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SOME NOTES ON FIRE PROOF BUILDINGS.

BY JAMES NANGLE.

When the importance of guarding against the enormous damage to property, and the loss of life, occasioned by the ravages of fire is considered, it is a matter for surprise that in the City of Sydney almost nothing has been done in the way of framing laws in accordance with modern practice to regulate the erection of buildings from a fire-resisting point of view. The provisions contained in the City of Sydney Improvement Act, are few, and fail altogether to deal with the matter in a comprehensive manner; and the range of the Fire Brigades Act, while embracing some of the important points connected with arrangement of Public Meeting buildings mainly relates to the equipment, maintenance, and powers of the Fire Brigade service of the City. The matter of providing that the buildings of the City shall be erected in such a way, and of such materials, as will afford the greatest safety from fire, is not one of singular concern, but is the business of the Citizens as a whole, and it is not wise to leave it to the individual to erect a safe building, or not, at his pleasure. Undoubtedly many fine buildings of a fire-resisting character have, during the last few years, been erected in Sydney, and the Council itself is showing the way at the present time, in the case of the City Market buildings, where a most elaborate system of fire-proofing is being carried out; but it is impossible to lose sight of the fact that the worthy examples hinted at are exceptions to the rule. A fire broke out some time ago in a large and very badly planned and built building, and in a short space of time the whole edifice was in flames, and the unprotected iron girders supporting the floors quickly collapsing, brought down the walls, thus endangering life, and adjacent property. Very large fires have happily been rare in the past, but this immunity from disaster has in a great measure been due to the efficacy of the Fire Brigade service, and to good fortune. It is, however, impossible to expect a Fire Brigade service, no matter how efficient, to cope with, and overcome all the dangers arising from badly planned and treacherous buildings; and laws in accordance with experience and modern developments in fire-resisting construction should be framed to regulate City building work. Since, however, these much needed laws are yet of the future, and as so much is left to the Engineer, Architect, and Builder, it may, perhaps, serve a good purpose to discuss some of the points connected with this interesting subject.

The Americans, by whom this question seems to have had special attention, divide the subject into the three following classes:—

(1). First-class fire-proof construction as applied to important buildings of a Public and Semi-Public character, such as Theatres, Hotels, Public Halls, Churches, Block Tenements houses. Office buildings, and large Street business premises; and embraces protection from fire of outside origin, special planning by subdivision into automatically closing isolated divisions as regards portions of the building, Stairs, and Elevators; and the best possible kinds of fire-resisting supports, floors, and roofs, with the inclusion of as little wood as possible.

(2). Mill construction for Factories, and warehouses, having protection from outside fire; all floor, and roof timbers of at least 80 square inches in section; all flooring not less than 3½ inches thick; and all wooden columns not less than 100 square inches in cross section; subdivided into easily isolated divisions; and all Elevators, and Stairs closed in with materials of strong resistive power.

(3). Slow burning construction for such buildings as small business premises and dwelling houses; provides for as much protection from adjacent outside fire as can be got by attention to parapets, roof coverings, and windows; complete division in the case of Terrace arrangement; of as much as possible of material such as plaster on metal lathing for ceilings, and partitions, or metal coverings for ceilings; the absence of all wood lining; and the enclosure of the Stairs.

Of course, the principle underlying the whole of the three divisions is the same, namely, that of getting a building which will offer resistance to fire, the difference only being that in the case of the first class, the vital importance of keeping off disasters from fire necessitates provision regardless of cost, while in the case of the slow-burning or private dwelling class, the property and life at stake are not so great, and cost is a matter for consideration, therefore, while in the first case every chance of improving the resistance should be eagerly sought for by Architect and Owner, in the third class it is only possible to adopt measures of an inexpensive character; but before passing on it is not too much to say that in the third, as above classified, it is within the power, and is the duty of the Architect to have all the ordinary precautions taken, that is to say, a dwelling may be made slow-burning without seriously touching the pocket of the Owner, hence there is not likely to be much opposition, and consequently the designer is to blame if it is not attended to.

