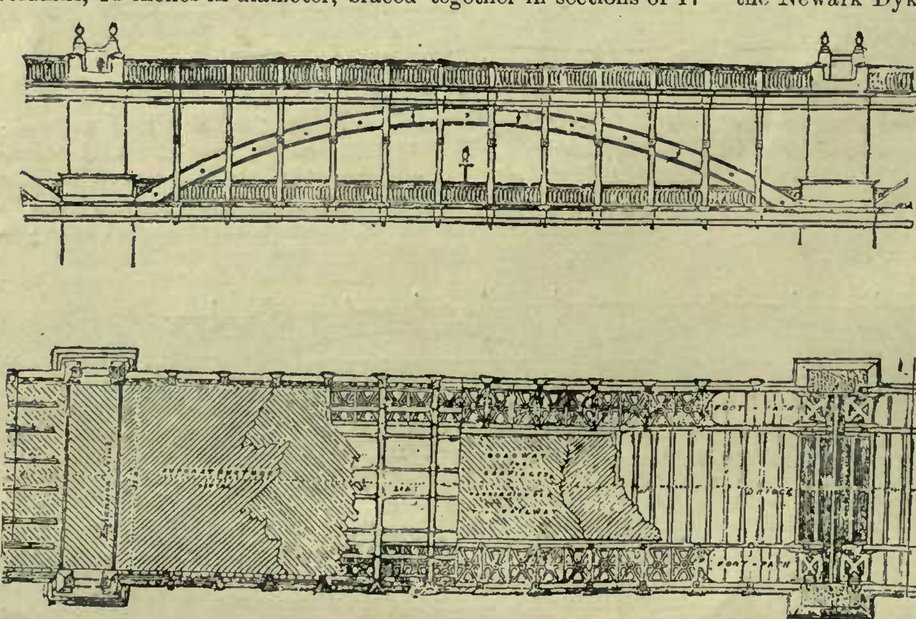
BRITANIA TUBULAR BRIDGE. (No. 9)

example, shown in elevation and section, which is the Newark Dyke Bridge, Cubitt Engineer, erected in 1853. (No. 13) It is the first, and a fine specimen of the Warren girder; and on account of its economy of construction and freedom from any unnecessary accessories, is a very frequent mode of truss construction, especially in America, in wood and iron, or both.



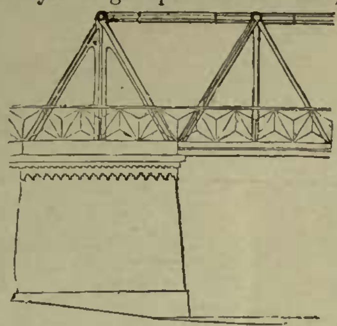
HIGH LEVEL BRIDGE AT NEWCASTLE. (No. 12)

The next example is the Crumlin Viaduct, (No. 14) which shows another fine truss on the same principle. It consists of 7 spans of 100 to 150 feet, and is carried on piers formed of hollow cast iron columns, 12 inches in diameter, braced together in sections of 17 feet each in length. The trusses are of wrought iron, and are 14 feet 6 inches in depth. The roadway is carried on the upper string of this example, but placed on the lower string of the Newark Dyke Bridge. The next example, (No. 15) is the Saltash Bridge, which was erected by Brunell. It is known by the name of "Fish" girder, on account of the construction of the truss which is formed by reversed segments of circles of cast and wrought iron plating connected by vertical and diagonal bracing to which the roadway is suspended. It is, however, less economical than the forms of girders founded on the Warren type, and so has had no children. The next illustration (No. 16) shows an example of a *wrought iron* arch bridge over the Rhine at Coblentz. But it is of no greater span, nor so economical in construction as many of the preceeding forms of bridges, and hence cannot compete with then in universal adoption. The next example (No. 17) shows the Fink type of truss. In this girder each division comprises a separate and distinct truss, all combined in one by the boom or horizontal tie which supports the roadway of the structure. It is composed wholly of vertical cast iron struts, inclined wrought iron braces, and one horizontal tie. It is a worthy competitor of the Warren girder as regards economy, but is less pleasing in form.



Top Plate represents the Elevation of one Span of Bowsting Arch of High Level Bridge New Castle. Lower Plate is the plan of the same. (No. 11)

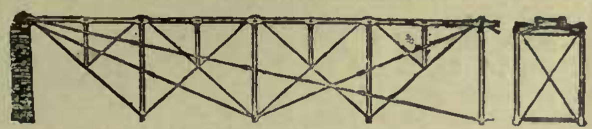
The Niagara Suspension Bridge, (No. 18) is the next example. It crosses the Niagara River some distance below the falls at a height of 245 feet above the water by a single span of 821 feet, 6 inches. The main structure is a hollow rectangular box. The steam cars traverse the upper surface, while the carriages pass through the tube. The walls are formed of double vertical timbers with wrought iron diagonal bars crossing between them. The railway or upper floor is carried by two wire cables, while the carriage way or lower floor is carried by two others, four in all. The total sectional area of iron is $211\frac{1}{2}$ square inches. This bridge was commenced in 1852, and open for traffic in 1855. It was designed and built by Roebling, and cost £80,000. The use of the two cables of different versed sines has been criticised as a defect in the principle of this bridge.



