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(54) IMPROVEMENTS IN TUBULAR CONCRETE BODIES AND THE MOULDING THEREOF

(71) We, AMEY ROADSTONE CORPORATION LIMITED, formerly AMALGAMATED ROADSTONE CORPORATION LIMITED, a British Company, of 15 Stanhope, Gate, London, W1Y 6AB, do hereby declare the invention, for which we pray that a patent may be granted to and the method by which it is to be performed, to be particularly described in and by the following statement:—

The reinforcement in reinforced concrete pipes is most commonly in the form of cages of steel wire mesh which are cast into the concrete of the pipe when the pipe is formed. Concrete pipes have, however, also been reinforced by wrapping them with a coil of glass fibre strand after the concrete has been cast and has hardened. When this is done, the glass fibre is set in a synthetic resin coating on the pipe in order to bond the glass fibre to the concrete and also to hold the glass fibre in position and protect it.

It has also been proposed to reinforce concrete pipes either by incorporating glass fibre in the wet concrete mix or by a spraying process in which a glass fibre mat is impregnated with a wet concrete or cement mortar mix. In both these techniques chopped fibre is used. In the first technique, the fibres extend in entirely random directions within the concrete and in the second technique the fibres lie in a cylindrical surface, but are still randomly oriented in this surface.

The glass fibre must, of course, be resistant to deterioration by the cement in the concrete. When the concrete which is reinforced with the glass fibre is made using Aluminous cement, ordinary "E" glass fibre can be used for the reinforcement, but with normal Portland cement concrete, alkali-resistant glass fibre must be used because ordinary glass fibre loses its tensile strength to a very con-

siderable extent in the alkaline concrete mix.

The reinforcement of tubular bodies of cementitious material, such as concrete pipes, which are to withstand external loads, or internal pressures, or both with either entirely randomly orientated chopped glass fibres or with fibres randomly orientated in a cylindrical surface is inefficient because only a proportion of the fibres increase the tensile strength of the pipe in the directions required to resist the tensile stresses caused by the applied external loads or internal pressure. Indeed, when the orientation is entirely random, as little as one-sixth of the total fibre content may be effective in the required directions and with planar orientation only one-third of the fibre may be effective.

According to this invention, a tubular body of concrete, cement mortar, or other cementitious material comprises an integrally and centrifugally cast cementitious mass reinforced with a glass fibre strand or roving which is resistant to deterioration by the cementitious mass and forms a winding extending around the body and incorporated and bonded in the cement matrix of the cementitious mass.

When the body is required only to withstand a hoop stress generated by internal pressure or otherwise, the winding is preferably incorporated in the outer peripheral layer of the cementitious mass. The peripherally oriented glass fibre is able to resist tensile hoop stresses efficiently and the proportion of the glass fibre in the concrete can therefore be much smaller than that which is necessary when entirely randomly or planar orientated fibre is used.

In order to withstand not only internal pressure, but also bending stresses in the wall of the body produced by external loads, preferably a second winding of glass

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fibre strand or roving is incorporated in the cement matrix of the inner peripheral layer of the cementitious mass. With two layers of glass fibre reinforcement, one in the internal periphery and the other in the external periphery of the body, the reinforcing effect is similar to that produced by the customary steel mesh cages used in pipes. A greater tensile strength than that produced by steel mesh cages can however be achieved and this enables pipes to be made thinner than steel reinforced pipes of the same strength. Further, because the glass fibre does not have to be protected from corrosion in the same way as steel reinforcement, the protective cover, if any, to the glass fibre may be of a much smaller thickness than is necessary with steel reinforcement so that the overall thickness of the pipe for a given strength may be reduced still more. This results in considerable economy of concrete and also makes the pipes lighter and easier to handle and lay.

In order to impart longitudinal tensile strength to the tubular body additional longitudinally extending glass fibre strand or roving may be introduced, but preferably the winding or each winding of glass fibre strand or roving is laid along a sinusoidal or other wavy path around the body so that the winding is able to withstand both circumferential and axial tensile stresses.

