

REINFORCEMENT, STRUCTURE AND METHOD FOR UNDERGROUND
REINFORCED CONCRETE CONSTRUCTIONS

The present invention relates to a reinforcement, structure and method for the production of underground reinforced concrete constructions.

The invention has been developed with particular reference, but is not limited, to the construction of tunnel walls and shafts during excavation works.

The excavation of tunnels by excavation machines, among which "tunnel boring machines" (TBM) are known, normally begins by launching the excavation machine from a reinforced concrete shaft structure designed to contain the earth around the tunnel entrance. The shaft is conventionally constructed by means of concrete diaphragms of a shape which tends to be parallelepipedic, excavated and cast in situ in the earth, or by circular piles driven into the earth before works to excavate a tunnel commence.

Excavation machines are normally removed at the end of the tunnel via a previously constructed shaft. It is fairly common, moreover, to provide similar ventilation or access station shafts along the path of the tunnel, or other reinforced concrete structures and diaphragms, as the excavation works proceed.

One of the main challenges to be met is the passage of the TBM through these reinforced concrete diaphragms or structures, which are reinforced by steel bars and rods in order to withstand the bending moments and loads exerted by the surrounding earth. Reinforced concrete is in practice very difficult to destroy because of the additional strength

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provided by the iron bars and their intrinsic ductility which prevents almost all excavation machines from passing through these structures.

For that reason, a reinforcing technique for concrete structures, which does not prevent the passage of an excavation machine, was introduced some time ago. In this technique, also known as "soft-eye" openings, the steel reinforcement is replaced by a fibreglass reinforcement in the area in which the excavation machine is to pass through the concrete structure. It is known in particular to produce a "soft-eye" with a plurality of longitudinal members formed by fibreglass bars held together by a plurality of ties appropriately shaped with respect to the geometry of the underground structure, whether it is a wall or a pile.

The use of fibreglass reinforcements in reinforcing structures for the construction of tunnels facilitates the work of excavation machines, which progress at a pace which is no lower than their pace when these machines encounter materials of similar compressive strength such as rocks and non-reinforced concrete.

Fibreglass typically has a tensile strength greater than iron, but is much more fragile, causing a longitudinal collapse of the polymer resin when the glass fibres are broken. These properties have to be taken into account when producing concrete structures with fibreglass reinforcement, and for that reason the number of longitudinal members and in particular ties is much higher than in conventional reinforced concrete structures with steel reinforcement of a similar strength. To simplify, the frame formed by fibreglass longitudinal members and ties for reinforcing concrete or cement is much denser than a similar

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conventional frame formed by steel longitudinal members and ties.

The above is a drawback when using fibreglass reinforcement in reinforced concrete constructions, which are relatively costly because of the large number of longitudinal members and ties needed to obtain a satisfactory strength. This financial cost is a particular drawback in respect of works that are intended to be temporary, such as temporary underground works which are destroyed when an excavation machine passes through them.

Fibreglass reinforcements are, moreover, relatively more complex to produce than conventional steel reinforcements. While steel bars may be readily deformed, even when cold, to produce ties of the desired dimensions, fibreglass ties have to be shaped in advance at the time of manufacture, with the result that mass production is more costly, complex and problematic. In other words, a fibreglass reinforcing cage or frame is assembled in the same way as a similar steel cage or frame, the main difference being that the fibreglass ties cannot be bent and welded on site, but must be prepared in the factory. This complicates construction and makes the manufacture, transport and installation of concrete structures reinforced with fibreglass reinforcements much more difficult, especially when constructing underground structures.

The present invention proposes to resolve these and other drawbacks of the prior art by means of a reinforcement, structure and method for a strong underground construction which is easy to produce and relatively economic.

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In order to achieve the above-mentioned objects, the invention relates to a reinforcement, structure and method for underground reinforced concrete structures having the features set out in the appended claims.