NEWARK DYKE BRIDGE. (No. 13)

NIAGARA SUSPENSION BRIDGE. (No. 18)

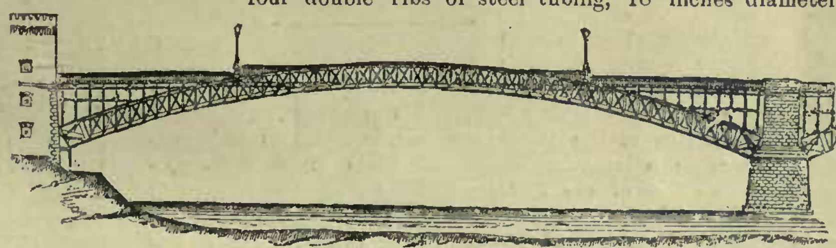
In this mode of construction the *tube* and the *truss* have been combined with the *suspension* principle, as introduced above, showing the progressive development of the idea of adaptation of means to ends, which is so marked a characteristic of the present age, and the drawing attention to which is one of the chief objects of this paper, especially in connection with the development of the same principle in architecture. The next examples of *Arch and Girder* construction, the first in America, and the other in France, show characteristic methods of spanning great spaces by permanent structures on sound principles.



FINK TRUSS. (No. 17)

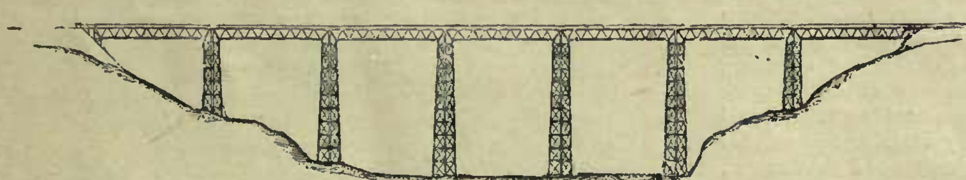
The St. Louis and Illinois Bridge, (No. 19) over the Mississippi, is a fine example of metal arch construction. It is in three spans, the center 520 feet, side spans502 feet wide respectively, and presents a novelty in bridge building. The spans of the arches are among the widest of the kind in the world. The rise of the center arch is $47\frac{1}{2}$ feet. Captain Eads was the engineer, and he must be credited with having designed and erected one of the finest bridges of any age. Each span consists of four double ribs of steel tubing, 18 inches diameter, bolted together and braced laterally and connected by wrought iron couplings, which were found better for the purpose than steel. The tubular ribs are in sections 12 to 13 feet long, and from $1\frac{1}{2}$ to $2\frac{1}{8}$ inches in thickness. It is designed to carry a double railway below, and foot passengers above.

The next example (No. 21) shows the great Garabit Viaduct, lately erected by Mr. Eiffel. It is a combination of a wrought iron lattice arch carrying a lattice trussed girder. It is of great height, 640 feet span, and a very masterly work. It was built by means of suspension cables, very much on the same principle, but by different methods to that adopted in the Forth bridge shortly to be noticed, viz., without scaffolding.

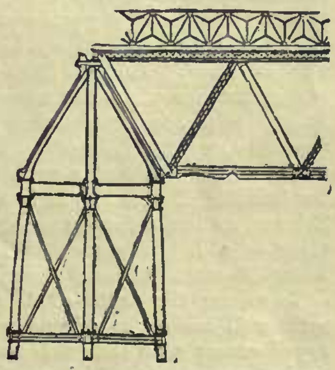


ARCH BRIDGE AT COBLENTZ. (No. 16)

The Brooklyn Bridge, (No. 21) of which I here produce an illustration, is the next great work to notice. It is 1,900 feet between supports, with piers 320 feet high, and is 250 feet above



CRUMLIN VIADUCT. (No. 14)



PART OF CRUMLIN VIADUCT.

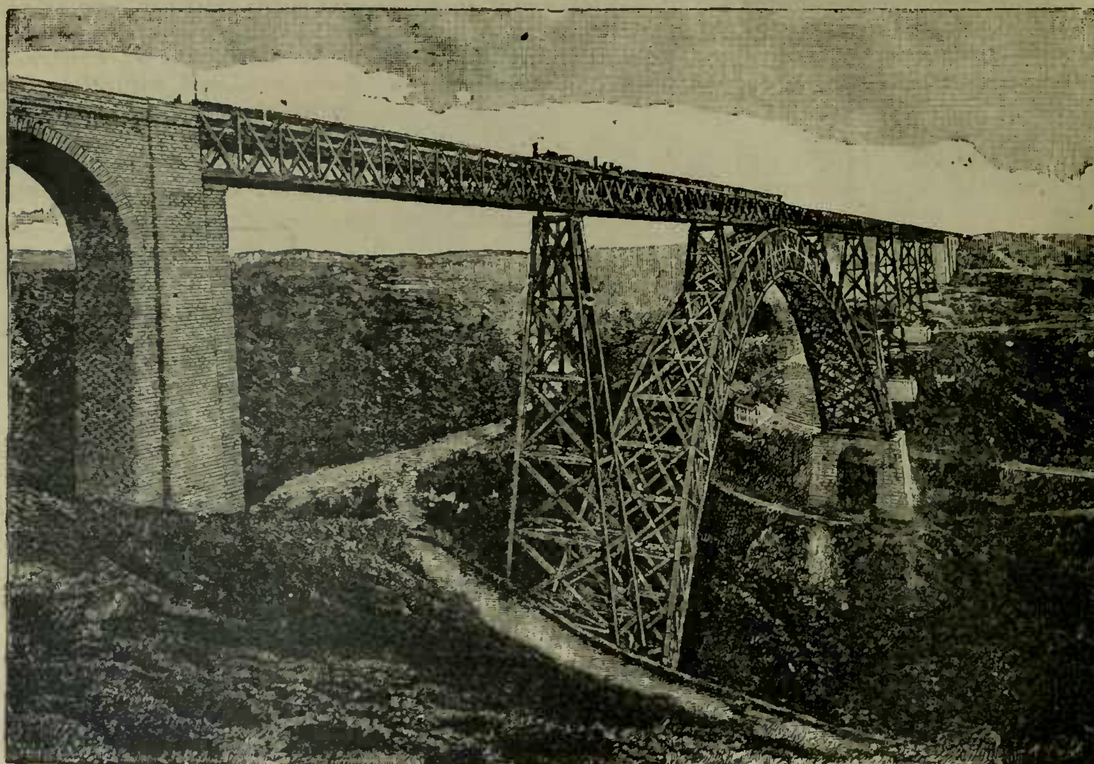
the East River. It is a mighty structure, and a daring and wonderful achievement. It also is a combination of tubular truss to secure lateral stiffness, with suspension cables as supporting agents. Cable cars, carriage roads and foot passenger ways are provided, and the whole constitutes one of the greatest of the many magnificent undertakings brought to a successful accomplishment in recent years.