Tubular bodies in accordance with the invention may be made, in accordance with another aspect of this invention, by a centrifugal casting operation in which a centrifugal casting mould is rotated and a glass fibre strand or roving is positively fed at a speed at least as great as the internal peripheral speed of the mould from a feeding device within the mould and is caused to adhere to the internal peripheral face of the mould, the feeding device is moved along the mould in the direction of the axis of the mould as the mould rotates so that a coil or winding is formed from the strand or roving around the inside of the mould and cementitious material is introduced into the mould to form an integrally cast tubular cementitious mass with the coil or winding incorporated and bonded in the cement matrix of the cementitious mass.

As the centrifugal mould is spun after the introduction of the concrete, cement mortar or other cementitious material, the centrifugal force acting on the material tends to force the cement matrix of the cementitious mass into intimate contact with the coil or winding and a very satisfactory bond is produced between the glass fibre strand or roving and the cementitious mass.

The expression that the strand or roving is "positively fed" from the feeding device means that the strand or roving is ejected from the feeding device by means forming part of the feeding device and is not pulled from the feeding device by the rotation of the mould.

In order to make a pipe reinforced both externally and internally with glass fibre windings, preferably cementitious material in the form of cementitious slurry is introduced into the mould with the glass fibre strand or roving, concrete is subsequently introduced into the mould and with the slurry forms the tubular body as the mould is spun and then a second glass fibre strand or roving is fed from the feeding device onto the internal surface of the body and the feeding device is again moved axially along the mould so that a second coil or winding is formed from the strand or roving around the internal peripheral face of the concrete and becomes embedded in the cement matrix of the concrete.

Preferably, the or each glass fibre strand or roving is impregnated with cementitious slurry by the feeding device and the or each strand or roving together with cementitious slurry are introduced into the mould simultaneously.

As an alternative to this, the glass fibre strand or roving or the first glass fibre strand or roving, when there are two, may be fed into the mould with the mould dry and this strand or roving then becomes incorporated into the cement matrix of the cementitious mass when this is subsequently added. However, the impregnation with cementitious slurry enriches the cement content of the peripheral portion of the concrete and the pipe and it assists in ensuring that the glass fibre is fully embedded in the cement matrix and that there is a satisfactory bond between the glass fibre and the cementitious mass.

In order to lay the winding or each winding along a sinusoidal or other wavy path around the tubular body when this is required, the strand or roving is fed from the feeding device at a speed substantially greater than the peripheral speed of the internal face of the mould or substantially greater than the peripheral speed of the internal face of the concrete and this causes the strand or roving to adopt the wavy path automatically as the feeding device is moved axially along the mould.

The present invention also includes, according to another of its aspects, apparatus for carrying out the centrifugal casting method and this apparatus comprises a centrifugal mould, a driving mechanism for rotating the mould, a device for impregnating a glass fibre strand or roving

with cementitious slurry and positively feeding it to the inside of the mould at a speed at least as great as the internal peripheral speed of the mould and in a position in which the strand or roving impinges on the internal peripheral face of the mould and a mechanism for moving the feeding device within the mould in the direction of the axis of the mould.

- 10 Preferably the device for feeding the glass fibre strand or roving comprises a pneumatic conveying tube having at its discharge end an ejector head having a connection for the supply of cementitious slurry and a series of nozzles in the head from which, in use, the slurry issues with an inward inclination so that the jets impinge upon the glass fibre strand or roving issuing from the pneumatic conveying tube to impregnate strand or roving with slurry and carry it along with the slurry.

- 20 To enable the glass fibre strand or roving to be laid either along a normal helix or along a wavy helical path according to requirements, the apparatus preferably also includes a pair of feed rollers to control the speed at which the glass fibre strand or roving is fed through the pneumatic conveying tube.

- 30 The rate at which the feeding device is moved within the mould in the direction of the axis of the mould determines the thickness and the pitch of the coil which is built up either on the internal face of the mould or on the internal face of the concrete and the coil may be built up in a single layer by a single traverse of the feeding device along the mould or it may be built up in a number of layers by moving the feeding device backwards and forwards along the mould. For convenience a double traverse is preferably made and the thickness of the winding is controlled by the traversing speed. In either case the glass fibre strand or roving may be laid either as a straight or a wavy helix, the amplitude of the wave-form of which can be controlled by controlling the speed of the feed rollers in relation to the peripheral speed of the mould.

- 50 The amount of glass fibre in the winding is, of course, dependent upon the strength which is required of the tubular body. Generally speaking, though, both coils will have a radial thickness of, for example, between 0.1 inch and 0.2 inch.