In an embodiment, a reinforcement, cage, frame or framework of fibreglass or a material having analogous properties of strength and fragility is produced with a plurality of longitudinal members, preferably long fibreglass bars having a smooth or corrugated outer surface, disposed parallel to one another and held together by a plurality of coupling members which are preferably, but not exclusively, flexible in a plane substantially transverse to the direction of the fibreglass bars such that the reinforcement may be made compact for transport.

The reinforcement may also include a limited plurality of relatively rigid coupling members, also of fibreglass, such as ties or the like, solely in order to provide the reinforcement with a predetermined geometric shape. In other words, the ties do not have a basic structural function and do not play a significant part in the calculation of the strength of the underground structure. The small number of fibreglass ties makes it much less difficult to construct the reinforcements than in the prior art in which a very large number of rigid ties are used. The concrete which is cast to incorporate the fibreglass reinforcement contains a certain quantity of metal and/or synthetic fibres which give it a substantial shear strength, especially in the case of large surface areas. Surprisingly, concrete of this kind reinforced by fibres, even when the fibres are metal, does not prevent excavation machines from readily penetrating its structure and destroying it. Moreover, the fibreglass bars which form the longitudinal members of the reinforced

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concrete structure of the present invention themselves provide an excellent bending strength as a result of the longitudinal continuity of the glass filaments within the bars. A reinforced concrete construction is provided with shear strength by including metal and/or synthetic fibres in the cement aggregate.

The flexible tie members are preferably made from strips of polymer material produced by bundles of very strong synthetic fibres incorporated in a strong and durable polymer sheath.

Further characteristic features and advantages of the present invention are set out in the following detailed description of an embodiment, made with reference to the appended drawings, given solely by way of non-limiting example, in which:

- Fig. 1 is a diagrammatic perspective view of an embodiment of a fibreglass reinforcement for the production of a pile for an underground reinforced concrete structure;
- Fig. 2 is a diagrammatic perspective view of a further embodiment of a reinforcement for the production of an underground diaphragm provided with a "soft-eye";
- Fig. 3 is a diagrammatic view in cross-section of an underground diaphragm comprising a "soft-eye" obtained by means of the reinforcement of Fig. 2.

Fig. 1 is a diagrammatic perspective view of an embodiment of a fibreglass reinforcement 1 for the production of a pile for an underground reinforced concrete structure. The fibreglass reinforcement 1 comprises a plurality of fibreglass longitudinal members 2 which extend substantially spaced from and parallel to one another and are arranged in

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a substantially analogous manner to the known metal longitudinal members used for reinforced concrete structures. The longitudinal members 2 are held in position by coupling members 3 which are in particular spaced from one another in comparison with known reinforcements. The coupling members 3 may be attached to the longitudinal members 2 by bindings, clips and the like, or may be coupled by adhesives or other like means.

The coupling members 3 may also be made from fibreglass, thereby helping to keep the reinforcement 1 in its predetermined geometric shape, for instance in the cylindrical shape shown in Fig. 1, or in any desired shape, typically parallelepipedic, for the construction of a wall or diaphragm, as shown in Figs. 2 and 3. In this case, the reinforcement is preferably made in the factory and then transported to its place of use.

In an alternative embodiment, the coupling members 3 are made from strips of polymer material made from bundles of synthetic fibres of high strength incorporated in a strong and durable polymer sheath. An example of a strip particularly suitable for use is the strip used in the earth reinforcing sector and known commercially as ParaWeb^(TM) produced by Officine Maccaferri SpA. The use of flexible coupling members 3 means that the reinforcement can be compacted by closing up the longitudinal members 2 in order to facilitate their transport from the place of manufacture to the place of use. The strips used for the production of the coupling members 3 make it possible to close up the longitudinal members 2 but prevent their relative displacement in the axial direction. In other words, the strips used as coupling members 3 are preferably, but not exclusively, flexible in a plane substantially transverse to

the axial direction of the fibreglass bars, such that the reinforcement may be compacted for transport, and may then be readily brought into the desired geometric configuration simply by moving the longitudinal members 2 apart in the transverse direction up to the maximum extension enabled by the strips used as connecting members 3.