The Firth of Forth Cantilever Bridge (No.22 3) is another structure of immense proportions, and of great complexity, being a combination of wrought iron arch-tubes, vertical and inclined tubular columns or posts, pitching inwards, double suspension bearings latticed together, and great latticed catenaries supporting a continuous box girder-tube which passes through the whole, carrying the railway track. The span is 1,710 feet, besides the side approaches. It is constructed on the *stable equlibrium* principle, and is wholly built of steel without scaffolding. It is without question the most stupendous structure of the kind in the world, and will scarcely be blown down like the Tay Bridge, in 1886. The above structure is a combination of *arch* and *catenary*, with the *lattice* principle. It is constructed by building out piece by piece from each side of the central supporting piers. It in fact provides its own scaffolding, and grows by gradual accretion of balanced parts as a tree does, and on the same principle, thus indicating a closer and closer return to nature by man as he

ST. LOUIS AND ILLINOIS BRIDGE. (No. 19)

assiduously studies her economic processes. Nevertheless, the apparent strlking disporportion between means employed and ends subserved is so manifest in this structure as to suggest grave doubts as to the soundness of some of the principles of design employed therein.

The next illustration here shown (Nos. 23, 24, 25 and 26) is the proposed great North River Bridge at New York. This enormous but beautiful structure as it is designed, will be fully twice as large as the great Brooklyn Bridge. It is to be 2,820 feet span between supports. The towers will be of steel, and 620 feet in height. It will cost $40,000,000, while the cost of the former was only $5,000,000.
The bridge itself is formed of latticed girders carried on latticed cables. The whole promises to be the grandest single span structure that has yet been conceived.



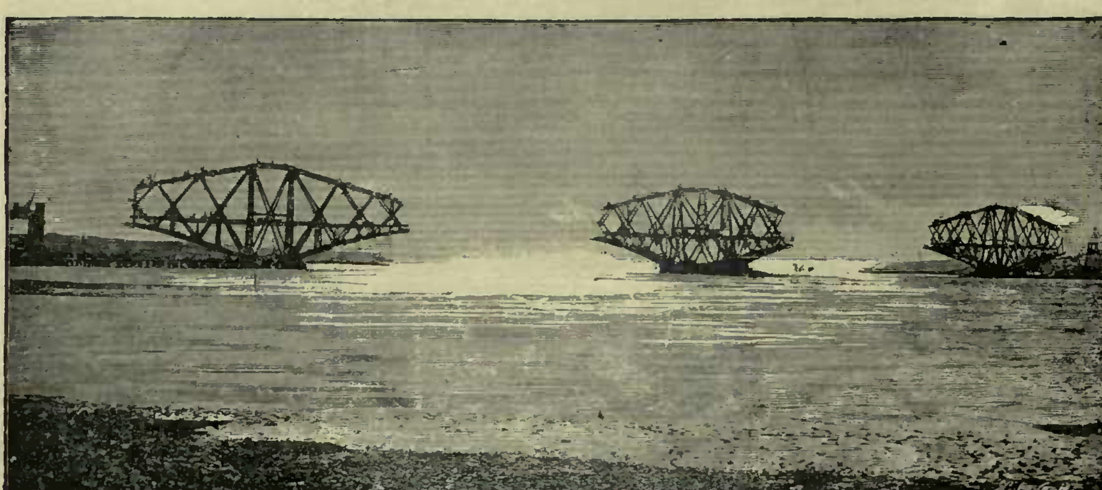
THE GREAT GARABIT VIADUCT. (No. 16)

It will be seen that in each of the above structures, while the technical, the utilitarian, the *objective* qualifications have in every case almost wholly governed the design, the result has also partaken of the higher æsthetic, ornamental and artistic qualities in a remarkable degree. From the straight simple bar-like effect of the Britannia Bridge, imposing from its magnitude and simplicity, to the great, sweeping curve of the catenaries of the proposed North River bridge, each design has presented features and combinations of features clearly expressed and resulting in a peculiar beauty which no mere architectural accessory could in any way produce. Not one of these designs depends for its effectiveness on any purely architectural detail as usually understood, but it is due entirely to the proper distribution of parts in the most efficient way that could, at the time, be reasoned out for the proper attainment of the object in hand. This we have to insist on again and again. It is the iron rule which can never be broken without departing from true principle, and with unhappy results to the beauty of the structure concerned, from the designing of the simplest moulding to the construction of a cathedral, the erection of abridge, or the building of a ship. It is the one paramount law in Art and Science, as imperative in such an apparently variable and volatile thing as a lady's bonnet, as in the construction of that useful, beautiful and significant thing, the steam engine.

