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(54) Title: HYBRID REINFORCED LAYER OF SPRAYED CONCRETE

(57) Abstract: A layer of sprayed concrete or shotcrete comprises a mix of hydrophilic fibres with synthetic fibres or steel fibres or both. The hydrophilic fibres improve the adhesion and cohesion of the sprayed concrete while the steel fibres or the synthetic fibres (or both) give structural strength to the sprayed concrete.

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Title: HYBRID REINFORCED LAYER OF SPRAYED CONCRETE

Description

Technical Field

[0001] The invention relates to a layer of sprayed concrete and to a method of spraying a layer of concrete on a substrate.

Background Art

[0002] Layers of sprayed concrete, more and more referred to as “shotcrete” or “gunite” are known in the art.

[0003] Sprayed concrete is mixture of cement, aggregate, other added ingredients such as admixtures, and water projected pneumatically from a nozzle into place to produce a dense homogeneous mass.

[0004] The main advantage of sprayed concrete is that no shutters or formwork are needed to hold the concrete in place while the concrete sets and hardens.

[0005] There are also disadvantages associated with sprayed concrete.

[0006] Depending upon the particular process applied and upon the composition, there may be a large amount of rebound.

[0007] In addition, problems of adhesion or sagging of the sprayed layer are sometimes met which can limit the thickness of the layer that can be applied at a time. Depending on the overall thickness requirement, this can result in multiple layers needing to be applied to obtain the overall specified thickness.

Disclosure of Invention

[0008] It is a general object of the invention to avoid the drawbacks of the prior art.

[0009] It is a particular object of the invention to help to reduce the degree of rebound.

[0010] It is another object of the invention to increase the adhesion of bond of a sprayed concrete layer to its substrate or underground, as well as its cohesion of the mixture which facilitates thicker layers of sprayed concrete

to be applied at one pass. Depending upon the ultimate required thickness of the concrete layer added cohesiveness of the mixture can eliminate the need for the shotcrete to be applied in multiple layers thereby greatly improving the efficiency of the spraying operation.

[0011] According to a first aspect of the the invention there is provided a layer of sprayed concrete. This layer comprises a hybrid reinforcement. The layer comprises a mix of hydrophilic fibres with synthetic fibres or steel fibres or both.

[0012] Apart from the steel fibres, the layer does not comprise elongated metal elements such as a metal framework or rebars or a wire net.

[0013] The hydrophilic fibres have an affinity with water and absorb water, which is beneficial for the mechanical and chemical bond of these fibres with cement. This explains the increased cohesion and adhesion of the sprayed concrete layer and a reduction in the degree of rebound as well as facilitating the ability to apply thicker layers at one time.

[0014] Another advantage of hydrophilic fibres is release of the absorbed water during drying of the concrete, which helps to reduce drying shrinkage cracking as well as provides for internal curing of the concrete. Moreover, the increased adhesion of the hydrophilic fibres results in improved finishing characteristics.

[0015] When adding either steel fibres or synthetic fibres or both to the sprayed concrete, the structural properties of the sprayed concrete are improved and the norms in existing standards can be met. With steel fibres or synthetic fibres the layer of sprayed concrete can be used in structural applications, i.e. applications where the layer functions as a load bearing element.

[0016] The hydrophilic fibres are not connected or bound to the steel fibres or synthetic fibres. Although there can be accidental point to point contact, in general the hydrophilic fibres remain loose from the steel fibres or synthetic fibres.

[0017] GB-A-1 429 167 discloses a cementitious matrix that is reinforced by absorbent fibres and other 'strong' fibres such as steel fibres, glass fibres, … In order to avoid damage to the absorbent fibres during mixing, the absorbent fibres are bound to the strong fibres, e.g. by means of a tape. GB-A-1 429 167 does not disclose sprayed concrete.

[0018] The hydrophilic fibres may be natural fibres. The most common natural fibres for this application come from the bast fibres classification. Amongst the main plants used for the supply of bast fibres are flax, jute, hemp, ramie and kenaf.

[0019] The layer of sprayed concrete may comprise between 0.75 kg/m³ and 4 kg/m³ of hydrophilic fibres, preferably between 0.8 kg/m³ and 2 kg/m³.

[0020] The layer of sprayed concrete may comprise between 20 kg/m³ and 40 kg/m³ of steel fibres, preferably between 25 kg/m³ and 35 kg/m³.

[0021] The layer of sprayed concrete may comprise between 4 kg/m³ and 8 kg/m³ of synthetic fibres, preferably between 5 kg/m³ and 7 kg/m³.

[0022] In order to further promote the adhesion and cohesion of the sprayed concrete and to further reduce the rebound, the synthetic fibres or the steel fibres are provided with anchorages in the form of thickened or enlarged portions or ends, flattened portions or ends, hooked ends, bent ends, undulated portions, or any combination thereof.

