May 11, 1954 G. CONSTANTINESCO 2,677,955

REINFORCED CONCRETE

Filed Feb. 10, 1948

Fig. 1.

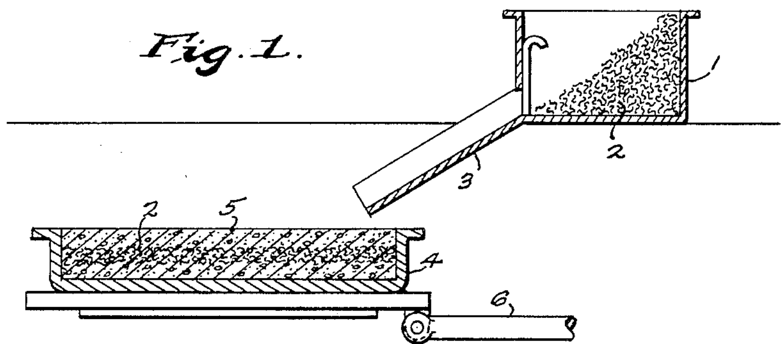


Fig. 2.

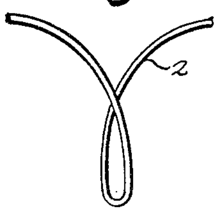


Fig. 3.

Fig. 5.

Fig. 4.

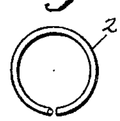


Fig. 6.

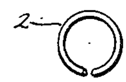


Fig. 7.

Fig. 9.

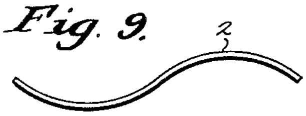


Fig. 8.

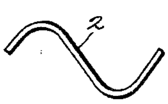


Fig. 10.

Fig. 11.

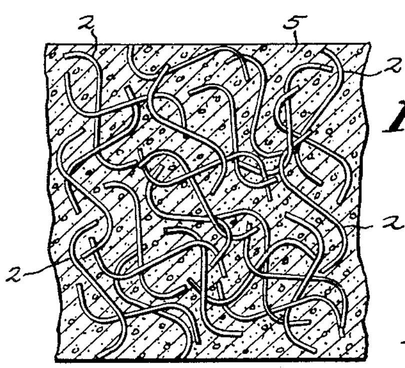


Fig. 13.

Fig. 12.

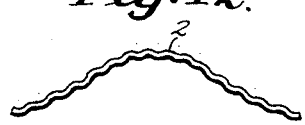
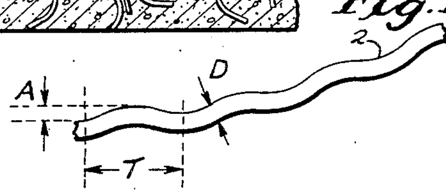


Fig. 14.



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REINFORCED CONCRETE

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5 Claims. (Cl. 72—50)

The object of this invention is to provide a method and means to produce a substitute material to replace metal castings.

The invention is particularly applicable to replace metal castings for frames, supports, bedplates, pulleys, flywheels, crank cases, gear boxes, engines, marine fittings, pumps, bearings, turbines, machine tools, pipes, armour protection, bomb-proof shelters, and generally any structures where strength under relative light weight and low cost are important considerations, but where volume occupied by the material is of secondary importance.

According to my present invention this substitute material is made of a three-dimensional and uniformly distributed mattress of wire composed of short coils of helical elements which are dropped into all the parts of the mould. The mould is finally filled with a suitable cementing mass like quick-setting cement, or cement mortar, plaster of paris, clay, resins, or any other compounds that will set hard.

The invention is illustrated by way of example in the accompanying diagrammatic drawings in which

Figure 1 is a sectional elevation of a moulding apparatus,

Figure 2 is a perspective view of one of the helices,

Figure 3 is a plan view of the same,

Figure 4 is an end view of the same,

Figure 5 is a plan view of a modified type of helix,

Figure 6 is an end view of the same,

Figure 7 is an elevation of a right-hand helix,

Figure 8 is a similar view of a left-hand helix,

Figure 9 is an elevation of a modified form of right-hand helix,

Figure 10 is a similar view of a left-hand helix,

Figure 11 is a plan view of a further modified form of helix having corrugated end portions,

Figure 12 is a similar view of another modification showing a helix corrugated throughout its length,

Figure 13 is a fragmentary view of a portion of one of the products, and

Figure 14 is an elevational view of a portion of a corrugated or crimped helix.

