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NOTES ON THE USE OF IRON AND STEEL IN BUILDING CONSTRUCTION.

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IN undertaking to read a paper on this subject before you, the author feels some diffidence, knowing that there are many among you possessed of higher attainments, and who are more competent to speak on this subject than himself. Yet he hopes that a few facts obtained from actual experience may prove useful to some, and, if those gentlemen who have had a larger and more varied experience will criticise his remarks in the kindly spirit which is always shown at our meetings, he will feel that he has done some good in being the means of getting them to give their opinions upon an important branch of the ironworking industry. The subject he has chosen is a large one, and it would be impossible to do it justice in the time at his disposal were he able to do so at all, but he will endeavour to point out a few of the advantages and disadvantages attendant on the use of iron and steel in the construction of buildings, and to suggest such remedies to overcome the disadvantages as have occurred to him.

The principal manner in which these materials are used is in the form of columns, girders, floor and roof framing, ties, &c., and also for ornamental purposes, and for external covering to walls, and for ceilings; the stamped iron lathing for carrying plaster-work is also steadily making its way into favor.

The author in this paper will deal with the use of these materials under three heads: (1) Their use in the framework of a building; (2) as clothing to the framework; and (3) in ornamentation.

FRAMEWORK.

Broadly speaking the advantages gained in using iron in this capacity are: 1. Being able to support heavy loads upon comparatively small areas. 2. Facility in building up long lengths of girders or roof trusses of light construction and of small depth, as compared with structures of similar strength made of wood. 3. The non-inflammable nature of the material; and 4th, its resistance to the action of climatic influences when properly attended to, to which might be added also its resistance to the attacks of insects, more especially the white ant, which appears to attack anything in the shape of timber and even lead, though he has never heard of its trying conclusions with iron or steel. Against these advantages we must put as a set off: 1. The liability to twist and damage or even to pull down the walls of a building in the event of a fire if suddenly cooled by the firemen playing upon it, and also its decrease of strength when heated in this manner often causing sudden failure during a fire. 2. The liability to rust when embedded in stonework, causing a swelling and consequent splitting of the stone; and 3rd, the expense as compared with our native timbers. In the case of columns, in which form iron is perhaps the most largely used of any at present in building, we have two things to consider, viz.: First, the importance or otherwise of saving space; and second, which only applies when the columns are used to support wall or portions of the face of the building, we have to consider the architectural effect. If this requires that the column be large enough to enable us to put in stone or brick, it will in all cases be better to use these latter materials, provided always that they are of good enough quality, or it may even be advisable to adopt a plan common in America and to combine the two materials, enclosing the columns in the walls to take the weight of the floors, &c., leaving the brickwork or stonework as a sort of dressing to the column only. There are buildings in which this system has been carried out successfully, in order to gain sufficient window space to allow of shops being placed under a building of ten to twelve storeys high, the lower walls of which, without the use of iron or steel columns, would have been too thick to admit of this. When we come to the interior of a building, the area occupied by the columns is of course an item of considerable importance, and therefore brick or stonework are out of the question, and we have to determine as between iron or wood for our columns. The timber he has chosen for his comparisons is our native iron-bark, being the timber mostly used where strength is required, and which has an ultimate resistance to compression of about 9,300 lbs. per square inch with a modulus of elasticity of from 1,580,431 to 1,960,682 lbs. per square inch. (Professor Warren, *Strength and Elasticity of Timbers in New South Wales*, page 19), and an average weight of 73 lbs. per cube foot. Iron and steel compare with this as follows :

	Weight per cube ft.	Ultimate resistance to Compression per sq. in.	E.
Cast Iron (average)	450 ..	75,000 lb. ..	17,500,000
Wrought Iron ,, ...	480 ...	40,000 lb. ...	29,000,000
Steel (such as is used for building purposes)	— ...	70,000 lb.	35,500,000

Of course these figures can only be taken as approximate, so much depending upon the quality of the material, and in the case of steel upon the hardness and process of manufacture, but they may be taken as sufficiently correct for comparisons.

