DESCRIPTION OF A SYSTEM INTENDED TO GIVE A GREAT SECURITY TO BUILDINGS IN MASONRY AGAINST EARTHQUAKES.

Abstract from a paper by M. J. LESCASSE, Mémoires de la Société des Ingénieurs civils. April 6th, 1887, page 212.

The question of earthquakes has been, up to the present, and with reason, seriously studied by builders in .countries, where such phenomena are frequent, and in Japan it is generally believed that timber constructions resist earthquakes better than buildings in masonry.

We are not quite of this opinion, as it has aways seemed to us that buildings in masonry with very thick walls, and composed of materials of good quality and solidly bound with the wood work of the floor and roof, offered the same security against earthquakes, being besides more durable than Japanese timber buildings. Yet, as the countrary opinion has up to now prevailed in Japan, we have believed it necessary to look for the means of obviating this so-called want of solidity, and we hope to have found a solution, simple, efficacious, and economical, which will enable us to render buildings in masonry incontestibly more resistant than the best timber constructions.

In consideration of the more and more noticeable sacrcity of timber and of the extension given in Japan to the manufacture of bricks, the cost of masonry buildings is diminishing every day, while that of timber constructions increases. The most serious obstacle against the adoption of brick buildings is therefore now only the belief that they do not offer sufficient security against earthquakes.

However, it would be dangerous to try to diminish these differences of price by employing in brick buildings materials of inferior quality or by reducing the thickness of the walls. Economy would be also unreasonable if used to suppress the most efficacious means of binding the walls together and connecting them with the timber-work. In both cases the consequences resulting from this false economy might be fatal. When masonry constructions are built in a country where earthquakes are to be feared, it seems to be absolutely necessary to *build well*, if we wish to be sure of obtaining a greater security than in timber constructions.

For a long time and in different countries it has been attempted to increase the security of buildings in masonry, without, at the same time, very much increasing the cost. We know several systems of iron trussings, bands, and tie-rod, the advantages of which have been more or less proved. At the same time, we have sought, as other engineers and architects have probably done, to make in masonry buildings the sills and the principal posts, either of sheet-iron, or of iron of special form or of cast iron, and between these to build with stone, bricks, or béton.

Finally, I had the following idea, the simplicity of which is perhaps its greatest merit, and which is specially to be used in stone and brick constructions.

Suppose a certain number of bricks be put one over the other, in the same manner as is customary in masonry walls, but dry and without mortar. Now if the table on which this small wall rests be shaken, it is evident that the bricks will fall down in every direction. But if these bricks are strongly tied together by a string, an iron wire or band, is it not true that there will be no disintegration of the pile of bricks or of the wall, and that if they fall, they will fall as one piece, either to the right or to the left, that is to say outside or inside of the building to which this small wall is supposed to belong. The whole new idea is in this, and it is only a question of applying the same to building.

Considering the ordinary thickness of the masonry walls, we can imagine a part of a wall having the height of a storey and about the same width, as being a pile or block of bricks or of other materials, which can be strongly tied together, and consequently, absolutely consolidated from the standpoint of the disintegration of materials, as we have already described for the pile of bricks. Evidently all the ad joining parts and finally all the walls of the buildings will be under the same conditions.

If we suppose now that all these different masonry blocks or piles are tied together, we shall have a construction as homogeneous and resistant by itself as any other masonry building, but to which we shall have to add a means for resisting rupture equal to the force of the irons which have been employed as ties.

Our principle therefore could be formulated as follows:— *To tie the masonry in piles or blocks, connected together, so neither the materials can be separated nor the walls broken.*

It remains therefore only to support the walls against falling inside or outside of the building.

The most simple and rational way to do this, seems to us to be the employment of strong timber or iron frames, which have to rest on the projections formed by the difference of thickness of the walls at the different storeys, and solidly connecting the principal pieces of timber work of the floor and roof. The walls must be always strongly connected with the different frames and principal pieces of timber-work, as well as the frames being solidly tied together, if there are several party-walls in every storey. Should the great extension of the walls render it necessary, we could complete the rigidity of the sides of the frames by means of iron ties (rods). We have made use of these different means in almost all the masonry buildings, which we have constructed in Japan.