- 60 The glass fibre strand or roving in the winding, or in both the windings when there is a winding on both the external periphery and the internal periphery of the concrete, may be continuous from one end of the pipe to the other or it may be discontinuous and the winding, or each winding, may be built up with a number of sections each consisting of one or more turns

of the strand or roving.

The mechanism for moving the feeding device within the mould preferably comprises a carriage outside the mould and a mechanism for moving the carriage to and fro along a track which extends parallel to the axis of the mould. The feeding device is then mounted on the carriage and extends from the carriage into the mould.

In accordance with a further feature of the invention a concrete pipe may be made by a vertical casting operation in which a tubular body with a single glass fibre winding impregnated with cementitious slurry is made by the method already described using slurry to form the cementitious mass and, when the cementitious mass has hardened, the body is introduced into a vertical casting device in which the body constitutes an outer peripheral mould wall, and concrete is introduced between the body and an inner peripheral mould wall of the device and is consolidated to form a concrete pipe which is reinforced by the glass fibre strand or roving incorporated in the body which constitutes the outer peripheral layer of the pipe.

With this technique, a second tubular body of smaller diameter than the first body is made by the method already described using cementitious slurry to form the cementitious mass and both bodies are introduced into a vertical casting device in which the body of larger diameter constitutes the outer peripheral mould wall and the body of smaller diameter constitutes the inner peripheral mould wall and the concrete is then introduced between the two bodies and is consolidated to form a concrete pipe which is reinforced by the glass fibre strand or roving incorporated in the bodies constituting the outer and inner peripheral layers of the pipe.

Some examples of tubular bodies in the form of pipes, of methods of making pipes and also of apparatus for use in carrying out the methods will now be described with reference to the accompanying drawings, in which:—

Figure 1 is a side elevation of a concrete pipe in accordance with the invention with a part of the concrete cut away to show glass fibre reinforcement;

Figure 2 is a circumferential section through a part of the pipe shown in Figure 1 as seen in the direction of the arrows on the line II-II in Figure 1;

Figure 3 is a diagrammatic perspective view of part of the apparatus for forming the pipe shown in Figures 1 and 2;

Figure 4 is a somewhat less diagrammatic side elevation of the apparatus as a whole;

Figure 5 is an end elevation of the ap-

paratus as seen in the direction of the arrow V in Figure 4;

Figure 6 is a plan view of the apparatus shown in Figures 4 and 5;

- 5 Figure 7 is a diagrammatic diametric section through a vertical casting mould with a pipe being cast in it; and,

Figure 8 is a radial section to a larger scale of a part of the pipe shown in Figure 7.

- 10 A concrete pipe 1 shown in Figures 1 and 2 of the drawings is of the Ogee or in-wall jointed kind with a spigot 2 at one end with a rebate 3 for receiving a sealing ring and a socket 4 at the other end formed within the thickness of the pipe wall. The pipe is reinforced with an outer winding 5 of glass fibre roving and a similar inner winding 6. The windings 5 and 6 are incorporated in outer and inner cement paste layers 7 and 8 respectively forming part of the matrix of concrete 9 of which the wall of the pipe is formed. The windings 5 and 6 may both be of helical form, but in this example the individual turns of both of the windings follow a wavy sinusoidal path as shown at 10 in Figure 1. The waviness of the windings 5 and 6 ensures that they impart not only circumferential tensile strength, but also axial tensile strength to the concrete 9. The outer winding 5 extends into the part of the concrete wall bounding the socket 4 and similarly the inner winding 6 extends into the spigot 2.

- The pipe shown in Figures 1 and 2 is made in the apparatus shown in Figures 3 to 6 of the drawings. This comprises a conventional centrifugal pipe mould 11 having radially projecting end flanges 12 and 13. The flanges 12 and 13 are each supported on a pair of rollers 14 and 15 which are themselves fixed on shafts 16 and 17 respectively. The shafts 16 and 17 are supported in journal bearings 18 which are fixed on channel bearers 19. The shaft 17 has a chain sprocket 20 fixed on it and this sprocket is rotated by a variable speed electric motor 21 through a driving chain 22. Thus, when the motor 21 is in operation, the rollers 15 are rotated in order to spin the mould 11. The mould 11 is spun in a counterclockwise direction as seen in Figure 5 and a shield 23 is provided to give protection against any detritus flung centrifugally from the mould.