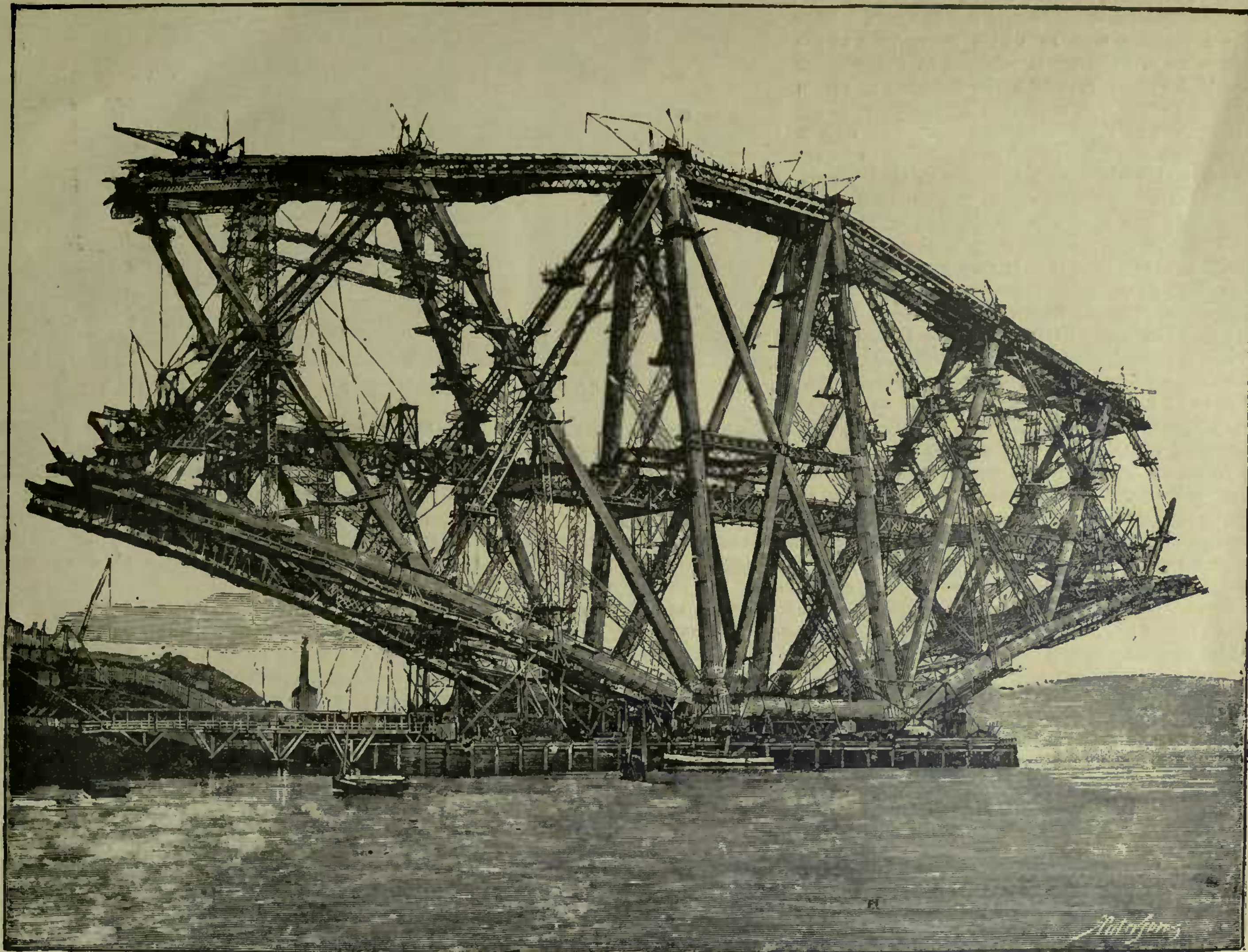
To evince the truth of this proposition we will present one more well known, nay,thsperaps, in past times, somewhat hackneyed example, to close this series of illustrations of the very imperfect remarks to which you have so kindly and forebearingly listened. I allude to the one great, significant, and really original building of the century. The conception of no professional architect, for no architect out of 245 who competed for it, proved equal to the task.—No builder: for none were found in the length and breadth of England who could suggest such a structure; but of a mere gardener, a constructor of green houses.—I allude of course, to the Great Exhibition Building of 1851. Truly great it was, and greatest, even, it will remain, until once again the exigencies of the occasion shall override mere precedent, and some future gardener shall produce as glorious a flower from as small a seed, simply by yielding unquestioning obedience to the needs of the occasion, unfettered by rule or any existing order of things which could in any way interfere with or encumber *pure utility*. The design sprang into being, and the world of that day was both astonished and delighted. It is said that when all the designs for the Great Exhibition of '51 had been received, classified and inspected, and the commissioners, rejecting them all, had concocted one of their own, apparently as unsuitable for the purpose, as any one of them all, Joseph Paxton, chief gardener to the Duke of Devonshire, sat down in his office and in half an hour sketched out his design for the proposed building on a sheet of foolscap. Submitting his idea to one of the Commissioners, he was encouraged to perfect it. The design was published and received the unanimous approval of the nation. The contractors, Fox & Henderson, in one week prepared drawings and estimates, and in four months from that date, 18 acres were covered with glass and iron in a structure, the quiet be auty, majestic simplicity and the unapproached convenience of wihch has been from that day to this, absolutely unrivalled in buildings of the kind. Every building of the sort since designed, has had a variety of accessories breaking up its mass by useless excrescences until the fantastic structures have finally lost every characteristic which made the original design great. The accompaning views, show exterior and interior views, and a few details. (Nos. 27, 28, 29 and 30)

The account of the designing, and construction of this building, reads like a fairy tale, in harmony with the fairy like structure which was the charming result.