Referring to Figure 1 there is shown a receptacle 1 for holding helical coil elements shown generally at 2, from which receptacle the elements can fall down a chute 3 into a mould 4 to be distributed at random into the cementing mass 5. The mould can be vibrated through an arm 6.

The mattress, part of which is shown diagrammatically in Figure 13, is obtained by dropping one by one, or feeding a continuous stream into the mould, of separate short helical coil elements 2 made of wire which has been corrugated as shown more particularly in Figures 11 and 12, in which the corrugations are in the form of a sinusoidal curve, whilst as shown in Figure 12 the sinusoidal curve is in the form of a large number of small waves so that the curvature changes rapidly from plus to minus many times in succession along the axis of the wire.

A simple way to obtain this result is to pass the wire through a pair of suitably shaped gears compressing and permanently moulding the wire between their teeth to the desired wave-like curve. This corrugated wire is then coiled in helical elements and cut to the necessary lengths to form the elements as described.

The proportions for the corrugations are important. If $\pm A$ is the amplitude of the wave-like line, T the length of the wave, and D the diameter of the wire, and $A=cD$ and $T=mD$, then suitable values of c are between 0.5 and unity and of m between 5 and 10; this is diagrammatically shown in Figure 14.

The correct values for these coefficients depend on the ultimate tensile strength of the wire and also on the crushing strength of the cementing compound and are best determined by experiment.

According to another example, the coil elements have a pitch of two coil diameters, are cut to lengths of about one convolution, and have a developed length of about one hundred diameters of No. 20 to No. 33 wire gauge.

If the wire is of very hard material the length of the elements can be increased to about three hundred times the wire diameter with a pitch of two to six coil diameters for one convolution, as shown more particularly in Figures 2, 5, 7, 8, 9, and 10.

For special purposes these proportions may be varied so as to obtain any desired proportion of metal in the final product.

If a large number of such elements are fed separately into any mould cavity of dimensions larger than the overall dimensions of the elements, a three-dimensional interlocked structure is formed in the cavity.

The coil elements are made and fed into the mould so that at any place half of their number are right-handed and the other half left-handed helices.

These elements assemble automatically into an uniform distribution of fibres in all directions, resembling a mattress, with sufficient interspaces to admit the cementing mass. To obtain this result, the elements are dropped independently, either by simple gravity, or fed into the mould in a continuous stream of separate elements projected with the help of a stream of air or water.

After the mould has been charged with elements as aforesaid, the cementing compound is poured into the mould so as to imbed the whole of the mattress formed in the mould, as seen more particularly in Figure 1.

In order to expel the air and assist the uniform distribution of the cementing compound, the mould is kept under continuous vibration until completely filled.

The final product, after setting and hardening, is a new material that has a three-dimensional and uniformly increased resistance, not only to compression, but also to traction, shearing and bending in every direction.

The elements being dropped at random but in a regular sequence of right and left helices, the resultant structure is a system of fibres distributed in all directions showing a regular and isotropic three-dimensional structure. I have found that such a system of fibres imbedded in a cementing compound, if subjected to a field of tension in one given direction, resists as an equivalent virtual system of continuous parallel straight fibres in that direction.

For example, in a unit volume of the product containing proportion p of steel wire distributed as aforesaid, if subjected to a tension in one direction, the equivalent virtual system of parallel straight and continuous fibres of the same resistance in that direction will have the proportion of kp of steel wire per unit of volume.

The factor k is smaller thn unity and for a three-dimensional isotropic distribution, k is the same in any chosen direction and has the value of about ⅓.

A non-isotropic three-dimensional structure is obtained with elements that are longer relatively to the cross section of the object, the length being several times the diameter of the helix.