- At the left-hand end of the mould 11 as seen in Figures 4 and 6 of the drawings there is a rail track 24 on which a platform 25 with wheels 26 runs. The platform 25 carries a device indicated generally at 27 for feeding a glass fibre roving impregnated with cement slurry to the inside of the mould 11. The provision of the rail track 24 enables the device 27 to be

aligned as necessary with the mould 11 and it also enables it to be moved to any one of a series of moulds 11 which are not shown, but which are arranged spaced apart side by side.

Some of the main parts of the device 27 are shown diagrammatically in Figure 3. The device comprises a bin 28 containing a package 29 of glass fibre roving. The bin 28 has a lid 30 from which a tube 31 extends centrally to a housing 32 containing a pair of feed rollers 33 which are driven by a variable speed electric motor 34 which is electronically controlled by an electronic speed controller 35 shown in Figure 4. The controller 35 is manually operable to set the speed of the motor 34 relative to that of the motor 21 and hence the speed of the roving 29 relative to the peripheral speed of the mould 11. The controller 35 also monitors the speed of the motor 21 and automatically adjusts the speed of the motor 34 so that, once set, the relative speeds of the roving 29 and of the mould 11 are maintained exactly.

Next to the housing 32 and connected to it by a tube 36 is a second housing 37 containing a pair of cutter rollers 38 the upper one of which carries a knife 39. The cutter rollers 38 are rotated by a motor 40 and are movable towards each other to make them operate by a handle 41.

An air mover 42 which is coaxial with the tube 36, is connected to the housing 37 and has a pipe 43 for the supply of compressed air connected to it. The tube 43 is fitted with a stop-cock 44. A flexible tube 45 leads from the air mover 42 to an ejector head 46.

The ejector head 46 comprises a tubular body 47 concentrically surrounding the end of the tube 45 and between the body 47 and the tube 45 is a filter 48. A flexible slurry supply tube 49 is connected to the annular space between the tubular body 47 and the tube 45. This annular space is closed at the left-hand end as shown in Figure 3 and at its right-hand end is filled by a nozzle plate 50 provided with four nozzle orifices two of which are shown at 51 and which are uniformly spaced at 90° angular intervals around the axis of the tube 45. As shown in Figure 3, the nozzle orifices 51 are inclined inwards towards the axis of the tube 45. A conical outlet nozzle 52 having an outlet orifice 53 surrounds the outlets from the orifices 51.

In use, the glass fibre roving from the package 29 extends through the tube 31 and thence through a nip formed between the feed rollers 33 by which the roving is gripped. Thence the roving extends through the tube 36 and freely between the cut-off rollers 38. Thence it extends through the tube 42 into the tube 45 which is a

pneumatic conveying tube through which the roving is conveyed by compressed air supplied through the tube 43. The roving issues from the tube 45 in the centre of the nozzle plate 50 and cement slurry is supplied from the tube 49 under pressure through the nozzle orifices 51 so that jets of the slurry impinge upon the roving 29 and both impregnate it thoroughly and also assist in positively feeding it through the tube 45 so that the impregnated roving issues from the nozzle 53.

As shown diagrammatically in Figure 3, the axis of the ejector head 46 is arranged at a slight inclination to a tangent of the inner face of the mould 11 so that the impregnated roving 28 is fed onto the internal surface of the mould 11 as the mould rotates. The speed at which the roving 29 issues from the nozzle 53 is dependent upon the speed of the feed rollers 33 which can be controlled by the speed controller 35. The roving 29 can be cut off in lengths as required by operating the handle 41 to move the upper roller 38 and trap the roving between the knife 39 and the periphery of the lower roller 38.

As shown most clearly in Figures 4 and 6, the ejector head 46 is supported on the end of a boom 54 extending from a housing 55 which supports the bin 28 and also the housings 32 and 37 on top of it. The housing 55 forms a carriage which slides on rails 56 and has driving chains 57 and 58 attached to it. The driving chains 57 and 58 extend around pulleys and lead to a traversing drive within a housing 59. The traversing drive operating through the chains 57 and 58 moves the housing 55 to and fro along the rails 56 so that the ejector head 46 is moved into the mould 11 as the housing 55 moves towards the right as seen in Figures 4 and 6 and the traversing drive is subsequently controlled so that the ejector head 46 is moved axially to and fro within the mould 11.