In designing columns of wood or cast-iron, it is necessary to allow a considerable margin for safety to compensate for defects in the material, and it is usual for these materials not to take more than one-fifth of the ultimate load as a safe working load. When wrought-iron or steel are used this margin can be made considerably less, and one-third the ultimate is the standard usually adopted, so that while cast-iron is weight for weight the cheaper material, yet when heavy weights are to be carried, it will often prove cheaper to use the wrought iron and still more so to use steel. The cost of this latter is from £3 to £4 per ton more than wrought iron, or one-third more, and its strength as resisting compression is one and three-quarter times that of iron, so that it will readily be seen that where other things are equal steel has a decided advantage. One drawback hitherto has been the uncertain quality of the steel produced, and though it is claimed by the makers that the Siemens-Martin process has overcome this objection, the author cannot from experience express an opinion upon this. In ordinary cases in buildings, iron and wood, whether used as columns or girders, are pretty nearly equal in weight for equal strength, but the cost of wood is only about one half that of iron. American practice tends largely now to use steel columns built into the outer walls as mentioned before; the columns in this case are built in segments, bolted or riveted together, and placed in position, and the brickwork is then built between and around them as a filling, merely the weight of the building being taken by the columns entirely. Plate XXXIII., Figs. 7 and 8 show two typical sections of this class, Fig. 8 being made up of 6 lengths of trough iron half-inch thick, being 9 inches external diameter, and the projections at the angles two inches. This column is easily built into a 14-inch wall, and is capable of carrying when built in steel a working load of 125 tons when 12 feet high, the weight of the column being 960 lbs. They are usually made to rest upon cast iron bases made so as to distribute the weight over a considerable area of masonry below. When used for supporting floors only, they are either encased in some non-conducting substance, such as terra-cotta lumber, or are filled in with concrete, or both these measures are adopted at the same time in order to protect them in the event of fire.

Girders.

The most usual form in which iron girders are used in buildings is that of the roller I type, either singly or in pairs, connected by top and bottom plates, and thus forming a " box " girder; but excepting for comparatively light loads or short spaces this is not an economical plan, and it is far better to build up a " plate " or " box " girder in such cases, and so get the thickness of metal proportioned to the strain at the various parts of the girder, where the extra costs of labor does not counterbalance the saving in material. Iron girders are usually employed only where the weight to be carried or the length of span would necessiate an inconvenient size in wood ; or in fire-proof construction, which he will take occasion to mention further on. The rolled *steel* joists now being made have cheapened the use of this class of work, but the difference is still so much in favor of wood as regards cost, that there is very little probability of its taking the place of the latter for a long time to come, excepting for very heavy weights or very long spans. Our hardwoods, or at least the best of them, have such a vitality also that it seems doubtful whether much will be gained by using iron in that respect, providing always that the timber can be kept clear of the white ant. The weight of iron and especially of steel girders will compare favorably with that of ironbark beams. A girder designed to carry safely a load of 26 tons, distributed over a span of 16 feet, would weigh in ironbark 1,687 lbs., with a rectangular section 16 inches deep by 13 inches in breadth; a rolled I beam to carry the same load would weigh 1,440 lbs., and one of steel only 960 lbs., giving a good margin in favour of steel as regards weight. For fireproof construction the objections urged against the use of iron and steel, that it buckles under the heat of a fire, is sought to be overcome by casing in the columns and girders with some non-conducting substance such as terra-cotta lumber, brickwork, cement, &c. As is generally known, iron does not begin to diminish its strength until it has attained a temperature of from 500 to 600 degrees; according to some authorites it increases slightly in strength up to that temperature. Plate XXXIII., Figs. 3 and 4, show an arrangement by which it is proposed to do away with the danger arising from over-heating in the case of hollow columns and box girders. Figs. 1 and 2, Plate XXXIII., represents a section of a column with this arrangement fitted; the column is divided by a wooden partition made to fit fairly well to the sides and reaching to within about 3 inches of the bottom, the base of the column is cast in a seperate piece and so arranged that the bottom can be caulked and made watertight. A discharge pipe is passed through this base, also with a watertight joint, and reaches up to within a inch or two of the top of the column and is secured to one side of the dividing board. On the other side is a pipe for letting water into the column; in the event of a fire taking place, the inlet pipe is opened either by the hand or by a fusible plug automatically, and a circulation of water is established through the column at once sufficient to prevent its overheating. This discharges into the column next below, and so on until at the bottom of the building it finally discharges into a drain. In the case of very high buildings two or three points of inlet could be provided for, as the water might become too hot if made to pass through too many columns. The principle as proposed to be applied to box girders is the same, but these being long in proportion to their depth there is no need of the compartments to ensure circulation, the only precaution to be observed being to have the inlet and outlet pipes both above the level of the top flange of the girder for obvious reasons. That this circulation is sufficient to keep the iron-work cool in the midst of very great heat is seen in the case of water jacket smelting furnaces, where with a temperature high enough to smelt iron inside, one can often place one's hand on the outside without inconvenience; a plug or cock would be required at the bottom of each column to draw the water off, after having been used.