[0023] In a preferable embodiment of the invention, steel fibres have anchorages in the form of at least three straight sections that are connected to each other by bent sections.
These types of steel fibres are disclosed in WO-A1-2012/080323. The steel fibres preferably have a tensile strength above 1400 MPa, preferably above 1500 MPa, e.g. above 1600 MPa.

[0024] According to a second aspect of the present invention, there is provided a method of spraying concrete to a substrate. This method comprises the following steps:
a) mixing cement, aggregates, added ingredients, hydrophilic fibres and synthetic fibres or steel fibres together to form a global mix;
b) projecting the global mix pneumatically from a nozzle to a substrate.

[0025] Preferably the hydrophilic fibres and the synthetic fibres or steel fibres are loosely mixed in the global mix, without forming a bond.

[0026] In one alternative way, water is added at the global mix before conveying the global mix to the nozzle.

[0027] In another alternative way, water is added at the nozzle and a dry global mix is conveyed to the nozzle.

Mode(s) for Carrying Out the Invention

SPRAYED CONCRETE

[0028] Sprayed concrete is a mixture of cement, aggregate, water and other added ingredients.

[0029] The water cement ratio is usually kept below 0.5, preferably below 0.45. The cement may be a Portland cement. Fresh cement is recommended for sprayed concrete. The fineness of the cement, as measure in accordance with the Blaine method ASTM 204-84, is preferably above 350 m^2/kg, most preferably above 400 m^2/kg.

[0030] The aggregate is usually an aggregate that is available. This can be crushed granite, sand, …

[0031] A preferable added ingredient is silica fume or microsilica. Microsilica may be present in percentages of 5% to 10% of cement weight. Microsilica

have a filler effect and make production of higher compressive strength sprayed concrete economical.

[0032] Another preferable added ingredient is a superplasticiser. The superplasticiser may be a water reducer to improve concrete workability and cohesiveness in the plastic state. The thus realized reduction in water cement ratio w/c may lead to an increase in compressive strength and durability. The superplasticiser may also be beneficial to pumpability. Combinations of naphthalene and melamine may be used as superplasticiser. Preferred dosage may range from 4 kg/m³ to 10 kg/m³. Recent alternatives are referred to as hyperplasticisers and are based upon modified polycarboxylic ether. They offer a higher water reduction without deteriorating the workability.

[0033] Yet another highly preferable ingredient to be added are hydration control admixtures. In short these admixtures extend the 'pot-life' of the concrete, i.e. the time during which the prepared mixture can still be projected without problems from one to two hours to three to seventy-two hours. Useful hydration control admixtures are put on the market under the name Delvocrete Stabiliser.

HYDROPHILIC FIBRE

[0034] Hydrophilic fibres are present in the layer of sprayed concrete of the invention. The hydrophilic fibres may be natural fibres, such as bast fibres, e.g. flax, jute, hemp, ramie and kenaf fibres. A bast fibre is a plant fibre collected from the phloem (the "inner bark", sometimes called "skin") or bast surrounding the stem of certain dicotyledonous plants.

STEEL FIBRE

[0035] Next to hydrophilic fibres, either steel fibres or synthetic fibres or both are present in the layer of sprayed concrete. The steel fibres, more particularly the middle portion of the steel fibres typically have a diameter D ranging from 0.10 mm to 1.20 mm. In case the cross-section of the steel fibre and more particularly of the middle portion of the steel fibre is not round, the diameter is equal to the diameter of a circle with the same

surface area as the cross-section of the middle portion of the steel fibre. The steel fibres; more particularly the middle portion of the steel fibres typically have a length to diameter ratio L/D ranging from 40 to 100. The middle portion preferably has a length exceeding 30 mm, e.g. 50 mm, 60 mm or 70 mm.

[0036] A particular advantageous steel fibre for layers of sprayed concrete is a steel fibre according to WO-A1-2012/080323. The steel fibre comprises a middle portion and an anchorage end at one or both ends of the middle portion. The middle portion has a main axis. The anchorage end or anchorage ends comprise(s) at least a first, a second and a third straight section. Each of the straight sections has a main axis, respectively the main axis of the first straight section, the main axis of the second straight section and the main axis of the third straight section.
The first straight section is connected to the middle portion by a first bent section; the second straight section is connected to the first straight section by a second bent section; the third straight section is connected to the second straight section by a third bent section.
This means that the first straight section is bent away from the middle portion by the first bent section; the second straight section is bent away from the first straight section by the second bent section and the third straight section is bent away from the second straight section by the third bent section.
The first straight section is bending away from the main axis of the middle portion thereby defining an included angle between the main axis of the middle portion and the main axis of the first straight section.
The second straight section is substantially parallel with the main axis of the middle portion.
The third straight section is bending away from the main axis of the middle portion in the same direction as the first straight section is bending away from the main axis of the middle portion thereby defining an included angle between the main axis of the second straight section and the main axis of said third straight section.