With regard to this new idea, it seems to us to be capable of very economical application, because the iron is employed there under conditions most favourable to the economy of the material, that is to say, by exposing it to tensile strain. In fact we know that an iron rod of a section of one square centimètre, bears, with a very great security, a minimum load of 1,000 kilos. and that the breaking of this rod can, according to the quality ofthe iron, take place only under a load of 4-6,000 kilos.

We consequently see that, with irons of slight dimensions, we can increase in a very great proportion the solidity of masonry buildings against the ruinous effects of earthquakes.

Application.

It remains now to describe how our system must be used.

Description.

On the foundation, a little over the soil, in a groove expressly made in about the middle of the width of the course, bars of flat iron (*A*) will be placed, which are tied together by means of rods of round iron (*B*), going in the holes (*a*), made by forging, and which are at the extremities of the flat iron bars (*A*).

The head of the vertical rods (*B*) is also forged and lies, when the rods are in position, under the horizontal bars (*A*).

The section of the flat bars (*A*) is equal to that of the found rods (*B*), and the length of the last corresponds to the height of the storey. The maximum length of the bars (*A*) will be also made nearly equal to that of the rods (*B*), in order to obtain nearly square blocks of masonry.

The upper part of the round rods (*B*) is cut in order to receive a screw or pierced to receive a key; and once placed they are kept perfectly vertical.

Then masonry will be constructed as usual over the bars (*A*) and round the rods (*B*), taking, however, care to employ the best materials in the points of joining of the irons, that is to say, at the angle of the blocks, and also to well cross the joints of the masonry around the vertical rods.

When the masonry has reached the height of a storey the masonry blocks will be closed by other bars of flat iron (A'). These bars (A') have the same section as those of (*A*), but instead of only one hole at each of their extremities they have two holes (a' and b), one of which (a') serves to receive the upper part of the rod (*B*) of the ground floor, and (*b*) for the rod (B') of the first storey.

Should the block not be closed by means of a key, the extremity of the rod (*B*) will be solidly bolted with a sufficiently long nut. The rods of the first story (B') are kept in a vertical position and the masonry work is commenced in the same manner as in the ground floor.

It must be understood that our system can be applied to as many stories as are required, and finally when we arrive at the top of the masonry walls the blocks are closed by flat iron bars (A''), the extremities of which have only one hole (b').

Expansion.

Although the expansion is not of great importance, nevertheless it is good to take it into consideration.

We can presume that in the interior of a masonry wall the difference between the extreme temperature will be never more than 10° to +30° centigrade; say 40° centigrade.

The expansion of iron averaging 0,0000125 per one mètre of length per degree, will therefore give an extreme expansion of the bars and rods of the ground floor, which have a maximum length of 4 mètres.

$0^m.0000125 \times 40^\circ \times 4^m = 0^m.002$ milimètres, say, a maximum expansion of only 2 milimètres, but which ought to be taken into consideration while arranging the lengths of iron, their joining, and their fastening.

The effect due to the expansion can, however, be annulled by a little play equally distributed, and by the employment, for instance, at the extremities of the vertical rods of small cauls of fir wood, or by any other means.

Determination of the Dimensions to be given to the Irons.

SECTION OF RODS OF THE GROUND-FLOOR.

We propose to give to the irons such dimensions as to be in proportion to the maximum resistance against breaking, or, what means the same thing, to the resistance against cracking of the parts of the masonry forming a complete block, viz., a block which does not include doors and windows.

If therefore we have in the ground floor iron rods and bars of 4 mètres length, and external walls of $0^{m}.40$ (four centimètres) thickness, the section of one of the complete masonry blocks will be:

$$4^{m} \times 0^{m}.40 = 1.60^{sq.\ met.} \text{ or } 1{,}6000.000^{sq.\ mm.}$$

We admit then that a crack is produced in the complete masonry block and suppose this masonry work to be of bricks of ordinary quality and of mortar composed of fat lime and sand.

