

DESCRIPTION

METHOD FOR PRODUCING PRESTRESSED CONCRETE

Technical Field

[0001]

The present invention relates to a prestressed concrete obtained by introducing a chemical stress induced by a concrete expansive material and a mechanical stress using a continuous fiber-reinforcing wire together, and particularly relates to a method for producing the prestressed concrete, using sulfate ions or seawater containing sulfate ions as a mixing water.

Background Art

[0002]

Conventionally, a concrete obtained by introducing a prestress into a cement-based material having an excellent mechanical characteristics (compressive strength, bending strength, or the like) has been developed.

[0003]

In a conventional prestressed concrete, in the case of a pre-tensioning method, using a high-tensile steel material (PC steel material) as a tensional material to introduce a prestress, a concrete is poured while a PC steel wire or a PC steel strand wire obtained by twisting two or three wires is tensioned by a long line method or a form-fixing method, and, these PC steel wires are cut after curing and hardening to

manufacture a prestressed concrete.

[0004]

In recent years, a prestressed tensional material using a rod of a fiber material reinforced in one direction with a glass fiber, a carbon fiber, an aramid fiber, or the like having a high-strength has been used, and has attracted attention as a prestressed concrete having excellent corrosion resistance.

[0005]

JP2004-155623A discloses a technique for expressing high tensile strength of a prestressed concrete, or high shear strength thereof.

[0006]

JP 2002-326285 A disclose a technique for a prestressed concrete tensional material using a continuous fiber-reinforced plastic composite material.

[0007]

In addition, usually, a concrete structure starts to be dried from a surface thereof. Therefore, when a shrinkage stress thereof is higher than a tensile strength of the concrete, a crack is generated.

[0008]

In order to reduce the cracks, it is necessary to make the expansion amount sufficient to compensate a drying shrinkage amount of a concrete or to reduce the drying shrinkage amount by blending a predetermined concrete admixture to the

concrete. As a concrete admixture thereof, an expansive material or a shrinkage reducing agent is known.

[0009]

Among these materials, the expansive material contains a material expanding in accordance with a hydration reaction, and prevents drying shrinkage of a concrete structure due to hydration expansion.

[0010]

JP 2005-162564 A disclose an expansive material of a concrete. This makes inexpensive quick lime sufficiently usable as an expansive material for a mortar or a concrete, for example, without subjecting quick lime to a complicated treatment such as a treatment for manufacturing a clinker burning materials by adding another raw material component like in prior art, and almost without causing an increase in cost. This provides an expansive material capable of granting such a stable expansion force to be able to complete with contraction of a mortar or a concrete or an external pressure sufficiently, in particular, an expansive material capable of introducing a chemical prestress without using a large amount of the expansive material, and a concrete capable of introducing a chemical prestress.

[0011]

AS described above, a prestressed concrete has been developed in order to overcome the largest problem of a concrete that the concrete is resistant to compression but is not

resistant to tension. The prestressed concrete makes a compressive force applied (prestressed) to a concrete member before a load is applied, prevents generation of a tensile stress in the concrete when the concrete receives the load, or controls the tensile stress .The prestressed concrete can prevent cracking due to a tensile stress compared to a reinforced concrete.

[0012]

In addition, in recent years, construction materials have been in short supply because of the post-disaster construction in the area stricken by the Tohoku Earthquake, etc., and concrete using seawater as a mixing water has been developed.

[0013]

For example, JP 2015-20925 A discloses a method for producing concrete using seawater as a mixing water for mixing a binder and a fine aggregate, which is injection mortar for use in a pre-packed concrete construction method using a concrete shell crushed to a size of 200 mm or more and 500 mm or less as a coarse aggregate or in a post-packed concrete construction method.

[0014]

Seawater is used as a mixing water for the purpose of improving the initial strength and reducing the duration until the removal of forms, which ensures sufficient strength, increases the production efficiency, and also contributes to

the suppression of bleeding.

[0015]

In addition, JP 2005-281112 A discloses seawater-blended alumina cement concrete obtained by disposing a reinforcing steel structure made of reinforcing steel in a concrete form, then mixing alumina cement, seawater, a fine aggregate, and a coarse aggregate to produce fresh concrete in a fluid state, and pouring the fresh concrete into the form to embed the reinforcing steel structure, followed by hardening.

[0016]

As compared with tap water-blended ordinary Portland cement concrete or tap water-blended alumina cement concrete, the corrosion prevention effect on the reinforcing steel is higher.

[0017]

In addition, it is stated that the above technology is also applicable to corrosion prevention in the PC steel material of prestressed concrete.