The included angle between the main axis of the middle portion and the main axis of said first straight section ranges preferably between 100 and 160 degrees. The included angle between the main axis of the second straight section and the main axis of the third straight section ranges preferably between 100 and 160 degrees.

[0037] In a preferred embodiment the anchorage end of this steel fibre further comprises a fourth straight section. This fourth straight section is connected to the third straight section by a fourth bent section. This means that the fourth straight section is bending away from the third straight section by the fourth bent section. Preferably, but not necessarily, the fourth straight section is parallel with the main axis of the middle portion and with the main axis of the second straight section.

[0038] Since steel fibres may appear at the surface of a layer of sprayed concrete, they may be subject to corrosion. Therefore, the steel fibres may be provided with a corrosion-resistant coating, e.g. a polymer coating or a metal coating such as a zinc alloy coating.

SYNTHETIC FIBRE

[0039] The synthetic fibres are usually derived from hydro-carbon (oil and/or gas) feedstock. The synthetic fibres may be macro-synthetic fibres from thermoplastic polymers. Suitable polymers are polyolefins, polyesters, polyvinylidene chlorides, polyamids, or polyacrylics. Suitable polyolefins are polyethylene and polypropylene. A preferred synthetic fibre is e.g. a polypropylene fibre with a length between 30 mm and 60 mm.

[0040] The layer of sprayed concrete according to the invention can be made by the dry-mix process or by the wet-mix process.

DRY-MIX PROCESS

[0041] In the dry-mix process all the ingredients such as cement, aggregates, added ingredients and the two or three types of fibres are put together and thoroughly mixed in a dry state. The dry mix is then conveyed by compressed air through hoses to a nozzle at which point the water is added. At the discharge nozzle an atomized spray of water enters through a water ring.

WET-MIX PROCESS

[0042] In the wet-mix process all the ingredients, including the proper amount of water, are thoroughly mixed. The thus obtained wet mix is fed into a hopper and conveyed to the spray nozzle either in dense-flow using a concrete pump or in a dispersed thin-flow using compressed air.

[0043] In the wet-mix process fast setting admixtures or set accelerators are added at the level of the nozzle. The purpose is to reduce the slump at the moment of spraying and to allow to spray on vertical substrates and overhead. These set accelerators may be modified sodium silicates or alkali-free accelerators.

APPLICATIONS

[0044] The layer of sprayed concrete according to the invention may be used on a hard substrate, such as rock or granite, or on a loose substrate, such as earth.

[0045] The layer of sprayed concrete with the hybrid reinforcement may be used as effective lining in underground tunnelling and underground mining. It may also be used in other applications such as concrete repair, coastal protection works, cement storage doms, etc…

Claims

1) A layer of sprayed concrete,
said layer comprising a mix of hydrophilic fibres with
synthetic fibres or steel fibres or both.

2) The layer according to claim 1,
wherein said layer does not comprise elongated metal elements for reinforcing apart from said steel fibres.

3) The layer according to claim 1 or 2,
wherein said hydrophilic fibres are natural fibres.

4) The layer according to any one of the preceding claims,
wherein said natural fibres are bast fibres.

5) The layer according to any one of the preceding claims,
said layer comprising 0.5 kg/m³ to 4.0 kg/m³ of hydrophilic fibres.

6) The layer according to any one of the preceding claims
said layer comprising 20 kg/m³ to 40 kg/m³ of steel fibres.

7) The layer according to any one of claims 1 to 4,
wherein said layer comprises 4 kg/m³ to 8 kg/m³ synthetic fibres.

8) A method of spraying concrete to a substrate, said method comprising the following steps:
   a) mixing cement, aggregates, added ingredients, hydrophilic fibres and synthetic fibres or steel fibres together to form a global mix;
   b) projecting said global mix pneumatically from a nozzle to a substrate.

9) The method of claim 8, wherein said hydrophilic fibres and said synthetic fibres or steel fibres are loosely mixed in said global mix, without forming a bond.

10) The method according to claim 8 or claim 9, wherein water is added at the global mix before conveying the global mix to the nozzle.

11) The method according to claim 8 or claim 9, wherein water is added at the nozzle and wherein a dry global mix is conveyed to the nozzle.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/073315

A. CLASSIFICATION OF SUBJECT MATTER
INV. C04B28/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 October 2019	16/10/2019

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/073315

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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