A slurry feed hopper 60 is supported on the platform 25 and it has a bottom outlet leading to a positive displacement pump 61 which is driven by an electric motor 62. An outlet from the pump 61 is connected through a valve manifold 63 to the flexible tube 49. A recirculating pipe 64 leads from the valve manifold 63 and when the supply of cement slurry to the tube 49 is restricted by partly closing a valve in the manifold, the slurry is recirculated by the pump 61, through the pipe 64 back to the hopper 60 thus enabling the rate of slurry supply to be adjusted.

An air compressor 65 is mounted on top of an air reservoir 66 which is in turn supported from the platform 25. The tube 43 is connected by a further flexible tube, 65 which is not shown, to an outlet of the

reservoir 66.

The various motors controlling the device for feeding the roving to the ejector head 46 together with the mould-driving motor 21, the motor 62 and a motor driving the compressor 65 are all controlled by controls on a control panel which is not shown.

In order to form a pipe such as that shown in Figures 1 and 2 of the drawings, the mould 11 is set in rotation and the traversing drive 59 is operated to move the ejector head 46 into the mould 11. The supply of compressed air through the tubes 43 and 45 is then started and the feed rollers 33 are set in motion to feed the roving 29 to the ejector head 46. At the same time, the pump 61 is started and the valves in the manifold 43 are set so that cement slurry from the hopper 60 is supplied through the tube 49 to the ejector head 46. The feeding speed of the roving 29 is controlled by means of the feed rollers 33 so that it is somewhat greater than the linear speed of the internal periphery of the mould 11. The roving which is impregnated with cement slurry issuing from the nozzle 53 impinges on the internal surface of the mould 11 and is held there by centrifugal force. As the mould 11 rotates, the head 46 is moved axially along the mould 11 so that a wavy helical winding is formed on the mould. This winding is intimately embedded in the cement slurry which passes through the tube 49 and issues from the nozzle 53 with the glass fibre roving. Thus the layer 7 shown in Figure 2 is built up and the head 46 is moved axially to and fro a number of times as necessary to build up a winding of the required thickness and number of turns.

When this has been done, the feeding of the glass fibre roving 28 and the cement slurry is stopped and concrete to form the body of the wall 9 is fed, by means of a conveyor not shown, into the mould 11 in the normal way for forming the spun concrete pipes. As the mould 11 is spun, this concrete becomes intimately combined with the outer slurry layer 7.

When the pipe wall has been built up to the requisite thickness, the ejector head 46 is moved back again into the mould 11 and it is operated in the same way as before to build up the winding 6. In this case, however, the supply of cement slurry through the tube 49 is reduced. As the mould 11 continues to be spun, some cement slurry from the concrete 9 tends to migrate radially inwards and this in itself is in some cases sufficient to impregnate the winding 6 and ensure that this is thoroughly incorporated in the inner slurry layer 8.

In order to form a vertically cast concrete pipe as shown in Figures 7 and 8 of the drawings, a tubular body 68 is first formed in the apparatus shown in Figures 3 to 6 of the drawings by forming a slurry impregnated winding similar to the winding 5 on the outside of the pipe shown in Figures 1 and 2. This is formed by feeding glass fibre roving and slurry through the ejector head 46 into a mould similar to the mould 11, and then continuing to spin the mould whilst allowing the slurry to set with the usual centrifugal casting technique, but without subsequently adding any concrete to the mould. When the body has become sufficiently self-supporting in the mould 11, the mould 11 is removed from the spinning rollers 14 and 15 and is set aside to allow the shell to harden. At this time a second tubular body 69 is formed in a similar manner, but using a centrifugal casting mould of a smaller diameter.

When the bodies 68 and 69 are sufficiently strong, they are placed in the vertical casting device shown in Figure 7 which comprises a bottom plate 70 and a top plate 71 which is slidable by a mechanism not shown upwards and downwards on guide rods 72. To place the bodies 68 and 69 in position, the plate 71 is raised, the bodies 68 and 69 are set, one inside the other on the bottom plate 70 and the top plate 71 is then lowered into the position shown in the drawing. When this has been done, concrete is introduced into the annular space between the bodies 68 and 69 and is vibrated to consolidate it. The concrete is then allowed to set and harden and the pipe is then removed from the casting mould.

