This invention relates to improvements in reinforced cementitious constructions, the term "cementitious construction" being employed herein as defining a substance such as Portland cement which when mixed with water or other suitable liquid to form a neat cement or mixed with sand, gravel, or the like to produce a concrete, will harden to provide a solid stone-like substance. Structural articles formed of cement or concrete have heretofore usually been reinforced by embedded steel wires, bars, cages, etc., embedded in the cementitious material.

I have discovered that cementitious constructions can be satisfactorily reinforced by embedded fibrous material particularly where the fibres or strands thereof are oriented in a direction to resist the tensile stress applied to such construction. Such reinforcements may be embodied in beams, sheets, bars, tubular constructions such as pipes for water supply mains, sewage pipes, drains, etc., in such manner as to resist tensile stress imposed upon them or upon the portions thereof to which the tensile stresses are most forcibly applied.

The object of the present invention is therefore to provide a rigid cementitious construction which is reinforced by embedded fibres or fibrous material adapted to resist tensile stress applied thereto.

I am aware that in the past fibres of various kinds have been added to plasters and mortars to hold them together during application and hardening to prevent sagging and to prevent shrinkage cracks. I am also aware that strips of wood, bamboo and the like have been employed as tensile reinforcements of concrete.

It is well known that animal and vegetable fibres which do not deleteriously affect the concrete in which they are embedded are not adversely affected by the concrete, but in fact are protected from disintegration by the enclosing film of cement, and further that the fibres are firmly bonded to and together by the cement.

The term "textile fibres" is used herein as descriptive of cellulosic fibres such as vegetable fibres, animal fibres, silk, and the like, which are used in the manufacture of textile materials as distinguished from mineral or metal fibres.

I have found from experimental tests that many fibres have a tensile strength sufficiently approaching that of mild steel, of for example 70,000 pounds per square inch, as to provide satisfactory reinforcement for commercial rigid cementitious constructions; for example, cotton has a tensile strength of approximately 45,700 pounds per square inch; hemp 55,000 pounds; jute and ramie approximately 35,000 pounds each per square inch; wool 25,000 pounds; as compared with asbestos, which has a tensile strength of only 15,000 pounds per square inch.

A further object of the invention is to provide a rigid cementitious construction, such as a beam, bar or rod, having the portion or zone thereof which is to be subjected to tensile stress reinforced by fibres properly oriented mainly in the direction of the tensile force.

In view of the scarcity of steel due to war conditions or to unavailability of steel in certain areas one of the objects of the invention is to provide a satisfactory reinforcement of concrete constructions by embedding therein suitably distributed and oriented fibrous material.

Another object of the invention is to provide a cementitious tubular construction which is reinforced by embedded fibres in the manner herein-after set forth.

A further object of the invention is to provide a cementitious tubular structure which is reinforced by providing alternate laminations of cementitious material and embedded fibrous material.

These and other objects and features of the invention will more fully appear from the following description and the accompanying drawing and will be particularly pointed out in the claims.

Illustrative embodiments of the invention are shown in the accompanying drawing, in which:

Fig. 1 is a perspective view of a beam or bar having a zone of the portion thereof which is to be subject to tensile stress reinforced by embedded fibres mainly oriented in the direction of the length of the beam;

Fig. 2 is a similar perspective view in which the portion or zone of the beam which is subject to tensile stress is reinforced by one or more layers of embedded fabric;

Fig. 3 is a perspective view of a beam which is reinforced throughout by embedded fibres oriented in the proper direction to resist stresses applied thereto;

Fig. 4 is a perspective view of a cage of metal or other rigid material having wound upon it a layer of fibres, threads, ropes, or fabric adapted to be embedded between an inner layer and an outer layer of cementitious material to produce a rigidly reinforced tube or pipe;

Fig. 5 is a transverse sectional view of the completed pipe embodying the construction illustrated in Fig. 4;
Fig. 6 is a transverse sectional view of a tube or pipe reinforced by embedded fibres; Fig. 7 illustrates the manner of making reinforced cementitious tubular construction by progressively winding alternating layers of fabric and cementitious composition to form a laminated reinforced construction; and Fig. 8 is a similar view illustrating the manner of producing a laminated reinforced pipe or tube by spirally winding alternately in opposite directions strips of fabric and intermediate layers of cementitious material embedding and uniting the fabric and the cementitious material to form a solid reinforced cementitious construction.

