SECTION I.

INTRODUCTION.

ART. 1. In consequence of the security which cast iron gives, when it is properly employed, for supporting considerable weights, pressures, or moving forces, it has lately been very much used; and is likely to wholly supersede the use of timber for many important purposes. Indeed, so considerable are the improvements which have arisen out of its use, that the period of its general introduction has been very justly considered as forming a new era in the history of machines.[1] "All other improvements," it has been remarked, "have been limited; confined to particular machines; but this, having increased the strength and durability of every machine, has improved the whole."[2]

Cast iron is a valuable material, because it gives

[1] Essays on Mill Work, &c., by Robertson Buchanan, Essay II. p. 254, 2d edit.; or 3rd edit. by G. Rennie, Esq., p. 177.

[2] Mr. Dunlop's Account of some Experiments on Cast Iron. Dr. Thomson's Annals of Philosophy, vol. xiii. p. 200.

safety against fire; it is not liable to sudden decay, nor soon destroyed by wear and tear, and it can be easily moulded into the form of greatest strength, or that which is best adapted for our intended purpose.

The fatal consequences that might result from the use of timber for supporting heavy buildings, either in case of fire or of decay, have often been foreseen; but in a few instances it has happened that where iron has been used for greater security against fire, the structure has failed from want of strength. Such failures have not occurred from any defect in the material itself; for it too often happens that such works are conducted by persons of little experience, and less scientific knowledge. Men of little experience too frequently imagine that a large piece of iron is almost of infinite strength; and they often have a like indistinct notion of pressure. They design to please the eye, without regard to fitness, strength, or durability; instead of ornamenting a support, they make the support itself the ornament, and sacrifice every thing to lightness of effect. The dimensions of the most important parts of structures are too often fixed by guess or chance; and the person who calculates the value of materials to the fraction of a penny, seldom if ever attempts to estimate their power, or the stress to which they will be exposed.

The manner in which the resistance of materials has been treated by most of our common mechanical

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writers, has also, in some degree, misled such practical men as were desirous of proceeding upon surer ground; and has given occasion for the sarcastic remark, "that the stability of a building is inversely proportional to the science of the builder."[3]

When it is considered that it is absolutely necessary that the parts of a building or a machine should preserve a certain form or position, as well as that they should bear a certain stress, it will become obvious that something more than the mere resistance to fracture should be calculated. In cases where the parts are short and bulky, it may do very well to employ the rules for resistance to fracture, and make the parts strong enough to sustain four times the load, but such cases rarely occur; and where long pieces are loaded to one-fourth of their strength, we may expect much flexure, vibration, and instability.

If a material of any kind be loaded with more than a certain quantity, it loses the power of recovering its natural form, when the load is removed; the arrangement of its particles undergoes a permanent alteration; and if it supports the same load during a considerable time, the deflexion will increase, and the more in proportion as the load is above the elastic force of the material.[4]

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[3] Ency. Method. Dict. Architecture, art. Equilibre.

[4] This important fact appears to have been first noticed by Coulomb, while making his experiments on torsion. (Some account has been given of Coulomb's experiments by Dr. Young,

On this part of the resistance of materials I have made many experiments, both with metals of various kinds, and with timber: I find that while the elastic force or power of restoration remains perfect, the extension is always directly proportional to the extending force, and that the deflexion does not increase after the load has been on for a second or two; but when the strain exceeds the elastic force, the extension or deflexion becomes irregular, and increases with time. I was led into this important inquiry by considering the proportions for cannon,

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Nat. Phil. vol. ii. p. 383, and also by Dr. Brewster in his additions to Ferguson's Lectures, vol. ii. p. 234, third edit.) But, in a great number of substances, we seem to have an instinctive knowledge of this property of matter: a bent wire retains its curvature; and it may be broken by repeated flexure, with much less force than would break it at once: indeed, when we attempt to break any flexible body, it is usually by bending and unbending it several times, and its strength is only beyond the effort applied to break it when we have not power to give it a permanent set at each bending. A permanent alteration is a partial fracture, and hence it is the proper limit of strength. Dr. Young, with his usual profound discrimination, pointed out the importance of this limit in applying the discoveries in science to the useful arts.