Such elements dropped on a flat surface produce a nearly two-dimensional istropic structure, the factor k approaching ½, while in the direction perpendicular to the surface the value of k diminishes.

As the elements pile up on the flat surface the two-dimensional isotropy is gradually changing to three dimensional. Consequently plates of the product will show a higher resistance to bending if the tension side is on the side where the elements have been dropped first into the mould, because the factor k is higher near the flat surface. Such a distribution is of advantage in slabs subjected to bending on account of the high value of the factor k in the direction of the principal tensions.

The size of the coil elements and the nature of the cementing compound depend on the thickness of the casting required. For thin castings, the section of the wire may be only a small fraction of a square millimetre imbedded in mortar of neat cement, or cement mixed with fine sand. For very thick castings, the elements may be made of steel sections up to several square centimetres imbedded in concrete made of cement mortar and gravel.

If desired, the elements may be made of different sizes mixed in appropriate proportions.

Material made according to this invention is very tough, possesses tenacity and plasticity, and can take considerable tension, shearing and bending stresses in every direction. This is due to the uniform distribution of fibres that form a three-dimensional reinforcing structure in every part of the mass. Experiment shows that fissures cannot be propagated in the material and internal cracks cannot take place. The material can be moulded in any curved and intricate shapes, in which reinforcement would be impossible by other means. For example, bearing casings can be made completely in one piece with all intricate inside cavities to locate the necessary metallic bearing surfaces, ring cavities, oil reserve, felt washers or any other desired accessories.

Experiment shows that the peculiar mattress of adhesive filaments curved in these dimensions, imparts to the whole mass new properties of tenacity and plasticity in every direction which are absent in the cementing compound alone.

For example, hammers can be made and a very considerable number of blows can be delivered without disintegration taking place.

The same applies to bearing castings, engine castings, crank cases, machine tool frames, armour plate, stoves, gas-producers and like structures subjected to vibrations, shocks and non-uniform heating.

For general purposes, the proportion of steel in finished products made by this method is about one-tenth of the weight. Therefore an economy of iron of some 90% can be achieved in replacing cast iron products with products according to the present invention of the same weight.

In all cases where ordinary metal castings have to be made much thicker than necessary, for the sake of rigidity and to resist corrosion, such castings could be replaced with the present material and a considerable reduction in weight results. The specific gravity of the product is between 2.30 and 2.50, and is therefore a little less than aluminium, and about one third of cast iron.

The product has a fairly high and uniform magnetic permeability and therefore is suitable for use in the construction of monolith frames for electric generators and motors, thus reducing to the minimum the quantity of iron required for the poles of stators or rotors. Moreover, the peculiar structure of the mattress in the castings prevents the building up of parasitic electric currents in the mass and therefore no heat can be generated from alternating magnetic fields. By increasing the iron content of the elements, the permeability can be increased very substantially and castings could be used directly as magnetic circuits in the construction of alternators, dynamos and transformers. To further increase the magnetic permeability, the cementing compound can be made of a mixture of iron filings with cement.

The capacity to resist shocks makes the product suitable for wheels of any kind, as pulleys, drums, for vehicles like motor cars, lorries, agricultural tractors, road rollers and railways.

In ship construction the non-corrosive properties of the product makes it suitable to replace most of the heavy and light castings on board. Emergency and permanent propellers can be made entirely of the product.

For the same weight, the castings can have sections three times larger than cast iron. Greater rigidity is thus obtained and simpler forms can be adopted, thus eliminating complicated stiffenings required in metal castings. Moreover, objects of the product can be cast in place ready in their final position and thus the transport of heavy castings can be avoided.

The product has a coefficient of expansion with temperature of the same order as steel and it is therefore suitable to be incorporated with iron or steel parts. Additional reinforcements can easily be provided in the form of tension bars in all parts of the mould where high tension stresses are expected. This permits the castings of, for example, fly-wheels, crank cases for engines, and cylinder blocks for steam or internal combustion engines, or machine tools, in combination with bolts and metallic rings and linings limited only to the parts where absolutely necessary.