As the cradles usually used to carry the weight of the post above to that below would probably give way, it is proposed in this scheme to do away with these, and to stiffen the parts of the box girder inside where the posts come, until they can carry the weight themselves, and so put all the weight-bearing parts in the circulation. Where practicable it is always a good thing to encase both girders and columns in some non-conducting material, and terra-cotta lumber appears to be as good a material as can be obtained for this purpose. It is especially useful in casing in I beams, which from their shape cannot have the water system adapted to them, but give a good firm hold to the casing material. Figs. 7 and 8, Plate XXXIII., are sections of two columns cased in this way, and Fig. 9, Plate XXXIII., shows the general construction of fire-proof floors in which brick arch and concrete forming the floor in themselves are intended to make the casing to the beam. It will readily be seen that in the event of a fire taking place, there is much in this method of construction that is faulty. The tie rods are exposed, and also the bottom flange of the joists, and would soon become sufficiently heated to materially weaken the floor. This might, to some extent, be remedied by casing these parts with some non-conducting material, although in the case of the tie rods this might be difficult. A mode of construction for fire-proof floors that has many points to commend it is that shown in Fig. 5, Plate XXXIII. The iron rolled into what is known as "trough" iron is rivetted together as shown in the figure, and the floor is thus practically one continuous girder; the hollow portions on top are filled with some light concrete, which can either carry cross pieces to secure a wooden floor to, or can be finished in cement or asphalt. The security of this floor against fire lies in there being nothing inflammable in the materials used, but should anything of an inflammable nature be stacked so that the heat could reach the underside of the underside of the floor there would be a danger of its failing if heavily weighted above. Yet another construction of floor is that known as the "Traegerwelblech," which is merely a very stout and deeply-grooved corrugated iron, the corrugations being in some cases from 3 in. to 5 in. deep. This is either laid flat between the I beams, and covered with concrete, or, which is the better method, is curved, and takes the place of the brick arch in Fig. 9, Plate XXXIII. In some buildings in America the whole of the internal framework is built of steel; built steel columns support steel girders, Plate XXXIV., Fig. 10, which in their turn carry steel joists, from which are turned the arches to carry the concrete floors; the partitioning is done in terra-cotta lumber, which, being light, can be built on any part of the floor as desired; the roof trusses are of steel, and covered with corrugated iron or slate; the ceilings are of stamped iron, or of plaster carried on iron lathing; the staircases are of steel, with slate or marble steps; the outside shell is of brick or stone, and is merely a shell round the internal structure, which is kept perfectly independent of the walls, and the whole aim of such buildings appears to be to use as small a quantity of wood in their construction as it is possible to do. From an engineering point of view, one cannot but admire these buildings, although the feeling is very often that we are quite satisfied that they should be in America and not in New South Wales; needless to say, this class of construction is too expensive to be indulged in here. In the building of roof trusses to cover long spans, we find in steel one of our most valuable materials, but a study of these is enough to fill a book, and he can only just mention this particular use in passing, although it is a subject worthy of a good deal more attention than it gets. A large area of floor space without any columns to impede the traffic is often a necessity, and any improvement by which the roof trusses can be lightened or cheapened is a step nearer to having this class of roof the rule in place of the exception, as at present. The cost of built iron or steel work is a bar to its extensive use in the colonies. The author will now pass on to the clothing of the