If it is required to make a pipe with only a single glass fibre winding near its outer periphery the body 68 is made and is placed in the device shown in Figure 7 together with a steel mould tube which takes the place of the body 69. The concrete is then cast as before, but when it has set and obtained sufficient strength, the tube which takes the place of the body 69 is removed.

In one example of the manufacture of a pipe similar to that shown in Figures 1 and 2 and having a length of 3 metres, an internal diameter of 900 mm and a wall thickness of 65 mm, using the apparatus shown in Figures 3 to 6 of the drawings, the mould 11 had an internal diameter of 1030 mm and was fitted with shaped ends to form the Ogee or in-wall spigot and socket joint as shown. The mould was rotated at a speed of from 80 to 85 r.p.m. giving a peripheral speed of from 4.31 to 4.58 metres per second. A single roving of Cem-FIL (Registered Trade Mark) alkaline-resistant glass fibre consisting of

about 6000 untwisted continuous filaments of 13 microns in diameter was fed to the head 46 at a speed 10% above the peripheral speed of the mould, that is from 4.74 to 5.04 metres per second. The speed of the roving was accurately controlled by the feed rolls 33, which were themselves controlled by a sensing device monitoring fluctuations in the rotational speed of the mould.

A Portland cement slurry having a water:cement ratio of 0.46:1 was pumped through the pipe 49 to the head 46 where it passed through the nozzles 51 at a speed somewhat higher than that of the roving. The roving met the slurry at the confluence of the jets from the nozzles 51 and owing to the turbulence caused by the jet impingement and because the jet velocity was higher than the speed of the roving, very efficient mixing of the slurry into the roving took place. The roving and slurry passed through the nozzle 53 with the roving only forming a relatively small fraction of the total material. The nozzle 53 was arranged at a distance of between 5 and 10 centimetres from the internal periphery of the mould 11.

The head 46 was moved once along the length of the mould 11 parallel to its axis of rotation and then back again at a speed dependent upon the amount of fibre reinforcement required in order to build up the winding 5. The angle of the head 46 was adjusted at the socket end of the pipe to ensure that the stream of slurry and glass fibre roving entered the part of the pipe surrounding the socket.

After the movement of the head 46 to and fro once along the mould, a 1:2:4 concrete mix with a crushed granite graded aggregate up to 3/4 inch maximum size was loaded into the mould in exactly the same manner as is conventional in the manufacture of spun concrete pipes. The amount of concrete added was such that after compaction approximately 60 mm of the wall thickness of the pipe had been built up. The speed of rotation of the mould was then increased to generate centrifugal compaction forces and to de-water the concrete and slurry, again in a manner similar to that used in conventional spun concrete pipe manufacture.

Next the mould was slowed down again to a speed of 80 to 85 r.p.m. and further glass fibre roving and slurry was ejected from the head 46 as this was again moved once to and fro along the mould. The slurry and fibre speeds were reduced to match the smaller diameter and consequently the smaller peripheral speed of the internal face of the concrete. This formed the second winding 6.

A 2:1 mixture containing granite dust

and cement was added to build up the pipe to its required wall thickness of 65 mm and to form a wearing layer on the bore of the pipe. The speed of the mould was then again increased for a short period to compact this layer and finish off the pipe in the usual way.

The spinning was then stopped and the pipe and mould were removed to a steam chamber for a twelve hour curing period followed by de-moulding and a 28 day air cure before the pipe was ready for use.

The bodies 68 and 69 forming part of the pipe shown in Figures 7 and 8 can be made in a manner similar to the formation of the outer winding 5 in the example just described. That is to say the slurry and glass fibre roving are supplied to a mould in the same way, and no concrete is added and after the winding has been formed, this is followed only by de-watering steam curing and de-moulding.

WHAT WE CLAIM IS:—

1. A tubular body of concrete, cement mortar, or other cementitious material comprising an integrally and centrifugally cast cementitious mass reinforced with a glass fibre strand or roving which is resistant to deterioration by the cementitious mass and forms a winding extending around the body and incorporated and bonded in the cement matrix of the integrally cast cementitious mass.

2. A tubular body according to claim 1, in which the winding is incorporated in the outer peripheral layer of the cementitious mass.

3. A tubular body according to claim 2, in which a second winding of glass fibre strand or roving is incorporated and bonded in the cement matrix of the inner peripheral layer of the cementitious mass.