The rupture resistance to bending of slabs of the product varies between 150 to 450 kilograms per square centimetre, depending on the tensile strength of the elements and the quality of the cementing compound. This permits the construction of girders, slabs, planks and the like, showing a load capacity comparable with that of cast iron or with standard laminated mild steel sections of the same weight.

The steel wires that form the elements in castings have a resistance to rupture from 3 to 12 times higher than ordinary iron or mild steel in laminated sections. Therefore in spite of the isotropic distribution of the metal fibres in products made in accordance with the present invention, the ultimate resistance to tension, shearing, and compression in every direction is high.

Sections of the product show a higher resistance to rupture than ordinary reinforced concrete structures. Consequently, lighter constructions can be obtained for floorings, roofings, columns, and other building components.

Columns subjected to heavy pressures show outside signs of heavy stresses long before the interior section is crushed, and give warning in time. This indicates the product as a suitable material for pit props in mining work.

The most suitable material for the coil elements is steel, and for the cementing material quick-setting aluminous cement mortar with sand, or even heat for small castings.

The invention is not limited to these materials. The elements may be made of any other metals, and the cementing materials may be magnesia or plaster of paris or any other materials like silica, resin, or clay compounds than can be set by the influence of heat.

Another property of the product is its capacity to resist penetration by projectiles. It is thus indicated as suitable for replacing steel armour plating.

The specific gravity is less than one third when compared with steel. Therefore armour can be made at least three times thicker for the same weight and can be cast in position as a monolith structure, thus avoiding weak joints.

The greater thickness offered to the penetration of projectiles, combined with great rigidity and inertia of the volume opposing the penetration would localize the damage to the outside of the armour.

It is known that fibrous masses like saw dust, offer great resistance to the passage of projectiles. The three-dimensional fibrous texture of the mattress imbedded in the present product has a similar effect.

The relatively low heat conductivity of the material combined with its tenacity and resistance to penetration makes the material suitable for the economical and rapid construction of complete monolith army tanks, mobile forts, pillboxes, air raid shelters, deck armour, gun cupolas, gun mountings and the like, with a corresponding large economy of steel.

Elements of such corrugated wire imbedded in the product when subjected to a field of tension produce, at all points of large curvature, high local pressures at right-angles to the axis of the wire. This considerably increases the grip, with the result that a much shorter length of the helical elements is required in order to secure the benefit of the high tensile strength of the wire for the major part of the element.

It can be shown by mathematical analysis and by experiment that the "idle" lengths at the ends of the elements (the portions where the actual tension of the wire diminishes rapidly towards nil at the extremities) are reduced to nearly one tenth of the idle lengths necessary for non-corrugated wires.

This advantage becomes of paramount importance when using wires of very high tensile strength. For example, elements made of wires showing a tensile strength of the order of 270 kilogrammes/square millimetre, if made from corrugated wire as above, have idle ends totalling only about 50 diameters of the wire. If the same wire is not corrugated the idle ends total 500 diameters.

Therefore, if the elements are made, for practical reasons, with a total length of only 300 diameters, such high tensile wire could never be stressed to its full capacity if made of normal wire. However, if the elements are made of the same wire but corrugated as specified above, a length of at least 250 diameters out of the total of 300 diameters could be stressed to its full tensile capacity without pulling out the idle ends.

It follows that very high tensile wire elements can be used for the material without the necessity of wasting a considerable length of wire in the idle ends.

Corrugated wire elements imbedded in the material have another important function when high tensile wire is used. Non-corrugated wire made of very high tensile steel has negligible plastic elongation and is apt to break "in succession" when the material is overloaded in tension. Thus in slabs subjected to bending, the external fibres in the tension regions are broken first and the other fibres towards the neutral axis of the slab break in quick succession afterwards.

Corrugated high tensile fibres provide a virtual elongation due to the minute elastic and plastic lateral compressions in the cementing compound caused by the alternating curvatures of the corrugated wire trying to stretch out in a field of tension. Thus a virtual elongation is possible in corrugated wire elements and is of an elastic nature, independent of the lack of plastic elongation of the wire.