While I was preparing this edition for the press, I received a copy of the "Essai Théorique et Expérimental sur la Résistance du Fer Forgé," of M. Duleau, which is founded on similar views of the strength of wrought iron. M. Duleau has ascertained, with an apparatus much more imperfect than mine, the fact that iron cannot be considered a perfectly elastic body when the strain exceeds a certain force. I shall, in the course of this edition, compare the results of his experiments with those I have made, wherever the conditions are similar.

and the common method of proving them. It appears from my experiments, that firing a certain number of times with the same quantity of powder would burst a cannon when the strain is above the elastic force of the material, though the effect of the first charge might not be sensible. The same remarks apply to the methods of proving the strength of steam engine boilers and pipes, by hydraulic pressure: if the strain in proving exceeds that which produces permanent alteration, an irreparable injury is done by the trial.

In the moving parts of machines the strain should obviously be under the elastic force of the material, and in the second Table will be found the flexure and load a piece of a given size will bear without destroying the elastic force.

I think every one, who carefully examines the subject, will feel satisfied that the measure of the resistance of a material to flexure is the only proper measure of its resistance, when it is to be applied where perfect form or unalterable position is desirable; and the measure of its resistance to permanent alteration, when it is used where flexure is not injurious nor objectionable.

In order to supply practical men with a convenient and ready means of assigning the dimensions of cast iron beams, columns, &c., to support known pressures, or moving forces, I have drawn up this volume. I am persuaded that its usefulness will find it a place among the common works of reference, which are more or less necessary to every architect, engineer, and builder. To bring it within as small a compass as possible, I have arranged the Tables so as to include as many distinct applications as the nature of the subjects seemed capable of admitting.

SOME PARTICULARS TO BE OBSERVED IN USING THE TABLES.

2. The weight of the beam itself is always to be estimated, and added to the load to be supported; or (because this method renders it necessary to estimate the weight before the bulk be determined) find the dimensions of the piece that would support the load by one of the Tables, and increase the breadth in the same proportion as the weight of the piece increases the load. If the weight of the piece, for example, be an eighth part of the load, then to the breadth, found by the Table, add an eighth part of that breadth; and so of any other proportion. It is not an absolutely correct method, but it is simple and correct enough for use.

3. The Tables and Rules are calculated for soft gray cast iron. Metal of this kind yields easily to the file when the external crust is removed, and is slightly malleable in a cold state. Dr. C. Hutton has justly given the preference to such iron, because it is "less liable to fracture by a blow, or shock, than the hard metal."[5]

[5] Tracts, vol. i. p. 141.

White cast iron is less subject to be destroyed by rusting than the gray kind; and it is also less soluble in acids; therefore it may be usefully employed where hardness is necessary, and where its brittleness is not a defect; but it should not be chosen for purposes where strength is necessary. When it is cast smooth, it makes excellent bearings for gudgeons or pivots to run upon, and is very durable, having very little friction.

White cast iron, in a recent fracture, has a white and radiated appearance, indicating a crystalline structure. It is very brittle and hard.

Gray cast iron has a granulated fracture, of a gray colour, with some metallic lustre; it is much softer and tougher than the white cast iron.

But between these kinds there are varieties of cast iron, having various shades of these qualities; those should be esteemed the best which approach nearest to the gray cast iron.

Gray cast iron is used for artillery, and is sometimes called gun-metal.

