

PATENT SPECIFICATION

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(54) IMPROVEMENTS RELATING TO CONCRETE SECURITY STRUCTURES

(71) We, CHUBB & SON'S LOCK AND SAFE COMPANY LIMITED, a British Company, of Wednesfield Road, Wolverhampton, Staffordshire, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

Concrete used in the construction of strong-rooms and similar security structures has to be capable of meeting particular stringent requirements. Not only must it make a proper contribution to the structural strength of the wall, but in addition it must be able to survive under conditions of attack by explosive and by the use of cutting tools driven by heavy sledges or by powered equipment such as pneumatic drills, jack-hammers and so forth. The main properties which determine its ability to withstand shock attacks of this nature are the general quality of the concrete, its tensile strength and its impact resistance. The first two of these properties can be developed on the basis of normal reinforced concrete design. Impact resistance is a specialised property which calls for particular consideration in concrete used for security structures.

When steel-reinforced concrete is subjected to a sudden shock, the initial state of compression is followed by a state of tension and then by a further state of compression of lower intensity as the materials tend to return to their normal states and these alternating states of compression and tension can be regarded as equivalent to the passage of a short train of longitudinal waves. The speeds of transmission and rates of absorption differ markedly between steel and concrete, the velocity in steel being appreciably greater than that in concrete so that the equivalent wavelength will be some fifty percent longer in steel than in concrete.

Thus if the shock wave is regarded as having a notional wavelength of 10 cms in the cement matrix of the concrete, the moment the wavetrain meets a steel inclusion some of the energy will be reflected and the remainder

will accelerate to the higher speed and be characterised by a wavelength of 15 cms. As a consequence, at positions some 5 to 7 cms from where the wavetrain entered the steel, it will already be considerably out of phase with the corresponding component travelling alongside it through the body of cement matrix so that high stress across the interface will result. For this reason it is advisable to restrict the straight and continuous runs of steel reinforcing elements to lengths of the order of 4 cms to 6 cms. While avoiding excessive stresses in the concrete, and particularly in the concrete/steel bonds, this does inevitably reduce the effectiveness of the tensile reinforcement provided by the steel. The object of the invention is to compensate for this and to provide a water-hardened mass which, in conjunction with the steel reinforcement which is designed to take account of the above-mentioned effects, exhibits enhanced resistance to explosive and mechanical attack.

The invention is based on the principle of providing additional fibrous reinforcement in the concrete mix so that the resultant properties of the concrete are more nearly matched to those of the steel reinforcement, thus reducing the risk of excessive stresses at the interfaces. Thus, according to the invention, a strongroom or similar security enclosure has walls of reinforced concrete in which the reinforcement is in the form of super-imposed, substantially horizontal layers of twisted strips of steel mesh connected together by substantially vertical coupling bars threaded through the mesh, the surrounding concrete including a proportion of polypropylene fibres sufficient to cause the tensile strength and impart resistance of the concrete to be more nearly matched to those of the steel reinforcement and thereby enhancing resistance to explosive or mechanical attack. It is found that the improved matching of the properties of the concrete with those of the steel reinforcement assists in causing energy applied in an attack to be dissipated into the mass without giving rise to local regions of stress con-

centration sufficient to lead to fracture and a proportion of polypropylene fibres of about 2% by weight of the cement used in the concrete mix is found to give best results.

- 5 The steel mesh reinforcement preferably comprises expanded metal with a diamond mesh, e.g. the material commercially available under the trade mark "Chubbmesh". This may be given one complete turn or twist
10 for each 120 cms of length and a number of these twisted lengths may be laid side by side, the number depending on the thickness of the wall.

- The coupling bars are preferably in the
15 form of twist grip bars, that is to say bars of generally square cross-section twisted to form a coarse helix. The length of these bars is preferably slightly greater than the distance between adjacent layers of steel mesh. Consequently, as each layer of steel mesh is
20 threaded into position over the coupling bars, a length of bar is left projecting above the surface of the mesh. The next set of bars is then threaded into this layer of mesh so as
25 to overlap the previous set and this procedure is repeated over the height of the wall.

- The production of concrete reinforced with polypropylene fibres is described in British
30 Patent Specification No. 1,130,612. The polypropylene fibres are preferably fibrillated fibres of approximately 12,000 denier and approximately 50 mm long. As mentioned above, these filaments preferably constitute
35 approximately 2% by weight of the cement used in the concrete mix, being sprinkled by hand during a period of about two to six minutes after the beginning of the mixing.