[0018]

Like this, conventionally, because seawater contains saline matters and rusts reinforcing steel, various regulations have been set in the production of concrete. However, in some usages, seawater has been increasingly utilized for improving the initial strength, preventing the corrosion of reinforcing steel, and the like.

Citation List

Patent Literature

[0019]

Patent Literature 1: JP 2004-155623 A

Patent Literature 2: JP 2002-326285 A

Patent Literature 3: JP 2005-162564 A

Patent Literature 4: JP 2015-20925 A

Patent Literature 5: JP 2005-281112 A

Summary of Invention

Technical Problem

[0020]

As shown in the above patent publications of related art, various types of prestressed concrete have been developed in order to increase the strength thereof..

[0021]

As an application, a conventional prestressed concrete is often applied to a bridge, a electric pole, a concrete pile, a construction member, a beam of building, or the like, and is mainly used for a structural material.

[0022]

A prestressed concrete is an effective technique capable of suppressing cracking on a surface, which may be a fate of concrete.

[0023]

In addition, according to the above patent publications

of related art, because of the use of seawater as a mixing water for concrete, effects of improving the initial strength and preventing the corrosion of reinforcing steel can be expected.

[0024]

In prestressed concrete, for the application of mechanical prestress, the concrete is placed with a tensional material being under tensile stress. However, after placement, the bond strength between the tensional material and the concrete is problematic. That is, a concrete expansion effect is required at the time of hardening.

[0025]

When the bond strength is small, sliding occurs at the bonding site between the tensional material and the concrete, whereby prestress is not sufficiently exerted.

[0026]

The above patent publication of related art (JP 2005-281112 A) states that the technique is applicable to prestressed concrete. Although alumina concrete has high density and can increase the strength, suppress the entry of chlorine ions from outside, and prevent a PC steel material from rusting, as compared with Portland cement, the hardening period is extremely shorter, and hardening takes place while the generation of ettringite, which exerts an expansion effect, is insufficient; accordingly, almost no expansion effect can be expected. Therefore, the bond strength cannot be increased.

[0027]

Ettringite ($3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot3\text{CaSO}_4\cdot32\text{H}_2\text{O}$) is a hydrate that is generated, at the time of cement hydration where SO_4^{2-} (sulfate ion) and H_2O are present, as a result of the reaction of an aluminate phase (tricalcium aluminate, $3\text{CaO}\cdot\text{Al}_2\text{O}_3$) with SO_4^{2-} (sulfate ions) and H_2O . When the amount of ettringite generation is too large, the cement hardened body is expanded.

[0028]

The generated ettringite ($3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot3\text{CaSO}_4\cdot32\text{H}_2\text{O}$) is in the form of extremely small crystals of about several microns. Such crystals are colloidal in the cement paste hardening process and develop into a burr-like form in fine voids in the gel, thereby functioning to reduce shrinkage due to hardening of the gel and shrinkage due to drying and further cause expansion. Expansion in this case means expansion deformation that occurs with an increase in strength. In the present invention, it is believed that in prestressed concrete, such expansion promotes the strength and expansion of the bonding site between the tensional material and the concrete and increases the bond strength.

[0029]

The present invention has been accomplished in view of the above problems, and an object thereof is to provide a prestressed concrete having increased bond strength and allowing for sufficient exertion of the strength by prestress,

using chemical stress by an expansive material and mechanical stress by a continuous fiber reinforcing wire together, and also using seawater as a mixing water.

Solution to Problem

[0030]

In order to solve various problems, in claim 1 of the present invention, a method for producing prestressed concrete, including introducing mechanical stress by a tensional material and chemical stress by an expansive material, the method being configured such that in the production, a cement material excluding alumina cement is used, and sulfate ions are mixed with a mixing water in a proportion of 1,000 to 5,000 ppm per unit mass of the mixing water.

[0031]

The mechanical stress by a tensional material may be any stress as long as mechanical tensile stress can be previously introduced into concrete using a wire rod as the tensional material. The prestress introduction method may be either a pre-tensioning method or a post-tensioning method.

[0032]

With respect to the chemical stress induced by an expansive material for a concrete, any expansive material used for a concrete may be mixed, and an admixture capable of introducing a chemical stress into a concrete or the like may be mixed.

[0033]

The mixing water is water for mixing binders, such as cement, and aggregates, such as gravel and sand. Conventionally, fresh water such as tap water is used. However, in claim 1 of the present invention, water having mixed therewith sulfate ions is used.