4. A tubular body according to any one of the preceding claims, in which the winding or each winding is laid along a sinusoidal or other wavy path around the body to impart both circumferential and axial tensile strength to the body.

5. A method of making a tubular body in accordance with claim 1 by a centrifugal casting operation, in which a centrifugal casting mould is rotated and a glass fibre strand or roving is positively fed from a feeding device within the mould at a speed at least as great as the internal peripheral speed of the mould and is caused to adhere to the internal peripheral face of the mould, the feeding device is moved along the mould in the direction of the axis of the mould as the mould rotates so that a coil or winding is formed from the strand or roving around the inside of the mould, and cementitious material is introduced into the mould to form an integrally cast tubular cementitious mass with the coil or

winding incorporated and bonded in the cement matrix of the cementitious mass.

6. A method according to claim 5, in which the cementitious material introduced into the mould is a cementitious slurry, concrete is subsequently introduced into the mould and with the slurry forms the tubular body as the mould is spun and then a second glass fibre strand or roving is fed from the feeding device onto the internal surface of the body and the feeding device is again moved axially along the mould so that a second coil or winding is formed from the strand or roving around the internal peripheral face of the body and becomes embedded and bonded in the cement matrix of the concrete.

7. A method according to claim 5 or claim 6, in which the or each glass fibre strand or roving is impregnated with cementitious slurry by the feeding device and the or each strand or roving together with cementitious slurry are introduced into the mould simultaneously.

8. A method according to any one of claims 5 to 7, in which the strand or roving is fed from the feeding device at a speed substantially greater than the peripheral speed of the internal face of the mould or substantially greater than the peripheral speed of the internal face of the body so that as the feeding device is moved axially along the mould, the strand or roving is laid along a wavy path.

9. Apparatus for carrying out the method in accordance with claim 7, the apparatus comprising a centrifugal mould, a driving mechanism for rotating the mould, a device for impregnating a glass fibre strand or roving with cementitious slurry and positively feeding it to the inside of the mould at a speed at least as great as the internal peripheral speed of the mould and in a position in which the strand or roving impinges on the internal peripheral face of the mould, and a mechanism for moving the feeding device within the mould in the direction of the axis of the mould.

10. Apparatus according to claim 9, in which the device for feeding the glass fibre strand or roving comprises a pneumatic conveying tube having at its discharge end an ejector head having a connection for the supply of the cementitious slurry and a series of nozzles in the head from which, in use, the slurry issues with an inward inclination so that the jets impinge upon the glass fibre strand or roving issuing from the pneumatic conveying tube to impregnate the strand or roving with slurry and carry it along with the slurry.

11. Apparatus according to claim 10, in which a pair of feed rollers is provided to control the speed at which the glass fibre

and cement was added to build up the pipe to its required wall thickness of 65 mm and to form a wearing layer on the bore of the pipe. The speed of the mould was then again increased for a short period to compact this layer and finish off the pipe in the usual way.

The spinning was then stopped and the pipe and mould were removed to a steam chamber for a twelve hour curing period followed by de-moulding and a 28 day air cure before the pipe was ready for use.

The bodies 68 and 69 forming part of the pipe shown in Figures 7 and 8 can be made in a manner similar to the formation of the outer winding 5 in the example just described. That is to say the slurry and glass fibre roving are supplied to a mould and after the winding has been formed, this is followed only by de-watering steam curing and de-moulding.

WHAT WE CLAIM IS:—

1. A tubular body of concrete, cement mortar, or other cementitious material comprising an integrally and centrifugally cast cementitious mass reinforced with a glass fibre strand or roving which is resistant to deterioration by the cementitious mass and forms a winding extending around the body and incorporated and bonded in the cement matrix of the integrally cast cementitious mass.

2. A tubular body according to claim 1, in which the winding is incorporated in the outer peripheral layer of the cementitious mass.

3. A tubular body according to claim 2, in which a second winding of glass fibre strand or roving is incorporated and bonded in the cement matrix of the inner peripheral layer of the cementitious mass.

4. A tubular body according to any one of the preceding claims, in which the winding or each winding is laid along a sinusoidal or other wavy path around the body to impart both circumferential and axial tensile strength to the body.