In another form of the invention, instead of providing corrugations on the whole length of the helical elements, I provide corrugations only on the idle portions at the extremities of each element, as shown in Figure 11. The corrugated lengths in this case are determined by the condition that the force necessary to pull out the wire from the corrugated ends, when imbedded in mortar aggregate, should be equal to the force necessary to break the wire in tension on the non-corrugated middle portion. In this case the adhesion on the non-corrugated portion of the element will be overcome in an intense field of tension and will not play any important part when the tension in the wire reaches high values. The idle corrugated ends will act then as progressive anchorages for the middle portion. Such end-corrugations may be made with variable amplitude, greater amplitudes at the extremities gradually diminishing towards the non-corrugated portions of the helical element.

An interesting feature of this invention is that the capacity of wires to resist tension is very little affected by corrugations as specified above, provided a large number of elements are present in every direction of the material. This is due to the fact that there is no freedom for an excessive deformation of the wave-shaped curve of the axis of the wire. Under a high longitudinal tension the tendency of the curve is to flatten out, but this cannot take place except if the cementing compound is crushed in a direction perpendicular to the axial direction of the wire. But such crushing cannot take place easily, there being no room for lateral expansion.

The adhesion due to corrugated elements, made as above, is of an entirely different kind than the adhesion produced by the sticking of cement mortar to ordinary wires. The difference will be made apparent at once if one will consider that such a corrugated wire will not pull out of its lodging in the mortar even if the coefficient of friction may be nil.

Due to the relative rigidity of the corrugations made with proportions as specified above, the adhesion comes chiefly from the necessity to shear a large perimeter of mortar in order to pull out the corrugated wire. This perimeter is proportionaly much larger than for square or rectangular twisted wires which act in a similar way.

As the ultimate tensile strength of the product is directly proportional to the tensile stress of the wire, this invention gives the possibility to increase the tensile strength of the product to the maximum possible with a minimum weight of steel wire and so at the same time allows ample space between the wire elements for the mortar aggregate.

I am aware that ready-made bundles of metal shavings, iron fibre (paille de fer), metal, wool, iron straw, metal hair and the like have been proposed as reinforcements in cementing compounds. The irregularly-shaped fibres of which these textures are made have not the correct curvature, nor the uniform distribution which are essential conditions for imparting to the final product an increased uniform capacity for tension resistance in all directions comparable with metal castings. Such ready-made bundles or packets of fibres cannot be inserted into intricate moulds without leaving surfaces of discontinuity where the fibres of adjacent bundles cannot be interlocked. Across such surfaces of discontinuity the tension resistance of the final product remains practically the same as if the cementing compound had not been reinforced at all.

I do not claim that my invention covers any such products made by imbedding ready-made bundles of irregularly-shaped wires into cementing compounds.

It has also been proposed to reinforce cementting compounds by imbedding parallel or adjacent helical wire springs having many convolutions. Such structures do not provide a uniform three-dimensional distribution of fibres capable of resisting tension in all directions. Any field of tension parallel or across the axis of the springs will rupture first the cementing compound and open out the springs afterwards.

I do not claim that my invention covers any products made by imbedding such helical springs in a cementing compound.

What I claim is:

1. A moulded composite structure comprising a body of set cementitious material, and a multiplicity of generally helical metallic wire elements interspersed relatively uniformly and positioned indiscriminately throughout and bonded to said body and projecting one through another, said wire elements each being of a length axially of the helix approximately equal to the pitch of the helix and such length being at least equal to twice the diameter of the helix and at least 100 times the diameter of the wire.

2. A structure as defined in claim 1 in which the wire elements are substantially equally divided between right- and left-handed helices.

3. A structure as defined in claim 1 in which the pitch of each helix is from 100 to 300 wire diameters.

4. A structure as defined in claim 1 in which each helix has a pitch of from 2 to 6 times its diameter.

5. A structure as defined in claim 1 in which the pitch of each helix is 100 to 300 wire diameters, each helix having a pitch of from 2 to 6 times its diameter.

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