The longitudinal members 2 preferably, but not exclusively, have a diameter of more than approximately 28 mm and preferably, but not exclusively, of less than approximately 42 mm. Although the preferred dimensions of the longitudinal members 2 depend on the particular design of the underground structure to be constructed, it will be appreciated that the use of longitudinal members of a smaller diameter is less advantageous as they have to be provided in relatively large numbers in order to provide the underground construction with the necessary strength to withstand the forces exerted by the surrounding earth. Longitudinal members with a diameter greater than that indicated tend to be less preferred as, because of the delay with which shear stresses are transmitted, the glass fibres closest to the centre of the cross-section of the bar are not subject to a stress that is as high as the stress borne by the fibres closest to the outer surface. This problem generally leads to a relative decrease in the strength and efficiency of fibreglass bars having large diameters in comparison with bars having smaller diameters.

Fig. 2 is a diagrammatic perspective view of the construction of a "soft-eye" with a reinforcement 11 substantially analogous to the reinforcement of Fig. 1, but having a parallelepipedic geometric configuration with longitudinal members 12 also formed by elongate fibreglass bars whose outer surface is smooth or, preferably,

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corrugated, spaced from and parallel with one another and held together by coupling members 13. As mentioned above, the coupling members 13 may be rigid, such as fibreglass ties, or preferably flexible, for instance using polymer strips of the above-mentioned type.

The fibreglass reinforcement 11 acting as a soft-eye is secured to a conventional steel reinforcement 10 formed by steel longitudinal members 15 and steel ties 16, for instance by means of bindings 17. The height D of the fibreglass reinforcement 11 free from the steel reinforcement 10 is at least equal to the excavation dimension of a TBM, as will be described in detail below.

As can be seen from the diagrammatic cross-section of Fig. 3, during use the reinforcement 11 forms the reinforcement of an underground concrete construction 20 in an excavation in the earth T, which is constructed by techniques known in the underground construction sector, by using a concrete aggregate 21 which incorporates the reinforcement 11 (and, when constructing a soft-eye, the steel reinforcement 10 as well).

According to a particular feature, the concrete aggregate 21 internally comprises a plurality of metal and/or synthetic fibres. Examples of such fibres are those known by the trade name Wirand^(R) produced by Officine Maccaferri SpA. The metal and/or synthetic fibres are distributed at random in the concrete as they are mixed with it when it is in the fluid state. The fibres are incorporated in the concrete aggregate and provide it with a shear strength sufficient to eliminate or at least substantially to reduce the need for transverse reinforcing ties in the fibreglass reinforcement 11.

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The production of a construction by means of the reinforced concrete of the present invention follows a procedure which is not dissimilar from the procedure normally used for underground reinforced concrete constructions and is particularly simple for personnel not expressly trained in the use of the invention to carry out on a construction site.

The fibreglass bars which form the longitudinal members 2, 12 respectively of the reinforcement 1, 11 mentioned above are prefabricated. The coupling members 3, 13 may be made from fibreglass and in such a case they are prefabricated with dimensions and measurements which are standard or tailored to the particular design in which they are to be used. In any case, the relatively small number of coupling members 3 means that their manufacture, even when tailored to a particular design, is relatively economic.

In the embodiment in which the coupling members 3, 13 are flexible, for instance using the polymer strips described above, the production of the reinforcements 1, 11 is particularly economic and advantageous, as the production of reinforcements of a geometry and dimensions that are also tailored to a particular design is facilitated by the possibility of cutting the strips, such as the coupling members, to size, and compacting the reinforcements so that they can be transported to the place of use for the construction of the underground structure.

At the construction site, the reinforcement 1, 11 is first prepared by disposing the longitudinal members 2, 12 in the predetermined geometry and holding them in position by fastening to the coupling members 3, 13 if they are rigid, or by expanding the previously compacted reinforcement when the coupling members 3, 13 are formed by flexible members,

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for instance the polymer strips mentioned above, or members functioning in a similar way.