According to Claudel, the load of rupture of this brick being $0^{k}.08$ per square milimètre of section and that of the mortar $0^{k}.04$ in proportion to the joints of the masonry, we will take as a maximum resistance against breaking or cracks, an average of these two quantities viz.:

$$0^{k}.06$$

We shall then have for the effort of rupture of a complete masonry block:

$1{,}6000.000^{sq.\ mm.} \times 0^{k}.06 = 96{,}000$ kilos, a quantity which represents the maximum resistance against cracks of a complete block of ordinary bricks.

We suppose now that we intend to double this maximum resistance of a complete block. To do this as two rods or bars are acting together, we have only to calculate the section of an iron rod capable of resisting half of the above load, say :

48,000 kilos.

The load of breaking the iron, which is convenient to us is about 40 kilos per square milimètre of section :

therefore $\frac{48.000}{40} = 1.200$ square milimètres, for the iron section capable of a resistance equal to that of the masonry which we have supposed, which corresponds to a round iron of a diameter of 40 milimètres.

NOTE.

We must note that in reality we have more than doubled the resistance of our walls, because we have operated on a complete masonry block, while the greater number of the blocks contain doors or windows.

The section of wall in this place will be not more than : $(4^{m} - 1^{m}.80) \times 0^{m}.40 = 188^{sq.\ met.}$ or $880.000^{sq.\ mm.}$

But in practice, we must not suppose the masonry to have a permanent resistance of more than $\frac{1}{10}$ of its load of rupture.

We therefore have as coefficient of resistance :

$$\frac{0^{k}.06}{10} 0^{k}.006$$

consequently :

$$880.000^{sq.\ mm.} \times 0^{k}.006 = 5,280 \text{ kilos.}$$

These 5,280 kilos represent, therefore, definitively the exertion of resistance of which one of our masonry blocks pierced by a window is capable.

We must also in the construction not expose the iron, which we have taken, to a permanent load of more than 10 kilograms per square milimètre of section ; say $\frac{1}{4}$ of its load of rupture.

Practically the resistance of iron of 40 milimètres of diameter will therefore be :

Section in square milimètres of the iron of 40 milimètres of diameter: 1.256 square milimètres:

1.256$^{sq. mm.}$ × 10 kil. = 12.560 kilos for each of the two rods or bars which act together, viz., for the 2 rods = 25.120.

From which it results that we have really increased the resistance of the walls of our house against cracking in the proportion of:

5.280 : 25.120
or 1 : 4.75

that is to say, we have almost quintupled the resistance of our walls against earthquakes (at least where there are doors and windows).

SECTION OF THE RODS OF THE FIRST STOREY.

We will also find what the section of the irons for the first storey ought to be, in order to double the force of resistance of a complete block:

$$\frac{3m.\ 40 \times 0m.\ 35 \times 0^{k}.06}{2 \times 40^{k}.} = 892^{sq.\ mm.} \text{ of section.}$$

3^{m}. 40=length of the rods or height of the storey.
0^{m}. 35=thickness of the walls of the first storey.
0^{k}. 06=load of rupture of the masonry.
2=number of rods or bars acting in the same direction on the same block of masonry.
40^{k}. =load of rupture of the iron.

892 milimètres section of an iron rod or bar; which correspond to a round iron of 34 milimètres in diameter.

SECTION OF THE BARS OF FLAT IRON.

The section of the bars of flat iron must, as we are making the masonry of almost square blocks, be equal to that of the round irons; it is therefore easy to determine their dimensions, width, and thickness.