Mr. Henderson, who made every important drawming with his own hand, werking 18 hours a day for seven



FIRTH OF FORTH CANTILEVER BRIDGE. (No. 22)



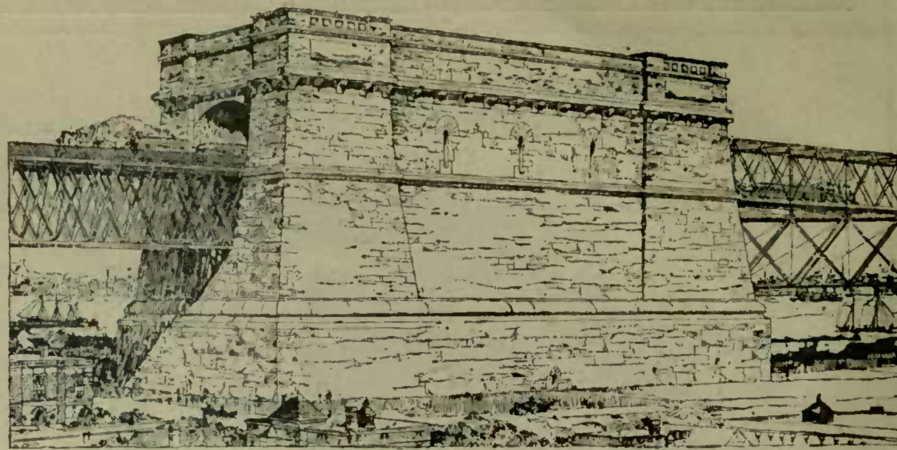
FIRTH OF FORTH CANTILEVER BRIDGE. (No. 23)

weeks, says in a speech made about that time, that hundreds of tons of glass were provided, of an unprecedented size; thousands of columns, hundreds of girders 34 miles of guttering pipes connecting the columns, which conveyed the rain water to the ground, 205 miles of sash bars, and more than 1,000,000 feet of flooring, were produced by the various firms engaged in the work, in the short space of time which was allowed to execute it. The setting out of the structure, the placing of the base blocks on concrete filled into holes dug in the ground, the raising of the columns, the lifting of the girders and keying them into their proper places in the structure, etc , proceeded with unexampled accuracy and rapidity, and, the first of its kind, and unique in the history of great expositions, the building was ready on the day when the contract expired. This was due to the entire simplicity and reduplication of every part of the structure, which again was due to the harmony of scale, which in this structure, as in the Parthenon and a few others, is perhaps after all, the most noticeable feature in the building.

Contemplating the excellent qualities exhibited by this great structure, which at the time of its erection, challenged the admiration of men of taste and judgment throughout the world, and in fact, elevated it to a level with the greatest edifices ever conceived by man, it is evident that it in no way differs in kind from any one of the great engineering works to which your attention has been directed above.

NORTH RIVER BRIDGE. (No. 34)

Adaptation of means to ends and that alone, in it, as in them, constitutes and includes all of its qualifications, and in this as in them, it is especially to be remarked that there is nothing imitated. No attempt is made to transfer to one material the appearance or proportions appropriate to another. On the contrary, each material is in its turn treated on its own merits, and hence its value is thereby enhanced in proportion. It is just as though the whole structure to its minutest part, was represented by two sets of figures, indicating in the first place the intrinsic value, in the other the value in application, and that both sets of figures in every case, were identical. In how many structures of the kind, erected before or since, can this be said to have been attained. In other words, that every material throughout the structure should be so applied as to attain the greatest measure of utility it is capable of, with the least expenditure of material compatible with safety, and with the best artistic effect. Would it be by adopting the forms and construction appropriate to some other and very different materials? to make iron resemble stone for instance, or wood iron or vice versa? It is evident that there must be in such a case a great and useless waste of labor as



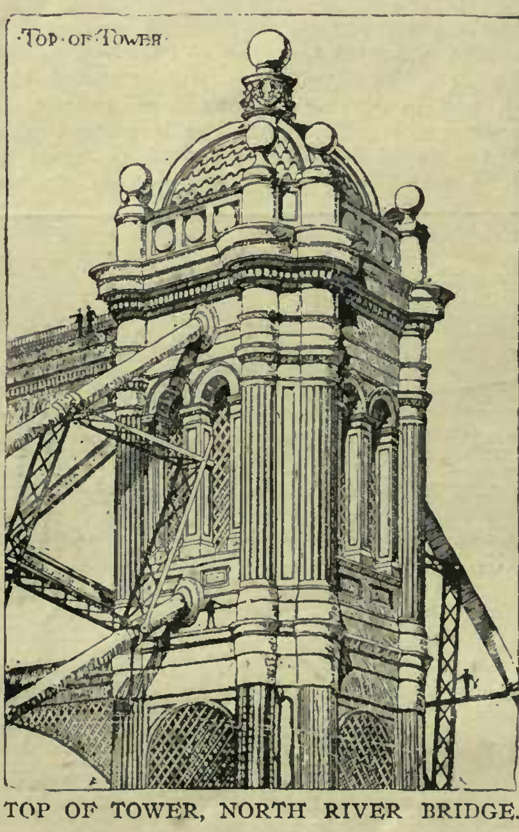
APPROACHES TO THE NORTH RIVER BRIDGE. (No. 25)

well as material, in other words, that the intrinsic and economical values would fail to agree. Note the admirable way in which every part of the above great building is adapted to every other part! The way in which the columns rise from ground to roof line, representing every one of the direct lines of support throughout. The way in which the connecting girders and filling in pieces are keyed rather than bolted into their places, and how directly and *easily* every part does its duty, and how by the proportioning of material to strength and position, such a degree of aerial elegance is attained that it may, perhaps, best be compared to the delicate twigs and branches of a tree divested of its leaves, whose dainty pencilings tax the skill of the artist fitly to represent. When in the full glory of its utility, it overflowed with a profusion of fabrics and materials, and objects of beauty and use from every quarter of the globe, it was like the same tree in full bloom, glowing with verdure . with color and with fruit.