The present invention comprises the production of a rigid cementitious construction which is adapted to be subjected to tensile stress reinforced by substantially uniformly distributed embedded fibres preferably fibres otherwise used in textile manufacture including cotton fibre waste, cotton thread waste, or fibres of silk, rayon, jute, hemp, ramie, etc., and woven fabric such as cheese cloth.

In producing rigid cementitious constructions the methods of using the fibres or fabric as reinforcement include the distribution of fibres uniformly throughout the cementitious material, cement or concrete manually or by concrete or mortar mixers alone or in conjunction with well-known special devices such as are used in paper and waterproofing felt manufactured to feed fibres, strands or threads oriented as desired into the mixture. Where the fibres are thus fed into the mixture during mixing or during its introduction into a mould a solid reinforced construction uniformly reinforced throughout, such as a beam 4 illustrated in Fig. 3, may be produced. Of course, any suitable form of mould may be provided to produce an article of desired form or contour. Also, pressure and heat may be applied to the mixture during moulding and curing or setting.

Sheets of material may likewise be reinforced by fibres oriented in the desired direction or by sheets of textile material embedded in and impregnated with the cementitious material.

An illustrative embodiment of the invention as applied to beams, bars, etc., is illustrated in Fig. 1, which illustrates a beam 2 adapted to be supported at its ends upon suitable piers or girders 3 and 4 in which a zone or zones 5 located at or in proximity to the lower face is reinforced by fibres mainly oriented in the direction of the length of the beam, the fibres being distributed in a layer of desired thickness in freshly laid cement or concrete at the plane where the reinforcement is most advantageous. If desired fibres may be similarly regularly distributed in lesser numbers through the material adjacent said zone, it being understood that all the fibres of the reinforced zone, as well as those adjacent thereto, are embedded in and adhesively bound together and to the surrounding cement. The upper portion 6 of the beam may if desired be free of fibrous material which of course will deplete the tensile strength thereof. Beams formed in this manner may be of neat cement but preferably of cement mixed with sand, gravel or the like as in concrete structures.

A modified form of the invention is illustrated in Fig. 2 in which a beam 1 of cement or concrete is provided at the plane where the tensile reinforcement is advantageous, as for example, near its under face 8 when supported upon piers by reinforcing layer or layers 9 of fabric which is thoroughly impregnated with and bonded by the cement to the body thereof.

In this construction the strands of thread extending and the fibres thereof are "mainly oriented" in the direction of the length of the beam.

The invention is also illustrated herein as embodied in a tubular construction which as illustrated in Fig. 6 comprises a hollow cylindrical tube 10 of cementitious material such as neat cement or concrete in which the fibres are uniformly distributed throughout or in concentric zones or zones, the fibres preferably being oriented in the direction in which tensile stress is to be applied to the pipe, for example, where the tubular construction is to be used as a water main, sewer pipe, or the like, in which the pipe is not evenly supported throughout its length, fibres will be mainly oriented lengthwise of the pipe, while other fibres extend in directions more or less circumferentially of the pipe, thereby giving it additional rigidity circumferentially as well as longitudinally.

As illustrated in Figs. 4 and 5 a reinforced tubular construction may be provided by winding a layer 14 of fibres or threads oriented in the proper direction upon a circular series of barns 12 where it may also be reinforced circumferentially by parallel or spiral wires 13. Inner and outer layers 14 and 15 of cement or concrete may be cast or otherwise applied upon the core and the surrounding fibres, as illustrated in Fig. 5. Such a construction is particularly adapted for use where considerable internal pressure is applied by the liquid flowing through the pipe.