5. A method of making a tubular body in accordance with claim 1 by a centrifugal casting operation, in which a centrifugal casting mould is rotated and a glass fibre strand or roving is positively fed from a feeding device within the mould at a speed at least as great as the internal peripheral speed of the mould and is caused to adhere to the internal peripheral face of the mould, the feeding device is moved along the mould in the direction of the axis of the mould as the mould rotates so that a coil or winding is formed from the strand or roving around the inside of the mould, and cementitious material is introduced into the mould to form an integrally cast tubular cementitious mass with the coil or

winding incorporated and bonded in the cement matrix of the cementitious mass.

6. A method according to claim 5, in which the cementitious material introduced into the mould is a cementitious slurry, concrete is subsequently introduced into the mould and with the slurry forms the tubular body as the mould is spun and then a second glass fibre strand or roving is fed from the feeding device onto the internal surface of the body and the feeding device is again moved axially along the mould so that a second coil or winding is formed from the strand or roving around the internal peripheral face of the body and becomes embedded and bonded in the cement matrix of the concrete.

7. A method according to claim 5 or claim 6, in which the or each glass fibre strand or roving is impregnated with cementitious slurry by the feeding device and the or each strand or roving together with cementitious slurry are introduced into the mould simultaneously.

8. A method according to any one of claims 5 to 7, in which the strand or roving is fed from the feeding device at a speed substantially greater than the peripheral speed of the internal face of the mould or substantially greater than the peripheral speed of the internal face of the body so that as the feeding device is moved axially along the mould, the strand or roving is laid along a wavy path.

9. Apparatus for carrying out the method in accordance with claim 7, the apparatus comprising a centrifugal mould, a driving mechanism for rotating the mould, a device for impregnating a glass fibre strand or roving with cementitious slurry and positively feeding it to the inside of the mould at a speed at least as great as the internal peripheral speed of the mould and in a position in which the strand or roving impinges on the internal peripheral face of the mould, and a mechanism for moving the feeding device within the mould in the direction of the axis of the mould.

10. Apparatus according to claim 9, in which the device for feeding the glass fibre strand or roving comprises a pneumatic conveying tube having at its discharge end an ejector head having a connection for the supply of the cementitious slurry and a series of nozzles in the head from which, in use, the slurry issues with an inward inclination so that the jets impinge upon the glass fibre strand or roving issuing from the pneumatic conveying tube to impregnate the strand or roving with slurry and carry it along with the slurry.

11. Apparatus according to claim 10, in which a pair of feed rollers is provided to control the speed at which the glass fibre



strand or roving is fed through the pneumatic conveying tube.

12. Apparatus according to any one of claims 9 to 11, in which the mechanism for moving the feeding device within the mould comprises a carriage outside the mould and a mechanism for moving the carriage to and fro along a track which extends parallel to the axis of the mould, the feeding device being mounted on the carriage and extending from the carriage into the mould.

13. A method of making a concrete pipe by a vertical casting operation in which a tubular body is made by a method in accordance with claim 5 or claim 7 when dependent on claim 5, using cementitious slurry to form the cementitious mass and, when the cementitious mass has hardened, the body is introduced into a vertical casting device in which the body constitutes an outer peripheral mould wall, and concrete is introduced between the body and an inner peripheral mould wall of the device and is consolidated to form a concrete pipe which is reinforced by the glass fibre strand or roving incorporated in the body which constitutes the outer peripheral layer of the pipe.

14. A method according to claim 13, in which a second tubular body of smaller diameter than the first body is made by a method in accordance with claim 5 using cementitious slurry to form the cemen-

titious mass and both bodies are introduced into a vertical casting device in which the body of larger diameter constitutes the outer peripheral mould wall and the body of smaller diameter constitutes the inner peripheral mould wall and the concrete is then introduced between the two bodies and is consolidated to form a concrete pipe which is reinforced by the glass fibre strand or roving incorporated in the bodies constituting the outer and inner peripheral layers of the pipe.

15. A tubular body according to claim 1, substantially as described with reference to Figures 1 and 2, or Figures 7 and 8 of the accompanying drawings.

16. A method according to claim 5, substantially as described with reference to Figures 1 to 6 of the accompanying drawings.

17. A method according to claim 13, substantially as described with reference to Figures 7 and 8 of the accompanying drawings.

18. Apparatus according to claim 9, substantially as described with reference to Figures 3 to 6 of the accompanying drawings.

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