There are many matters connected with the laying-out or planning of a building, which from the fireman's point of view, require attention, and one of the first duties of the Architect when sketching out the general scheme of the arrangement of the building is to provide for reasonable means of ready access to all parts thereof from the streets, and to so arrange, if it is at all possible, for completely isolating the various portions of the building. Innumerable cases exist where to get at a fire, say, in some upper part of the building, it would be necessary for the firemen, after getting in at the only possible entrance—in the front—to go right to the rear to reach the Stairs, and so cause delay, and also, which is far more serious, the chance of the only retreat of the firemen being cut off by the rapid descent of the fire in the front. Amongst firemen there is always a desire to have the stairs as near the entrance as possible. Again, where there are strong cross walls with doors of fire-resisting material it is possible for the firemen to isolate or cut off the seat of the fire from the other portions of the building. Of course, there are some cases where it is impossible to avoid having very large areas of floor space, as, for instance, large store-rooms, and large indivisable rooms are required at times such as in the case of the Auditorium of a Theatre. In such cases as these, however, the least that should be done would be to provide means of cutting off from adjacent portions of the building. In every Theatre the Auditorium should be protected against that part of the building—the stage—which is the most likely to be the seat of fire origin, by an easily worked and effectively fire-proof curtain. It is a question whether there is one of the Sydney Theatres so equipped. In buildings containing materials of easily burning character, divisional arrangement of the whole is a matter of urgency, and these compartments should be accessible only through openings guarded by automatically closing fire-proof doors. Doors to fulfil such requirements are easily arranged for, by being run on slightly slanting rails, and held, when open, by catch-back fastenings of low fusion materials. The practice which is largely followed in warehouse construction of having large openings, or well-holes in the centre of each floor and under a large glass roof, offers splendid chances for the fire to jump from one floor to another, and quickly outclass the firemen in the race for mastery. Such an arrangement also creates a mighty draught in the very centre of the building, the effect of which on the fire is irresistible. The modern lift service, without which no large building is now complete, is often enough the cause of much trouble in times of fire, for the well-hole running from bottom to top of the building, unless completely cut off from each floor, acts as a draught-causing medium in the same manner as the smoke stack in a Hoffman brick kiln. To avoid dangerous results, it is necessary to enclose the well-hole with brick walls, with iron framing and terra-cotta filling, or with some equally effective fire-resisting material, and the entrances thereto should be protected with the automatically-closing fire doors before referred to.

The importance of having good strong walls, built of hard bricks, or of some equally incombustible material, and possessing enough of stability to stand independently of the floors and roof, is equally applicable to all three classes. Bricks, if used (and it is difficult to find a much better material, if of good quality), should be capable of standing heat. Those of poor quality, containing alkalies or iron in excess, or containing too much pure clay, fuse or warp and twist under the influence of heat, and cause the walls to bulge. It is essential, especially in the case of City buildings, that the walls be carried up on all sides past the roof, for overhanging eaves no matter how Architecturally pleasing, are a most fruitful cause of fire spreading. In cases where the floors are not of fire-proof materials, it is necessary to have them so connected as that in the case of a collapse they shall not pull the walls down. The practice, which is common, of securing the joists to plates, and to each other by means of iron straps built in the wall, is to be condemned, for under such conditions it is impossible for the floor to collapse without causing serious damage to the walls.

Piers and columns perform, in a greater or less degree, according to the surrounding circumstances, important functions in the maintenance of stability in building work, and require to be of fire-resisting material, or if not, to be well protected. Piers built of bricks, or some of the stones, such as hard sandstone or magnesian limestone, are reliable, when, as weight bearers, they are subjected to heat, provided water is kept from them, but the exigencies of modern planning cause such piers, in many cases, to be rejected, on account of their size, and iron is used instead. From the constructive point of view, there is, of course, nothing whatever to urge against the use of iron and steel for columns and girders in building work. The danger, however, of relying on unprotected iron or steel columns is well known, but there are, nevertheless, many places in Sydney, for instance, where such columns, wholly unprotected from possible fire, are supporting heavy walls.