After the excavation in the earth T has taken place by means of known methods, the cylindrical reinforcement 1 is inserted in it, in order for instance to form a pile, or the parallelepipedic reinforcement 11, connected for instance to the reinforcement 10, is inserted in it in order to form a soft-eye in a diaphragm or shaft for the launch of a TBM. The concrete, prepared on site or made remotely at a production plant and brought to the site by concrete mixer, is then poured into the excavation. The concrete aggregate is mixed with metal and/or synthetic fibres of generally known type, for instance of the type disclosed in Patent Specification EP 0 475 917 in the name of the applicants. The fibres may be mixed with the concrete in accordance with the methods disclosed in Document WO 2011/015966 in the name of the applicants. After the concrete has been cast and has hardened, the construction of the underground structure is complete.

The construction provided in this way is characterized by its compressive strength, provided by the concrete, its bending strength, provided by the fibreglass longitudinal members, and its shear strength, provided substantially by the fibres incorporated in the concrete matrix. Another important feature of the structure is that it can be readily penetrated and demolished by an excavation machine, especially a TBM, during works to build a tunnel. This makes the present invention particularly useful for the construction of temporary tunnel walls and TBM launch shafts. The use of the fibres mixed with the concrete makes it possible substantially to reduce the number of coupling members for the longitudinal members without compromising

the strength of the overall structure. By reducing the number of coupling members, the time needed to couple them to the longitudinal members is also proportionally reduced, providing major cost savings for the construction of structures which are typically short-lived as they are designed to be demolished as excavation works progress.

When the coupling members used are flexible, the costs of constructing structures having different geometries, possibly tailored to a particular plan, are also reduced, as are storage and transport costs.

The principle of the invention remaining the same, it will be appreciated that the embodiments and constructional details may be widely varied with respect to those described and illustrated, without thereby departing from the scope of the invention.

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CLAIMS

1. A reinforced concrete structure comprising a reinforcement (1, 11) made from a plurality of elongate longitudinal members (2, 12) of fibreglass or like material, disposed substantially parallel with one another in at least one predetermined direction and coupled to one another by means of coupling members (3, 13), metal and/or synthetic fibres being mixed with the concrete matrix.

2. A reinforced concrete structure according to claim 1, wherein the elongate longitudinal members (2, 12) of fibreglass have a corrugated outer surface.

3. A reinforced concrete structure according to claim 1 or 2, wherein the elongate longitudinal members (2, 12) have a diameter greater than approximately 28 mm and not more than approximately 42 mm.

4. A reinforcement for a reinforced concrete structure according to any one of the preceding claims, comprising a plurality of elongate longitudinal members (2, 12) of fibreglass or like material, disposed substantially parallel with one another in at least one predetermined direction and coupled to one another by means of flexible coupling members (3, 13).

5. A reinforcement according to claim 4, where the flexible coupling members (3, 13) comprise strips of polymer material made from bundles of synthetic fibres of high strength incorporated in a polymer sheath.

6. A reinforcement according to claim 4 or 5, wherein the elongate longitudinal members (2, 12) are connected to

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respective metal longitudinal members of a metal reinforcement for the production of a "soft-eye".

7. The use of a reinforced concrete structure according to any one of claims 1 to 3 for the construction of temporary underground structures in the construction of excavated works such as tunnels and the like.

8. A method for the construction of underground reinforced concrete structures, comprising:

- the preparation of a reinforcement (1, 11) made from a plurality of elongate longitudinal members (2, 12) of fibreglass or like material, disposed substantially parallel with one another in at least one predetermined direction and coupled to one another by means of coupling members (3, 13),
- the preparation of an excavation in the earth (T),
- the insertion of the reinforcement (1, 11) into the earth excavation (T),
- the filling of the earth excavation with concrete (21) in order to incorporate the reinforcement (1, 11), metal and/or synthetic fibres being mixed with the concrete.