The best and most certain test of the quality of a piece of cast iron, is to try any of its edges with a hammer; if the blow of a hammer make a slight impression, denoting some degree of malleability, the iron is of a good quality, provided it be uniform: if fragments fly off, and no sensible indentation be made, the iron will be hard and brittle.[6]

[6] For more information upon this subject, see Mr. Fairbairn's

The utmost care should be employed to render the iron in each casting of an uniform quality, because in iron of different qualities the shrinkage is different, which causes an unequal tension among the parts of the metal, impairs its strength, and renders it liable to sudden and unexpected failures. When the texture is not uniform, the surface of the casting is usually uneven where it ought to have been even. This unevenness, or the irregular swells and hollows on the surface of a casting, is caused by the unequal shrinkage of the iron of different qualities. A founder of much observation and experience in his business, pointed out to me this test of an imperfect casting.

Now, when iron of a particular quality is obtained by mixture of different kinds, it will be difficult to blend them so thoroughly as to render the product perfectly uniform; hence we easily perceive one reason of iron being improved by annealing, for in passing slowly to the solid state, the parts are more at liberty to adjust themselves, so as to equalize, if not neutralize, the tension produced by shrinking. But, it is clear that an annealing heat applied after the metal has once acquired its solid state, must be sufficiently intense to reduce the cohesive power in a very considerable degree, otherwise it will not be

Experiments upon the Transverse Strength, &c. of Bars of Cast Iron, from various parts of the United Kingdom. (Manchester Memoirs, vol. vi. new series).—EDITOR.

sensibly beneficial.[7] These remarks apply to glass, and to various metals as well as to cast iron.

It has been remarked that "iron varies in strength, and not only from different furnaces, but also from the same furnace and the same melting; but this seems to be owing to some imperfection in the casting, and in general iron is much more uniform than wood."[8] I am glad to find my own experience supported by the opinion of a writer so well known to practical men as Mr. Banks. But the very great strain which large masses of well mixed cast iron will bear, when applied to resist the greatest stresses in mill and engine work, is now extremely well known in this country. Its value was foreseen by our celebrated Smeaton at an early period of his practice. Upwards of forty years ago he combated the prejudices against it in the following language: "If the length of time of the use of these (cast iron) utensils is not thought sufficient, I must add, that in the year 1755, that is, twenty-seven years ago, for the first time, I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the powers, what must happen from the brittleness of cast iron? It is sufficient to

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[7] Dr. Brewster has shown that the mechanical condition of unannealed glass is not capable of being altered by the heat of boiling water. Edin. Phil. Journal, vol. ii. p. 399.

[8] Banks on the Power of Machines, p. 73. See also p. 94 of the same work.

say, that not only those very pieces of cast iron are still at work, but that the good effect has in the north of England, where first applied, drawn them into common use, and I never heard of one failing."[9] These remarks were written in 1782, and the good opinion of Smeaton has been fully justified by the experience of succeeding engineers; the grand and varied works of Wilson, Rennie, Boulton and Watt, Telford, &c., &c., abundantly confirm it.[10]

Yet I must not omit to remark, that cast iron

[9] Reports, vol. i. pp. 410, 411.

[10] One of the boldest attempts with a new material was the application of cast iron to bridges: the idea appears to have originated, in the year 1773, with the late Thomas Farnolls Pritchard, then of Eyton Turrett, Shropshire, architect, who, in communication with the late Mr. John Wilkinson, of Brosely and Castlehead, ironmaster, suggested the practicability of constructing wide iron arches, capable of admitting the passage of the water in a river, such as the Severn, which is much subject to floods. This suggestion Mr. Wilkinson considered with great attention, and at length carried into execution between Madely and Brosely, by erecting the celebrated iron bridge at Colebrook Dale, which was the first construction of that kind in England, and probably in the world. This bridge was executed by a Mr. Daniel Onions, with some variations from Mr. Pritchard's plan, under the auspices and at the expense of Mr. Darby and Mr. Reynolds, of the iron works of Colebrook Dale. Mr. Pritchard died in October, 1777. He made several ingenious designs, to show how stone or brick arches might be constructed with cast iron centres, so that the centre should always form a permanent part of the arch. These designs are now in the possession of Mr. John White, of Devonshire Place, one of his grandsons, to whom I am indebted for the preceding particulars of this note.