With a view of accurately gauging the weakness of iron and steel columns under load and subject to the influence of heat, a series of tests were, during last year, made in America, under the best conditions and most expert supervision.* Among the tests recorded there is one on a steel z bar column, 14ft. 1⅛in. long and cross-section area of 14.15 square inches, which was calculated to have a breaking strength of 270 tons. This column, when subjected to a temperature of 1125 degrees Fahrenheit, began to yield with a load of 84.8 tons (the temperature was gradually increased from 80, and the test only lasted 23 minutes). Another record shows a cast-iron column, 13ft 1.16in. long, 8in. external diameter, 6in. internal diameter, and calculated breaking strength of 402 tons, yielding with the load of 84.8 tons under a temperature (which

*See report presented by special Committee to the tariff Association of N.Y. Architectural League of N.Y., and the American Society of Mechanical Engineers.

was also gradually raised) of 1137 Fahrenheit. In both the cases noticed above, the 84.8 tons was put on quickly, during a low temperature, but it is significant that during one of the tests, a delay with the hydraulic apparatus prevented more than 48.06 tons being put on before a temperature of 1210 Fahrenheit was reached, when the column began to yield, a result which makes it appear probable that the columns in the two cases noted would have failed just the same at the high temperature with a lighter load. It is thus quite clear that fire about iron or steel columns upsets all calculations based on the assumption of normal conditions, and that they are quite worthless when subject to heat. Consequently it becomes a matter of absolute necessity to provide for protection, if the calculated working strength as a column, pure and simple, is to be relied on.

The best method to prevent the heat from getting to the iron or steel is to build porous terra-cotta in the form of suitably shaped hollow blocks round, but at a little distance from the column. These blocks are allowed to touch the columns as little as possible, but are secured thereto by stout copper wire anchors, and are held together by mortar.

Several severe tests, under actual conditions, of this class of fire proofing for columns have accidentally occurred in burning buildings, and the results have been most satisfactory; the column being in no way damaged, nor their supporting powers interfered with. The terra-cotta is, of course, covered with an external coat of plaster.

Among other methods of protection may be noticed that of surrounding the column (leaving an air space) with wire netting, or metal lathing, which is secured to the column by metal connections, and covered with plaster. In some cases, two coats of plaster and wire lathing are used. This method, if carefully carried out, is fairly effective, and is permitted in some of the modern building Acts of old world cities.

In buildings coming under the 2nd and 3rd classes, it is not generally possible on account of cost to have iron columns properly protected, and the problem presents itself of finding some alternative method of supporting the floors or walls safely as regards fire dangers. The stout resistance against fire offered by timber of large cross sectional area, has been recognised for a long time, but there was a difficulty to get timber of great compressive resistance to serve in carrying heavy loads.

Our own well-known iron bark is, however, a timber capable of standing great compression, and when in large pieces, is slow to burn. An excellent illustration of its behaviour, under the influence of severe fire, was afforded in the case of the large fire at the Federal Timber Coy.'s Works at Rozelle Bay, Balmain, during last year. The fire, which lasted for 2½ hours, occurred in a large building used as a saw-mill and joinery works, in two stories—the upper one supported on iron-bark storey posts or columns. A specimen was exhibited on the table of a portion of one of the columns, which was situated near to a saw bench of cast-iron. The intensity of the heat may be estimated by the fact that the top of the saw bench was melted. It was seen that the column was not much damaged by the fire, being charred for only one inch in from the original surfaces, and the inner portions seemed to be as good as ever, so that only a comparatively small percentage of the carrying power was lost.