- During the construction of a wall in
40 accordance with the invention, the concrete needs to be placed in "lifts" between vertical shuttering, each lift including one or more horizontal layers of reinforcement, the coupling bars being first fitted in position and the
45 steel mesh reinforcement threaded over the coupling bars or wired to them, after which the lift of concrete is placed and finally compacted. For this purpose the newly placed concrete needs to be rammed and vibrated
50 so as to avoid the occurrence of voids or of regions where the flow of cement paste may have been impeded. This is preferably achieved by the well-known method of employing vibrating poker to encourage the
55 concrete to flow into all parts of the construction.

- A construction in accordance with the invention will now be described in more detail, by way of example, with reference to the
60 accompanying drawings, in which:—

Figure 1 is a perspective view partly in section and partly broken away showing the construction of adjacent walls and part of the roof of a strongroom;

Figure 2 shows details of a strip of reinforcing mesh; and

Figure 3 is a more detailed perspective view showing the arrangement of reinforcement in the walls shown in Figure 1.

In the view of Figure 1, the shuttering
70 necessary for the construction of the walls has been removed, but horizontal broken lines 10 illustrate the height of each successive "lift" in which the concrete was placed in position in the construction of the wall. The details of the construction are best seen from the portion where the reinforcement is exposed, from which it will be seen that this
75 comprises a number of vertical spaced coupling bars 11 over which are threaded strips of notched steel mesh reinforcement 12. Each of the strips 12 comprises a strip of expanded metal with a diamond mesh which has been given a slight twist, e.g. one complete turn of twist (360°) for each 120 cms of length.
85 Figure 2 shows a length of such strip prior to twisting, the notches being shown as 13. In a typical example of strip 23 cm wide, the notches are 5 cm wide and 3.5 cm deep and occur at 10 cm pitch in each edge of the
90 strip, there being half a pitch displacement between the notches in opposite edges.

Details of the reinforcement are better seen in Figure 3 which provides a clearer
95 illustration of the nature of the coupling bars, showing that these are of generally square cross-section twisted to form a coarse helix. The mesh and configuration of the twisted strips can also be seen more clearly, the notches of adjacent strips interfitting at
100 intervals as indicated at A.

In starting the construction shown in Figure 1, a normal concrete base 14 is first laid. On top of this is a reinforced concrete floor indicated generally as 15 which has a
105 construction similar to that of the walls in that it comprises successive strips of twisted mesh 22 and horizontal coupling bars 21. Shuttering is next erected for the walls, being built up in stages as the work proceeds. The height between the horizontal lines 10A and 10B represents the first lift of concrete for the walls. It will be seen that this comprises three layers of steel mesh reinforcement connected together by coupling bars. After all the
115 concrete in this lift has been placed, it is thoroughly compacted, e.g. by the use of vibrating poker as already described. Before the next lift of concrete is placed, a further series of coupling bars 11 is placed in position and wired to the first series, the strips 12 of twisted mesh are threaded over the bars and the next lift of concrete is poured and compacted. Both the horizontal and vertical reinforcement is wired as necessary to maintain it in position whilst placing the concrete.
120 In addition to the vertical coupling bars 11, diagonal coupling bars (not shown) may be inserted, if desired. This sequence is repeated
125

until the top of the walls, indicated as 25 is reached. The uppermost lift, indicated as 26 needs to have tie bars (not shown) bent into "L-shape" and projecting horizontally for coupling to the roof construction. A similar construction (not shown) is then used for the roof.

EXAMPLE

To construct a 45 cm thick wall 244 cm high and 488 cm long a quantity of 14,000 kg of concrete was prepared from the following mixture:—

	Aggregate 20 mm down to 4.5 mm	6,700 kg
15	Concreting Sand	3,350 kg
	Ordinary Portland Cement and Water	2,230 kg
	to which was added polypropylene fibre of 12,000 denier and approximately 50 m long	860 kg
20		45.5 kg

The mixture was made up in several convenient batches, the fibre in the proportion shown being sprinkled by hand into each batch over a period of 4 minutes, starting at two minutes after the beginning of the mixing. Samples were taken from each batch and tested for slump by the conventional method, a slump not exceeding 2.5 cm being indicated. Test Cubes were taken from each batch for subsequent testing for crushing strength whilst maturing as is generally accepted practice. A crushing strength of 55—70 MN/m² was exhibited by the test cubes after 28 days.