Thus, in the example which we have given, we will choose for the bars of the ground floor, iron of $600^{mm.}$ by $20^{mm.}$:

$60 \times 20 = 1.200^{sq.\ mm.}$ of section (corresponding to the round iron of 40 milimètres of diameter), and for the flat bars of the first storey, $50^{mm.}$ by $18^{mm.}$

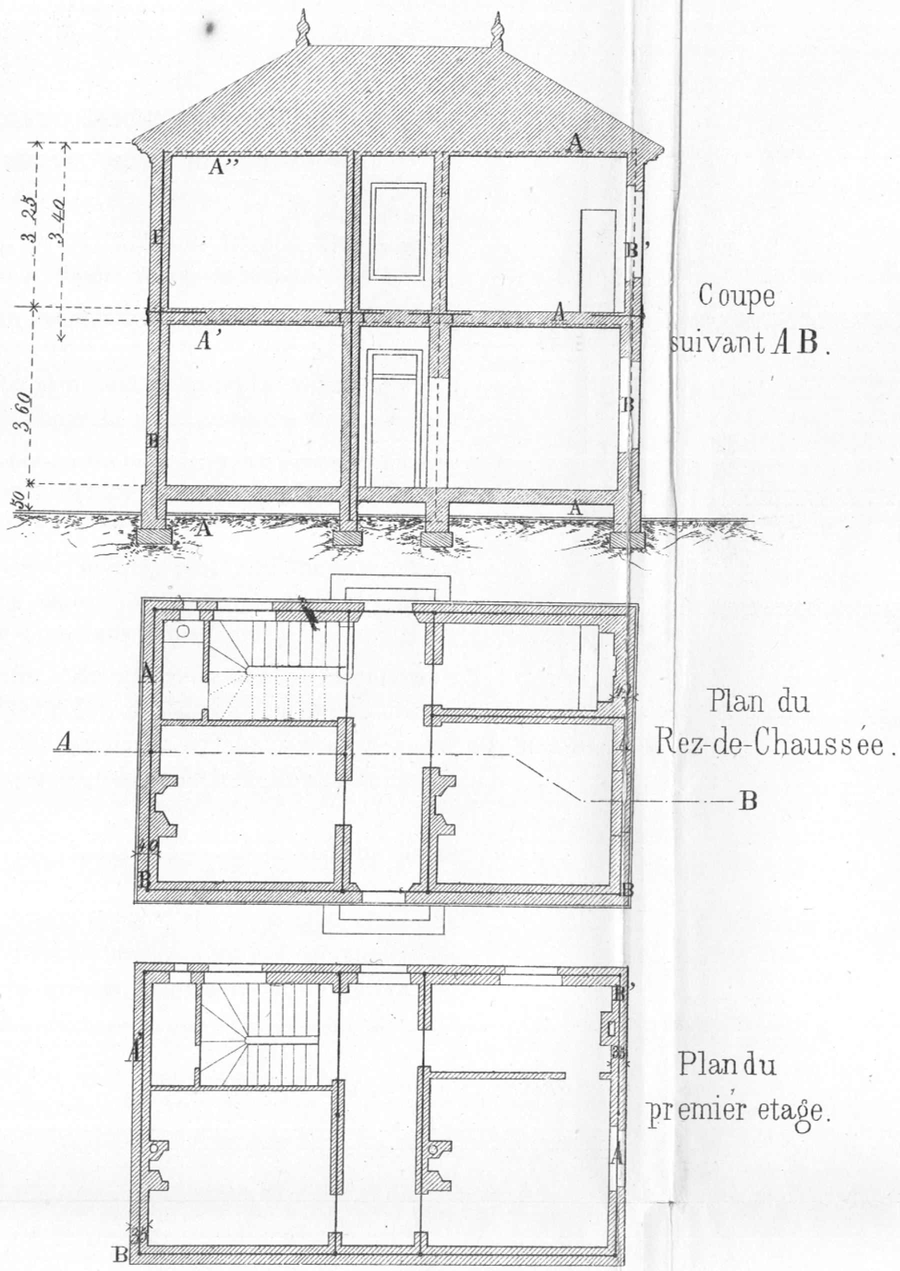
$50 \times 18 = 900^{sq.\ mm.}$

(corresponding to the round iron of 34 milimètres diameter).