This test brings out vividly what has all along been the experience of firemen, and there can be no doubt that where the breaking strength will, under ordinary conditions, suit the requirements of loading, as in the case of floor supports in large buildings, and for supports of front walls of ordinary business premises, iron-bark columns and girders are preferred to those of unprotected or imperfectly protected iron. The eminent American Architect (Mr. E. Raht) was not slow to recognise the value of this timber, and used it for columns and girders to support the brick arch and steel joist floors of the building adjacent to the magnificent Sydney Office of the Equitable Life Insurance Coy., U.S.A., and now occupied by Messrs. Nicholson and Coy.

Every thing that has been written concerning the danger of having unprotected iron columns applies also to unprotected iron girders, and in no case, where important loads are borne, should they be allowed to pass without being covered with terra-cotta, or at least, the metal lathing and plaster. A very good example of the manner in which girders should be protected occurs in the case of the lower girders spanning the interval between the trachyte piers along the facades of the City Market buildings. The girders in question are covered completely with porous terra-cotta hollow blocks, together with cement mortar; and as experience has gone to show, should be quite isolated in the event of fire.

The porous terra-cotta referred to, as suitable for columns and girders, is fire-clay (or fire-clay and ordinary clay together) mixed while wet with sawdust or fine-ground coal, which, during the fireing in the kiln, is burnt out, thus leaving the terra-cotta full of minute holes, and so greatly reduces the weight, and renders it not so liable to crack if, when heated, it is sprinkled with water.

There are many methods of building fire-resisting floors, but the best seems to be that of flat arches, formed with hollow blocks of the porous terra-cotta, with steel T beams, kept in position with tie rods for abutments. At first the blocks for these arches were made with the voids at right angles to the line of thrust, but, as will be obvious, much of the material under such conditions was useless, and it soon became evident that to have all the material available for arch work, the holes should run through each block in the same direction as the line of thrust. This was amply demonstrated by some tests on the two kinds of arches made during the year 1892, in America, by a committee of well-known Architects, which conclusively shows that the arch with the voids at right angles to the abutment was much stronger than the arch with void parallel to the abutment.

The chances of a better fit (for they can be cut with a saw), and the simplification of the method of covering the flanges of the T beams, together with the fact that these arches have several times successfully stood, observed severe tests of alternate fire and water, are additional reasons for selecting this form of fire-proof floor as the best.

This description of arch was used for the floors of the Sydney Office of the Equitable Life Insurance Coy., U.S.A., and is also being used for the floors of the City Market Buildings.

A practice much in vogue at the present time in Sydney is to lay concrete on sheets of curved corrugated-iron or steel, which rest on T beams for abutments. It would appear that by this kind dependence is placed on the concrete rather than the metal, which is left exposed on the under side, or for decorative purposes covered with zinc ceilings. The two well-known systems, i.e., the Monier and the Melan, also depend upon the concrete for resistance to heat, and are superior to the ordinary concrete arch, only on account of their increased carrying powers, owing to the embedded metal. All these, together with the ordinary concrete arch, have the defect of a curved under surface, and to obtain a flat surface a false ceiling is necessary, a by no means satisfactory adjunct, even from the fire point of view, for such is often enough made of light, inflammable material. The efficacy of concrete as a fire-resisting material must also come under review, for it is questionable if it is altogether as reliable as its general use would lead one to believe it is. The Portland cement compound, formed of crystals of hydrated aluminium silicate, and calcium silicate, cannot but be affected by the action of the heat, which tends to drive away the water of crystallisation, and a loss of strength must ensue. A comprehensive series of tests were made some time ago in Canada* on briquettes made of Portland cement, neat, and with sand, which, after being subjected to great heat, showed loss of weight and serious loss of strength—results which make it clear that concrete floors cannot be regarded as safe.