Other embodiments of the invention are illustrated in Figs. 7 and 8 which show the manner in which a laminated tubular structure may be made. In producing this construction as illustrated in Fig. 7 a suitable mandrel 16, which is fixedly secured upon an axle shaft 17, is rotated in any suitable manner and alternating layers of cement or mortar 18 and fabric 19 progressively wound upon the mandrel until a pipe section having walls of suitable thickness is formed.

In this construction the web strands of the fabric mainly extend or are "mainly oriented" in the direction of the length of the pipe and reinforce the pipe against longitudinal tensile stresses while the warp strands of the fabric are embedded circumferentially in the cement and cooperate with the longitudinally extending strands with which they interface further to resist transverse tensile strains to which the pipe may be subject from without or from within.

While in the construction illustrated a pipe section cylindrical throughout its length will be formed, it will be readily understood that the mandrel may be so constructed as to provide a bell-shape end or socket, or other shape, adapted to receive or connect with the opposite end of the next adjacent pipe section as is usual in pipe constructions.

The construction illustrated in Fig. 8 is formed in a similar manner in which the mandrel 16 has wound upon it alternating layers of cement 20 and fabric by progressively applying the cement 21 to a strip 22 of fabric which is directed to the mandrel at an angle to the axis thereof to provide a spiral winding. Such spiral windings may be made successively in the same direction but preferably an alternating spiral 22 is similarly wound in the opposite direction so that the spirals cross each other as illustrated.

In the constructions illustrated in Figs. 7 and 8 the concrete may be progressively applied.
uniformly to the upper face of the fabric or fabric sheet 19 or fabric strip 21 and sufficient tension maintained upon the fabric to wind the same smoothly and to cause impregnation of the cement into the interstices of the fabric and the fibres thereof so that the whole will be firmly cemented together. After completion of the winding a further layer of neat cement or concrete may be applied to the surface to enclose and protect the final winding of fabric and to present a smooth surface. After the cementitious material is set the mandrel can be withdrawn longitudinally thereby providing a true cylindrical pipe.

Any suitable fibres or fabric may be employed as heretofore stated to produce a satisfactory reinforced cementitious construction, the cost of which will be comparable with bars or cages of iron or steel. The reinforcement of the concrete by the present invention is advantageous over that of concrete reinforced by rods or wires of iron or steel in that the fibres are uniformly distributed throughout the cementitious material and firmly bonded thereto throughout their lengths whereas in steel reinforcements there is considerable space between adjacent bars or wires which are not reinforced. The bonding of the fibres together and to the cementitious material is more uniform as the cement not only engages the surface of the fibres but also to a great extent impregnates them whereas in usual iron and steel reinforced constructions the cement adheres merely more or less firmly to the surface of the bars or rods.

Reinforcement of cementitious constructions by fibrous material in the manner above described may be embodied not only in beams, bars, slabs, or columns, but also in tubular constructions such as sewer pipes, water pipes, electric service conduits, or in fact any other type of construction which has heretofore been reinforced in a usual manner by bars, wires, or the like, or in which reinforcement against tensile strains may be desired.

It will be understood that the embodiments of the invention shown and described herein are of an illustrative character and are not restrictive of the meaning and scope of the following claims.

Having thus described the invention, what is claimed as new, and desired to be secured by Letters Patent is:

1. A lengthy rigid cementitious construction having the portion thereof which is to be subjected to tensile stress reinforced in proximity to its surface by a plurality of narrow spaced zones of substantially uniformly distributed embedded textile fibres mainly oriented in a direction to resist the tensile force.

2. A rigid cementitious tubular construction comprising a plurality of interlaminated layers of cementitious material and fibrous material impregnated therewith in which the fibres are mainly oriented in the direction of the length of the tubular construction.

3. A rigid cementitious tubular construction comprising a plurality of progressively wound alternating laminations of cementitious material and a sheet of woven fabric bonded together thereby, in which parallel strands of the fabric extend continuously throughout the length of the tubular construction.

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