It seems at this point permissible to consider, as a comparative test of the proper treatment of other materials, some of the reecognized qualities and properties of Iron. Whether as wrought or cast iron, or in the form of that now abundant material, wrought and cast steel, innumerable tests and experiments have settled to so large an extent the available qualities of all these substances that there is no particular need of dilating upon that subject further than may suffice to note some of the ways in which they may be better used and less abused. In the first place it must not be forgotten that all materials, without exception, are subject to change, that no material, whatever its form or qualities, is free from the liability to alter its shape; and that therefore when a perfectly spherical cast iron ball rests upon its side, it is no longer spherical, it is really oblate. That a piece of cast iron ten inches square in section and a standard foot in length, if placed resting on its extremities, is no longer a standard foot in length, and that when a great weight is placed unsymmetrically on any form of support, that support will be acted on unsymmetrically and will change its form, and the arrangement of all its molecules in the effort to adjust itself to the conditions thereby imposed upon it, which in construction means a great deal, involving as it does under given conditions the theory of re-crystallization, etc.

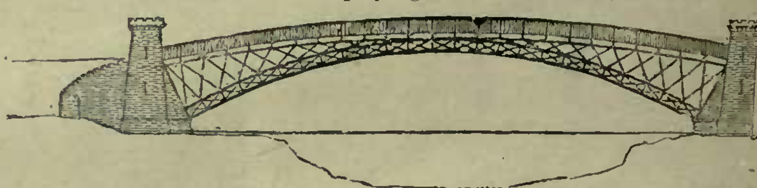
We are accustomed to suppose that our friends, the engineers, are the men above all others who are used to taking account of the minute changes in the form and direction of the substances and forces with which they have to deal.

But architects are expected to abolish all such changes, and to produce a structure of variable materials absolutely fixed in form for ever; at least so one would suppose from the sort of criticism to which they are at times subjected. But it is to be feared that they themselves are chiefly responsible for the inappropriate use too often made of materials, and the untoward results which frequently occur. Uniformity of material means uniformity of action in the changes which those materials inevitably undergo under the influence of temperature and strain. Some of the ways in which iron should not be used, we beg now to note.



TOP OF TOWER, NORTH RIVER BRIDGE.
(No. 26)

First: No great strain ought at any time to be thrown in an unsymmetrical manner on any unsymmetrical section of cross iron. This means an unequivocal condemnation of *brackets*. The extent to which that mode of employing cast iron is used, is remarkable



CAST IRON BRIDGE AT CRAIGELLACHIE.

when the treacherous nature of the material so used is so well known.

To founders and machinists who are well and practically acquainted with the behavior of cast iron under strain and temperature, there is nothing more objectionable than a large extent of *cross iron*, as it is called. They refuse to trust to it under any circumstances and yet we find in all the published examples an almost unlimited use of this objectionable and dangerous feature. Smooth, round columns of cast iron of small diameter, are set upon end and a number of brackets are projected from them at a sharp angle at cap and base plate, bearing heavy loads of beams and arches and this for many stories in height. Such an accident as occurred in the Owens Building, at Chicago, or an unsuspected flaw in one of the brackets or any other adequate reason, causing the snapping of one small section, may possibly occasion in a moment the destruction of a large building, hundreds of lives and much valuable property. Is this either wise or necessary? Can bad construction ever be necessary? Is it scientific? Is it artistic? That there are few authentic cases of failure of this kind that can be referred to is no argument in favor of the practice. Is it not something which may occur under any sudden shock? The fall of comparatively few degrees of temperature, in view of the great inequality between bracket and shaft, must cause unequal strains in both. A settlement causing undue strain on any one part, or a local *rise* of temperature, or some stress occasioned by any one of a hundred different causes, may ultimate the conditions which may bring about a failure such as I have

SPAN OF SALTASH BRIDGE. (No. 15)

BROOKLYN BRIDGE, NEW YORK. (No. 21)

indicated. Another wrong use of the material is indicated in the ordinary form of cast iron girder in which the upper flange is arched. This is an altogether mistaken idea, and an utterly fallacious, improper, and unscientific use of material. In the girder here shown (No. 31) the lower flange is straight; the shortest distance between the two ends, in the upper flange, the distance is the greatest that can be found between the two ends. In cooling flange (A) occupying greater length, shrinks more and flange (B) being shorter, shrinks less, in proportion; consequently there is an internal strain set up between the top and bottom flanges and brought to bear upon the web, which added to the weight that the girder is supposed to bear, greatly lessens its effective strength, if, (as in large girders of this form, is a frequent result,) it does not occasion their destruction. This is one of the principal reasons why such cast iron girders frequently snap, even before being placed in the building. The ordinary form of the rolled girder, indicates also the best general form for a cast iron girder under ordinary circumstances. Parallel flanges, the upper one-half the width and thickness of the lower, with square or inclined skewbacks at the end, indicate generally the best practical form for cast iron girders of short span. (No. 32)

The latticed girders used in the great exhibition building (No. 29) were in every respect admirably adapted to the purpose for which they were intended; and either as stiffeners for the nave columns, in which position, of course, they were much lighter, or as the bearers of the gallery floors, they were found in every respect equal to their work.