In mill construction, a very effective method, which it is almost impossible to burn through, is to have the floors all joists, so to speak; that is, to have the floors composed of timber, the size of ordinary joists, close together and bolted.

For buildings of the third class, it is desirable to have at least joists of fairly heavy cross-section, with mortar pugging, whilst wood ceiling linings should on no account be permitted. The ordinary plastering on metal lathing, and the sheets of ornamental steel, now being used for ceilings, are useful means of keeping back the fire, for a little while, and can be used with advantage in dwelling houses.

Partition walls for first-class fire-resisting buildings are now being built with porous terra-cotta hollow blocks, about 3in. or 4in. thick, set in cement, and certainly, for lightness and stiffness, nothing better could be desired. Permitting, as they do, on account of their lightness, of being built across floors of ordinary stiffness (especially those of terra-cotta arches and I beams), without girder provision they are very convenient, and are about the best that can be got to resist fire. For buildings of the second and third classes, they can also be used, for they are not expensive, and it is safe to predict, in the future, such partitions will supersede the, now, too commonly used wood stud and plaster partitions.

It is impossible to conclude these desultory notes without some reference to the importance of having fire-resisting roofs. For buildings of the best class, the roofs should be no

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*See papers of Eng. Soc. School of Practical Science, Toronto, Canada. Paper published in American Architect and Building News, 1896.

less capable of standing fire than any other part; and in all buildings provision should, at least, be made in proportion to their importance. It seems that with first class structures, it would be best to have the roof, where possible, composed of I beams and terra-cotta arches, similar to the floors, but graded to allow of necessary fall, and covered with concrete, or other suitable composition. Failing such an arrangement, the roof might be built of iron, of the usual L. and T. section, with terra-cotta hollow book tiles in between the rafters and protecting the vital parts with an external covering of corrugated metal, or in the case of an iron roof to have a flat suspended ceiling composed of thin terra-cotta book tiles, supported on and protecting iron or steel of T section. Again such a suspended ceiling might be attached to a roof composed of timber scantling. For those buildings coming under the Mill construction class, very heavy roof timbers with metal covering is the most convenient method. The glass skylights so commonly used are very troublesome in time of fire, on account on the readiness with which the glass breaks at a comparativelv low temperature, and the openings so made creating a draught help the fire. The glass now in the market, with a wire-netting of fine mesh embedded in it, does not so readily break, and is very suitable for skylights, and even for upper floor windows.

Mr. Fitzmaurice said that it would be interesting to get Mr. Bear's opinion on a question raised by the author with regard to making special arrangements for preventing the spread of fire from the stage to the auditorium of theatres. The author made some reference to the closing of doors automatically by catches which were set in motion with metals of low-fusing properties. He recollected witnessing an experiment with some automatic fire grenades at the Metropolitan Fire Station a few years back. These grenades were supposed to be thrown down into the fire, and as soon as a metal, which fused at a very low temperature, had released a string, the liquid was precipitated into the fire. These were supposed to work automatically. For the purposes of the experiment, a small weather-board building was erected in the yard of the Station, and set fire to. Then the automatic grenades were thrown in. Some went off; others didn't. Then more grenades were thrown in; but they didn't act and ultimately the fire had to be extinguished with hoses. It seemed to him that the same objections held good in the case of all these automatic contrivances. First, the fire has to get to them, and when it does get to them they don't always go off.

Mr. Nangle: The automatic-closing doors were mentioned as being applicable in division walls, not in theatres.

Mr. Bear: As regards theatres, there is only one way of dividing them, and that is with an iron curtain, worked by hydraulic power. Asbestos curtains are unreliable.