Shuttering to establish the position of the wall was erected to a height of 61 cm and the vertical coupling bars 75 cm long erected at positions where the twisted "Chubbmesh" could be conveniently laid over them. Laying was commenced at one end of the wall in 185 cm lengths and two lengths each 23 cm wide were laid side by side so that the centre lines were 18 cm apart and the outer edges came to 2.5 cm of the inside of the shuttering defining the inner and outer surfaces of the wall. The runs of "Chubbmesh" were extracted by allowing the next lengths to overlap those already laid by 7.5 cm so that the final pair were 137 cm long.

Concrete prepared as above was placed and compacted around this lowest level of twisted "Chubbmesh". A second layer of two 183 cm lengths of twisted "Chubbmesh" was added so that the centre line lay 18 cm above the lowest level and the edges interlocked. The concrete related to that was next placed and compacted. Then the "Chubbmesh" was extended at this second level (centre lines 18 cm above that of the lowest level) until the "Chubbmesh" and the concrete for the second level were all in position. The third level was similarly placed and extended so

that the concrete was at a level somewhat below the level of the shuttering which was originally erected. The vertical coupling bars then projected some 15—20 cm from the top surface of the concrete.

The next level of shuttering was then erected and the first level of "Chubbmesh" related to that placed in position with a fresh supply of coupling bars which were 69 cm long. This "Chubbmesh" in some degree penetrated into the surface of the concrete already laid the vertical coupling bars overlapped those first erected by 7.5 cm being wired into position with their predecessors.

The process for placing the concrete and the "Chubbmesh" employed in the lowest lift was repeated until again the level of concrete was just below the top edge of the shuttering. Shuttering to contain the third lift was then erected, the "Chubbmesh" and coupling bars positioned and the concrete placed in the same manner as before. For the fourth lift, bringing the height of the wall to 244 cm the process was again repeated and in order to cast the roof integral with the wall coupling bars bent to carry the "Chubbmesh" into the roof were used.

The arrangement of the work to enable it to be stopped at the end of one working period and restarted at the beginning of the next was planned according to the conditions on site and involved the definition of the shuttering so that the interruption occurred with a flat surface of concrete running around the walls with "Chubbmesh" and coupling bars protruding. For the commencement of the next period of work the exposed surface was wire brushed and dressed with grout to ensure a good key to the concrete which was next laid.

Following the procedure outlined above the observance of good concrete formulation principles was shown to provide a wall with enhanced resistance to penetration by mechanical cutting tools and improved endurance under explosive attack.

The number of lengths of "Chubbmesh" to be laid side-by-side depends both on the width of strip and thickness of wall. Most usually either two (as described in the Example) or three (as illustrated in Figures 1 and 3 of the drawings) such strips will be used, but more may be required in some circumstances.

WHAT WE CLAIM IS:—

1. A strongroom or similar security enclosure having walls of reinforced concrete in which the reinforcement is in the form of super-imposed, substantially horizontal layers of twisted strips of steel mesh connected together by substantially vertical coupling bars threaded through the mesh, the surrounding concrete including a proportion of polypropylene fibres sufficient to cause the tensile



until the top of the walls, indicated as 25 is reached. The uppermost lift, indicated as 26 needs to have tie bars (not shown) bent into "L-shape" and projecting horizontally for coupling to the roof construction. A similar construction (not shown) is then used for the roof.

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strength and impact resistance of the concrete to be more nearly matched to those of the steel reinforcement and thereby enhancing resistance to explosive or mechanical attack.

5 2. An enclosure according to claim 1 in which the concrete includes a proportion of polypropylene fibres of about 2% by weight of the cement used in the concrete mix.

10 3. An enclosure according to claim 1 or claim 2 in which the steel mesh reinforcement comprises expanded metal with a diamond mesh.

15 4. An enclosure according to any one of the preceding claims in which the coupling bars are of generally square cross-section twisted to form a coarse helix.

20 5. An enclosure according to any one of the preceding claims, in which the length of the coupling bars is slightly greater than the distance between adjacent layers of steel mesh.

6. An enclosure according to any one of the preceding claims, in which the polypropylene fibres are fibrillated fibres of

approximately 12,000 denier and approximately 50 mm long.

7. A method of constructing a wall for an enclosure according to any one of the preceding claims in which the concrete, including polypropylene fibres, is placed in "lifts" between vertical shuttering, each lift including one or more horizontal layers of twisted strips of steel mesh reinforcement, coupling bars being first fitted in position and the steel mesh reinforcement threaded over the coupling bars, after which the lift of concrete is placed and finally compacted.

8. A method according to claim 7, in which the shuttering on at least one side is built up in stages as the work proceeds.

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