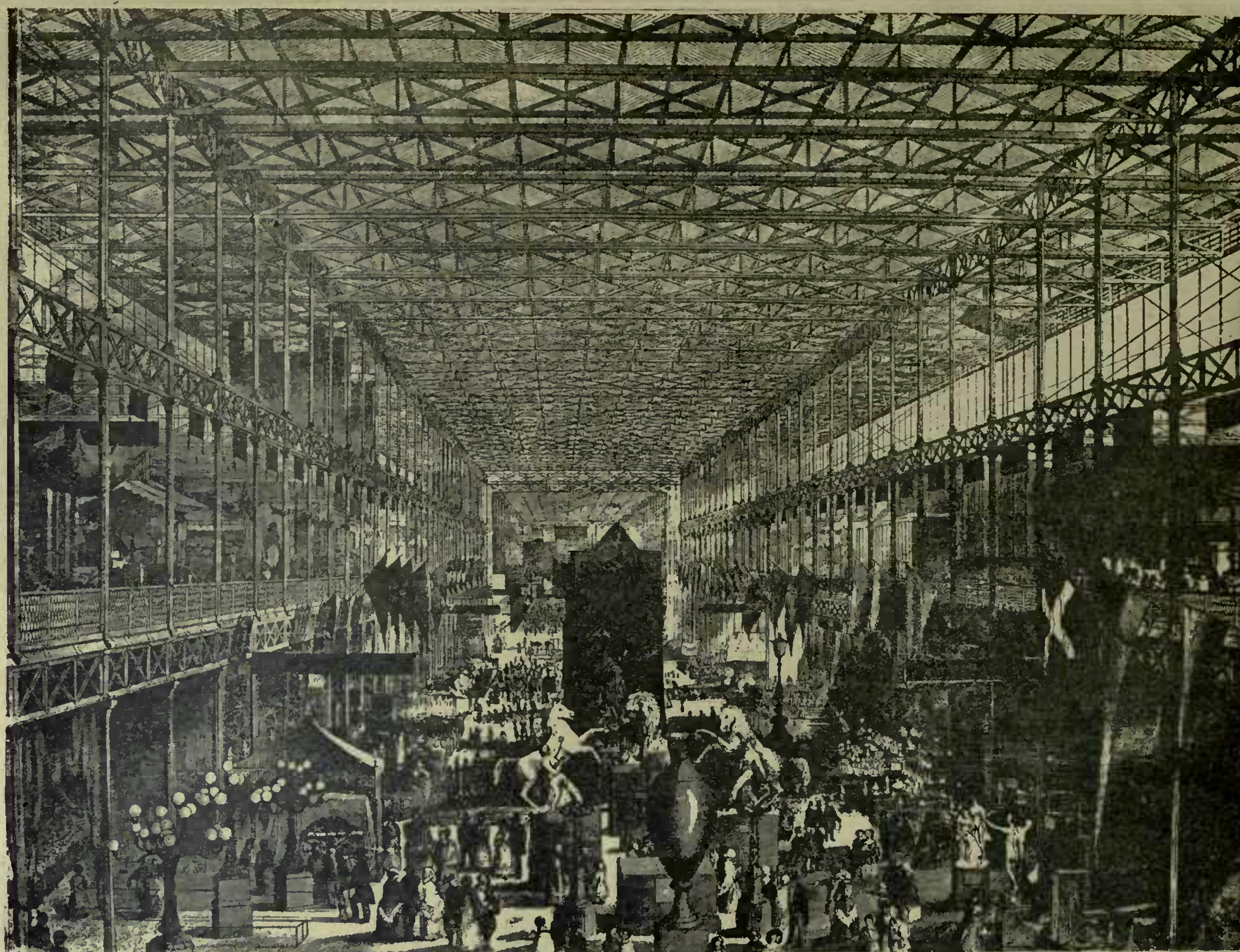
Before closing these perhaps too lengthy remarks, I will venture to indicate a few ways in which it may be found advantageous to use cast iron. Describe a circle in a square, (No. 33) and fill in the angles of the square with other squares; apply the thickness of one of the small squares round the circle internally, and you have the section of a cast iron column of any diameter, and any length within the prescribed limits of 30 diameters. In elevation, place the flanges diagonally (as they are drawn) to the length of the superimposed girders. Grow the flanges out by means of curves, into brackets of modraete projection and cast a plate of equal thickness on top, andthe cap is formed. A greater projection and a proportionately larger plate forms the base. If supporting a great weight, as in the case of a basement column, separate the base, and form circular flanges between the angle ribs, on shaft and base sections, and bolt the two together. To adjust wrought I beams to this form of columns continued two or more stories in height; cut away the flanges of beams next the columns on each side (using coupled beams) and fit the same to flanges of columns, and bolt diaphram plates between the beams, (which should always break joint) on each sideof column. In this way a perfectly immovable system of columns and girders is formed, symmetrical in bearing, and adjusted to the required conditions throughout. The brackets are simply extensions of the ribs, and there is *no initial point of fracture*, and the girders, on account of being firmly held at each end, will bear double the weight of unfixed girders. If it is desired to fireproof these columns and girders, the shafts and brackets are admirably adapted thereto. One other suggestion and I will conclude this section. The subject of *Tempering* is one which does not seem to have attracted the attention of constructionists to any large extent up to the present time. A gentleman of my acquaintance in Ontario, Canada, some years ago, patented a carriage spring of peculiar merit. Instead of being made in the usual way of several laminae of thin steel, secured with rivets or loops, it was made solid, ogival in form, and tempered in an oven. The reason why springs had never been made solid before was because it was not easy to give equal temper throughout the thick and thin parts. This was secured by means of an oven of a peculiar kind. The ogival form of the spring causes the bearing to be *shortened with the increase of load.* Why is not this a principle which might be taken advantage of in designing cast or wrought steel lattice girders, (No. 34) and why should they not be tempered? The tempering alone, the gentleman informed me, added 300 per cent. to the strength of the springs.

LONDON EXHIBITION BUILDING OF 1851. (No. 27)

The lately invented method of rendering iron unoxidizable, known as the "Bower-Barf" process, by which a film of carbonate of iron is formed on the surface of the metal, seems calculated still further to increase the availability of iron as a building material.