Mr. Cruickshank said that the subject under discussion was not quite in his line, but, at the same time the author was to be congratulated on the very interesting and enjoyable paper that he had read. It was only too evident that a large number of buildings in Sydney had been, and are being built, in which sufficient attention has not been given to the importance of providing against fire. In his opening remarks, the author had directed attention to this fact, and however much those interested in building differed among themselves as to the materials and construction, still there was no eluding the fact that in this great city many buildings were in such a state as to be practically unprotected from fire. The author's remarks with regard to the use of terra-cotta seemed to him to be the most interesting in his paper. A terra-cotta division wall running across a room would be so very light, and yet so very strong and stiff, that it probably would, as the author had stated, ultimately supersede the old-fashioned methods of construction partitions. With regard to the melting of the iron of the machines, some specimens of which the author had produced, he noticed that there had been no mention in the paper of what the probable temperature of the fire might have been. They knew that in an ordinary furnace, with a natural draught, the temperature would be about 2000 deg. F., and with a forced draught equal to a column of water about 3in. high, the temperature of the furnace would be about 3000 deg. F. In some of the mail steamers with forced draughts, the temperature of the furnaces are not only equal to, but above the melting point of wrought iron, and it is very interesting to notice that the natural timber of this country, such as iron-bark, would stand when iron and steel melted. In conclusion, he could say that he had enjoyed the paper very much, and he considered the best thanks of the meeting were due to the author.

Mr. Bear said that, unlike Mr. Cruickshank, the subject was in his line—it was his business, in fact, and he enjoyed it immensely. For the last 30 years the subject had had his attention, and he should, by this time, know something about it. To begin with, he would like to endorse the author's remarks concerning the need for legislation on this subject. There was no doubt whatever that in Sydney they required a Building Act, with stringent fire provisions. Speaking for himself, he had done all he possibly could, but no one would move. They could not expect to have a code Napoleon in a young country like this, but he maintained that they might advantageously take from it parts relating to this subject. They wanted Acts like those of Glasgow and Edinburgh. Here there was too divided an authority. First you have the City Council, then the City Building Act Committee, then the Government Architect, and afterwards the Colonial Secretary's Office—all have a finger in the pie, until ultimately when the building is finished it is, from the fireman's standpoint, only ready to be condemned. One theatre, for instance, has been built with 12in. steps, having a 6½ft. rise from the street. If, unfortunately, there is ever a fire there, people will know it.

Mr. Pritchard: The Central Hall is a very dangerous place in that way.

Mr. Bear: He did not want to mention the names of the different places he had particularly in his mind, but in some of them, if a fire ever broke out, there will be great loss of life. He, himself, was supposed to be an Inspector of Theatres, but what was the good of condemning places if you haven't the authority to see the matter through. He reported one theatre in particular; but what was the use? They persisted in having doors 3ft. 6in., instead of 4ft., and they've got them. The sooner some effective legislation was passed to deal with this state of things the better for everybody.

The President, after expressing himself as very pleased with the author's paper, said with regard to terra-cotta itself, there could be no two opinions as to its value as a fire-resisting substance. Beyond doubt it was the coming thing. You could do almost anything with it that you could do with timber. He had heated it in a forge to a considerable heat, and then plunged it into water, but it remained intact. A remark had been made with regard to fire-proof curtains. He had an idea that it was compulsory for every theatre to have fire-proof curtains.

Mr. Bear:—No it is not. There is practically no Act to deal with the matter.

The President:—The reason he put the question was that some time ago down at the Haymarket, a small theatre was erected, and he knew that pressure was brought to bear upon the proprietor of that theatre—in fact he was compelled to put in an iron curtain. With regard to the Building Act, it was quite time they had a change. He hardly thought that it was the duty of aldermen to draft a Building Act, nor did he think that the best men were the architects. Men like Mr. Bear, who see buildings on fire and note the results were better qualified to advise on the subject than the majority of architects. From his own experience of the present Building Act, he could say that there was one clause which was particularly obnoxious, and that was the one which required that a certain description of building should be erected—merely for the sake of appearance—when another and cheaper description of building would do. In conclusion, he would say that the paper was most opportune, and stimulated interest in a subject which badly needed attention.