[0034]

Sulfate ions (SO_4^{2-}) used in the present invention are not limited as long as they serve as sulfate ions in the mixing water. For example, water-soluble sulfates, sodium sulfate (Na_2SO_4), and the like may be used.

It is necessary that the sulfate ions in a mixing water are such that the amount of ettringite generated at the time of cement hydration is sufficient to cause an expansion effect.

When the proportion of sulfate ions in a mixing water is 1,000 ppm or less, the generation of ettringite is insufficient; therefore, this is undesirable. When the proportion is 5,000 ppm or more, the amount of ettringite generation is too large, resulting in an excessive expansion effect, which causes cracking; therefore, this is undesirable.

The proportion is preferably 1,500 to 4,000 ppm, and still more preferably about 1,800 to 3,000 ppm.

[0035]

In claim 2, in the method for producing prestressed concrete, seawater is used as the sulfate ions mixed with the

mixing water.

[0036]

Seawater is water extracted from the sea and composed of water as a main component, about 3.5% salt, and trace metals. The content of sulfate ions (SO_4^{2-}) is about 0.2649 mass%. (The content varies depending on the sea area.)

[0037]

Generally, in the case of reinforced concrete using Portland cement as a concrete material or prestressed concrete using a PC steel material, the inside of concrete is alkaline, and, on the surface of the steel material of reinforced PC, for example, a thin film of iron hydroxide ($\gamma\text{-Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$, wherein n is a natural number) having a thickness of about 20 to 60 μm (hereinafter referred to as "passive film") is formed. Thus, such a steel material is electrochemically stable and resistant to corrosion.

[0038]

However, a concrete structure has a problem in that when chloride ions (Cl^-) penetrate into the concrete, the passive film on the surface of the steel material is broken, resulting in corrosion of the steel material. Therefore, generally, seawater has been hardly used as a mixing water.

[0039]

As the seawater, seawater extracted from the sea may be directly used, but it is preferable to use seawater from which

garbage and the like have been removed through a filter or the like. It is also possible that instead of surface seawater having a large amount of floating matter, seawater from a certain depth, where garbage and the like are hardly present, is pumped up and used.

[0040]

In claim 3, in the method for producing prestressed concrete according to claim 1 or 2, the tensional material is a rust-resistant wire.

[0041]

The rust-resistant wire may be any wire as long as having no risk of rupture of a concrete by expansion due to the rust of a tensional material after the concrete is poured. Examples thereof include a rust-resistant metal such as stainless steel, an aluminum alloy, a titanium alloy, a nickel alloy, a chromium alloy, a molybdenum alloy, or a tungsten alloy, and a non-metal material such as a resin material and a vegetative fiber material.

[0042]

In claim 4, in the method for producing prestressed concrete according to claim 1 or 2, the tensional material is a continuous fiber-reinforcing wire.

[0043]

The continuous fiber-reinforcing wire is a linear continuous fiber reinforced material, which is a PC tensional

material using a reinforced fiber reinforcing material continuously molded in a linear shape. The Continuous fiber reinforcing material is a generic name of materials obtained by binding a carbon fiber, a glass fiber, a aramid fiber, a vinylon fiber, or the like with an epoxy resin or the like.
[0044]

The reinforced fiber reinforcing material has better physical properties (tensile strength, elastic modulus) than reinforcing steel together with excellent anticorrosive and electromagnetic properties that reinforcing steel does not have, such as light weight, high strength, high elasticity, corrosion resistance, a non-conductive property, or a non-magnetic property, and the like.
[0045]

The linear shape generally means a linear shape or a two-dimensionally or three-dimensionally assembled shape from a shape unit thereof, such as a round shape, a rectangular shape, an irregular shaped (rib, or indented surface) rod, a braided shaped rod, a twisted wire-shaped strand, or a lattice shape.
[0046]

In claim 5, in the method for producing prestressed concrete according to claim 4, the continuous fiber reinforcing wire is a reinforced fiber wire of one or more kinds of fiber selected from a metal fiber, a aramid fiber, a carbon fiber, a glass fiber, and a poly-p-phenylenebenzobisoxazole fiber.

[0047]

In claim 6, in the method for producing prestressed concrete according to any one of claim 1 to claim 5, the expansive material for a concrete is a mixture of one or more kinds selected from a lime-based expansive material such as a quick lime, a calcium sulfoaluminate, an ettringite-based expansive material derived from seawater, ettringite-lime composite expansive material, an iron powder-based expansive material, a magnesium-based expansive material, an aluminum powder-based expansive material, a shale-based expansive material, and a silica-based expansive material.

[0048]

The chemical stress only needs to act on a surface of a concrete. Any chemical stress can be used as long as having effects for reducing a weight and suppressing crack. A combination thereof is not limited.