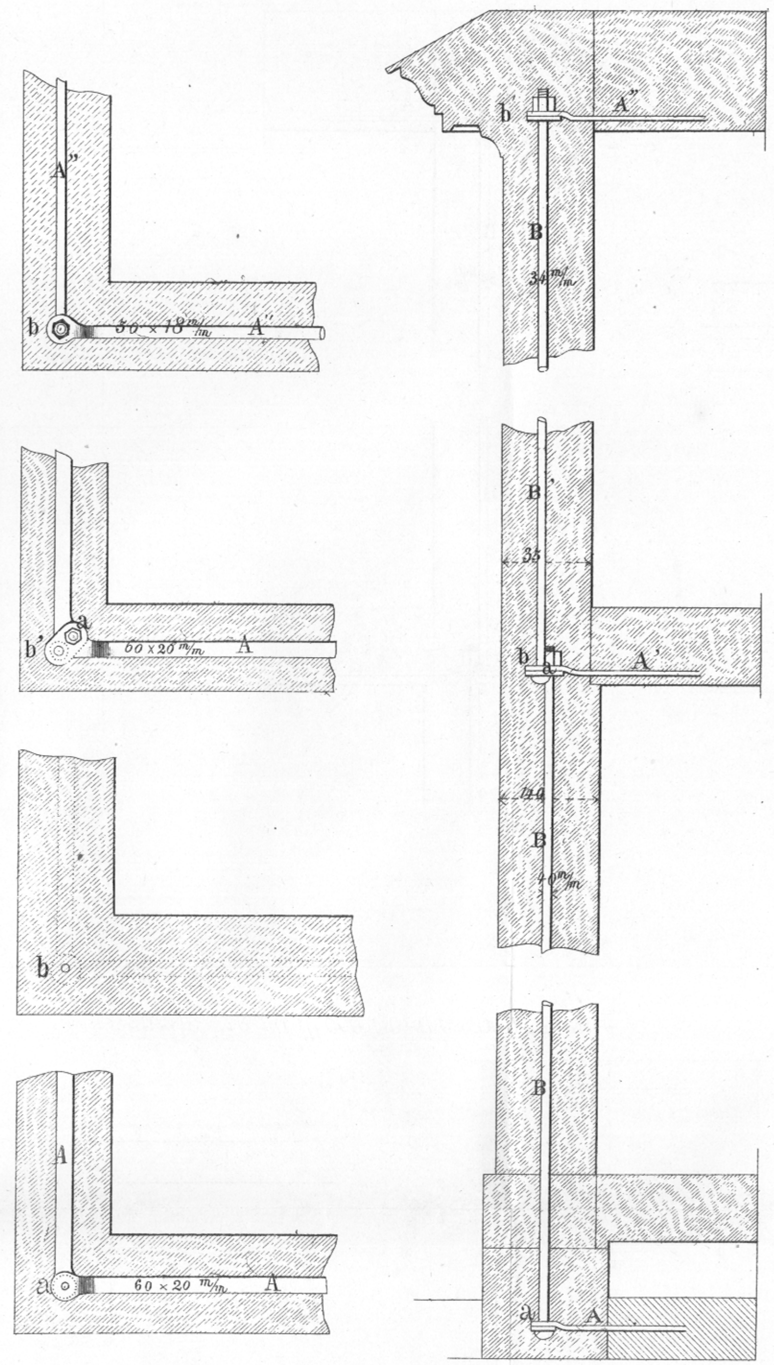
NOTE.

The section of the irons of the party-walls could be equally calculated proportionally to the section of those walls.

CONSTRUCTIONS EN MAÇONNERIE, AU POINT DE VUE DES TREMBLEMENTS DE TERRE



Echelle 1/200 ou 2 centimetres pour métre.



Echelle 1/40 ou 10 centimetrés pour métre.