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frame-work. In the case of columns, this is often done, as in Figs. 7 and 8, Plate XXXIII; the methods of external covering and partitioning by means of plain sheet or corrugated iron is too well-known to need mention, the iron lathing, already spoken of, is a device to prevent the cracking of the plaster through the wooden laths warping, and is also useful in fire-proof construction. When used in the latter case it is bolted on to T or small channel iron studs and the plaster then put on in the ordinary manner. This is also adopted for plaster ceilings, and wherever lath and plaster work can be used; other forms in which iron is used for ceilings are the finely corrugated and the square sheets stamped in patterns, but these being so thin are only fireproof to a small extent. Iron is also used as a roof covering in the form of tiles, and of wove wire with the meshes filled in with some waterproof substance. Excepting in the ways above mentioned, its employment as a covering material for buildings is but limited, but where great resistance or strength is required, as in military buildings and lighthouses, steel is often used in plates, or any other convenient form, for the outside of the walls of the structures.

Ornamentation.

3. In this department iron has been used from very early times. In modern practice it is largely used for gratings or grilles, gates, railings, finials, friezes, &c., principally in the form of cast ironwork where ornamental design is required. The hammered wrought ironwork is in many cases very beautiful, and in every way superior to the best castings. The delicate finish, play of light and shade, sharpness of outline, and the verrousness of the curves, give it a character of lightness and artistic beauty which can never be attained in castings. It is especially good where richness and lightness of design are required, and some of the finest effects ever obtained in metal ornamentation have been in work of this description. Belgium is the chief centre of its productions and most of the buildings of any note there are decorated with it in places. It is also largely

used throughout the continent of Europe and in England, and is without exception the best form of ornament in metals ever produced. Some very good specimens of this work are made in Sydney. One of the objections to the use of ironwork for outside work in connection with stone or other facing materials is its tendency to rust, unless in such a position that it can be painted from time to time. It is stated that a small percentage of aluminium in cast iron will prevent oxidation under ordinary conditions, but the data on this subject that he can command is uot sufficient to enable him to form an opinion. While upon the subject of aluminium it may be as well to give the pratical results of some tests made made with this metal alloyed with iron and steel. The experiments were made and the results published in 1890 by Messrs. Jno. Langly and Chas. Hall, of Pittsburg, Pa.. and the results are briefly as follows:–On wrought iron it will increase the tensile strength and improve the fibre when added in small quantities; it is also said to render wrought iron capable of being cast, but the report does not give the nature of the metal after the casting has been made. On cast-iron the influence of aluminium is to make white iron into grey by reducing the combined carbon into the graphitoidal state, and to render its texture closer. It is also said to make the metal more fluid, to help in keeping the castings sound and free from blow-holes, and to increase the tensile strength of certain grades. On steel, its influence is the same in effect, the aluminium used in these experiments was from 1-10th per cent. to 2 per cent. It also destroys the hardening action of the carbon in tool steel. In that used for structural purposes, containing about 2 per cent. carbon aluminium will, when added to the extent of about 1 per cent., increase the tensile strength without materially decreasing its ductility, and by its aid thick steel sections that have not been much worked in the process of manufacture can be made to stand a higher tensile strain than they would do without. It is claimed also that it makes cast steel more fluid, and, as in cast-iron, the castings are more solid and free from blowholes. We need a great deal more information upon this subject before we can deal with it in a practical way, but it is always of interest to know what is being done in any direction tending to improve the materials at our command. Time has limited the author to the merest outline of a study which to enter into fully requires the labor of years, and one that should command the attention of all who are in any way engaged in constructive work. He is afraid that he has scarcely done justice to his subject, but he trusts that he may be the means of inducing some other gentleman to give us some more information bearing upon this branch of engineering.