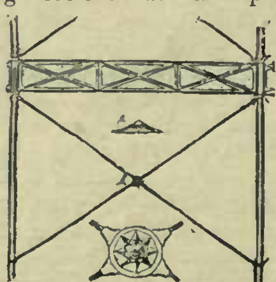
In conclusion, it is in order to revert briefly to the original title of this paper, "The Iron Age."

While to speak in parables in the promulgation of truth and to embody symbolism in the statement of principles has been, perhaps, peculiarly characteristic of past times, and of people of a genius different to ourselves, to clearly formulate the same principles, in logical terms and in unmistakable language, is believed to be the special province of the philosophy of the present day. And, while this may be conceded so far as it goes, it is also certain that the wisdom of our own times still continues to be embodied in, as that of other times must be interpreted by, modes of utterance which condense into single expressions the ideas, sentiments and general characteristics qualifying whole ages. Just such a term is the one above mentioned, as expressing the peculiarities of our own time or age. One, indeed, it is, in which the fallacies



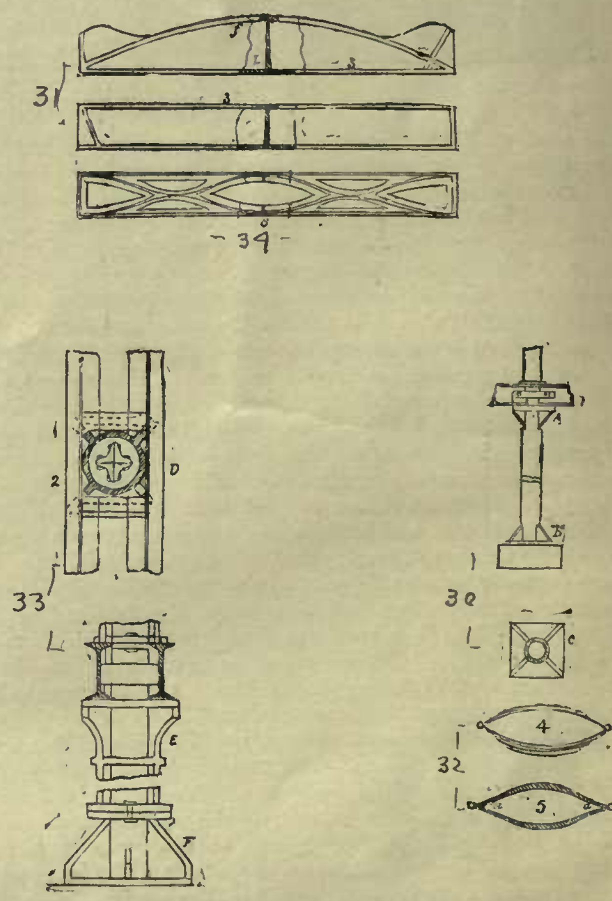
INTERIOR VIEW GREAT LONDON EXHIBITION BUILDING. (No. 28)

of the past are being tried in the furnace of modern scientific research, and the pure metal of simple *utility* is being evolved from the comparatively worthless philosophistical *Hœmatite* and *Iron Stone* of former eras. And lo! everywhere and in every sphere of human endeavor, order is emerging from confusion, and progressive development takes the place of stagnation; and in religion, politics, science and art, the symmetrical lines of the Social Structure begin to appear and to assume an aspect in some degree corresponding with the material improvements in so many



Diagonal Bracing used in above building (No. 29)

directions visible round about us. In the pregnant words of the Son of Amoz, luminous as they are with the true spirit of prophetic utterance, " For *Stones* I will bring *Iron* !" But not only must the useless representative of a false philosophy be exchanged for the rational science of an advanced civilization, but the rotten symbol of a spurious morality must give place to a more enduring substance in the Social Fabric of the day; for the grand old prophet, with a rocket-like forecast of 3,000 years, goes on to say, "For *Wood* (I will bring) *Brass* !" But neither iron nor brass—nor the principles they represent—will suffice the great artificer who builds above the heavens! for the one will rust and the other will tarnish, and the structures they build will go to decay, containing as they do the elements of their own destruction within themselves; for, though iron may be converted from the coarsest "pig" to a substance lustrous as silver and strong as adamant, it represents only a selfish rationalism at best;



DIAGRAMS SHOWING 31, 32, 33 and 34.

and, though brass may endure for a while and superficially burn with a glory like gold, it exemplifies only the poisonous egoisms of the age, and both it and its antitype will blacken in time. It is only another word for the conventional policy of the day. So again the prophetic voice comes proclaiming across the centuries in a still loftier strain: "For Iron I will bring Silver!" Not Rationalism and its fallacies, however scientific and intellectual, nor mere morality with its sophistries, persuasive though they be, can redeem the age or restore the lost lineaments of divine humanity to the race; but an enlightened spiritual philosophy, which is also rational, must prevail, whereby the high principle which regards the *true* well-being of mankind, in the broad sense of universal brotherhood, may be realized in the new social science which must more and more mould the social organism of the world. But not even *silver* alone,or the high principle it repsesents, will suffice for the structure of the City of the Soul, for once again the final promise comes as truly as of old, in divine prophetic utterance,saying, "For Brass(I will bring)*Gold.*" For the sympathies and perceptions as well as the sensibilities and sentiments of men must be aroused, and *mediate* good or the love of man, represented by silver, must be vitalized by *essential* good or the "love of God," represented by "Gold" "like unto transparent glass." And *these* must be the substances out of which the mental, moral, yea the *spiritual* "habitations" of mankind must be constructed, ere the true Golden Age of perfected *wisdom* can come again in place of the original Golden Age of untried innocence in the prehistoric childhood of the race! Then, and then only can the *Spiritual Jerusalem* be said to be indeed established among men, in the good time coming, in the far off æons of futurity.