[0049]

In claim 7, in the method for producing prestressed concrete according to any one of claim 2 to claim 6, the seawater for use as the mixing water is used in an amount of 50 to 200 wt% relative to the total weight of the mixing water.

[0050]

With respect to the amount of seawater used as a mixing water, when it is 50 wt% or less, the amount of sulfate ions in the seawater is small, and the amount of generated ettringite

($3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 3\text{CaSO}_4\cdot 32\text{H}_2\text{O}$), which serves as an expansive material that expands the cement hardened body, is so small that no expansion effect can be expected. The amount is preferably 60 to 150 wt%, and still more preferably 80 to 120 wt%.

[0051]

In the case of using concentrated seawater prepared by concentrating seawater, the amount of seawater is calculated in terms of the weight of natural seawater before concentration.

[0052]

In claim 8, in the method for producing prestressed concrete according to any one of claim 2 to claim 7, sulfate ions contained in the seawater are contained in a proportion of 1,500 to 3,000 ppm per unit mass of the seawater.

[0053]

Sulfate ions in natural seawater are considered to be about 2,000 to 2,800ppm. The concentration somewhat changes in the case where garbage and the like are removed through an ordinary filter, but is within a range of 1,500 to 3,000 ppm no matter which seawater is used.

[0054]

In claim 9, in the method for producing prestressed concrete according to any one of claim 2 to claim 8, the seawater for use as a mixing water is seawater from which chlorine ions have been removed.

[0055]

For the removal of chlorine ions, various existing techniques may be used. For example, a method in which chloride ions are precipitated in an aqueous silver nitrate solution as silver chloride and removed may be employed, and it is also possible to use an ion exchange resin and the like.

[0056]

In claim 10, in the method for producing prestressed concrete according to any one of claim 1 to claim 9, a discontinuous fiber reinforcing material has been mixed at a time of concrete placement.

[0057]

The discontinuous fiber reinforcing material may be any material as long as it is a fiber reinforced material in a discontinuous state.

[0058]

With respect to a size of a fiber, a diameter of 0.005 to 1.0 mm and a length of 2 to 30 mm are preferable, and a diameter of 0.01 to 0.5 mm and a length of 5 to 25 mm are more preferable from viewpoints of preventing material separation of the fibers in a formulation and improving bending strength or toughness after hardening. An aspect ratio of a carbon fiber (fiber length/fiber diameter) is preferably 20 to 200, and more preferably 30 to 150.

[0059]

With respect to the blending amount thereof, it is

suitable that the volume percentage in the blend is 0.2 to 5.0%, preferably 0.5 to 3.0%, and more preferably 0.8 to 2.0%. When the blended amount is less than 0.2%, improvement in bending strength or toughness cannot be expected. Meanwhile, when the blended amount is more than 5.0%, the unit water content increases in order to secure fluidity and the like. In addition, an increase in blended amount does not improve the reinforcing effect of fibers and thus is not economical, and is further likely to cause the formation of so-called fiber balls in the mixture. Therefore, this is undesirable.

[0060]

In claim 11, in the method for producing prestressed concrete according to any one of claim 1 to claim 10, the discontinuous fiber reinforcing material is a reinforced fiber material formed of one or more kinds of fiber selected from a metal fiber, a carbon fiber, a glass fiber, and a resin fiber.

Advantageous Effects of Invention

[0061]

The present invention has the following effects.

1) In the method for producing prestressed concrete, sulfate ions are used in a mixing water. As a result, ettringite, which is an expansive material, is generated at the time of cement hydration. Accordingly, due to its expansion effect, the bond strength between the tensional material and the concrete can be increased.

[0062]

2) In the method for producing prestressed concrete, seawater is used as a mixing water. As a result, because of sulfate ions in seawater, ettringite, which is an expansive material, is generated at the time of cement hydration. Accordingly, due to its expansion effect, the bond strength between the tensional material and the concrete can be increased.

[0063]

3) Because of the enhancement of bond strength described above, sliding at the time of mechanical prestressing can be suppressed, whereby strong and highly reliable prestressed concrete can be realized.

[0064]

4) Because of the enhancement of bond strength described above, the effective range of the tensional material in mechanical prestressing can be greatly extended.

[0065]

5) Because seawater is used as a mixing water, due to its expansion effect, the portion unlikely to be affected by mechanical prestress can be compensated with chemical stress.

[0066]

6) Because seawater from which chlorine ions have been removed is used as a mixing water, even when a PC steel material is used as a tensional material, the problem of rusting can be

solved.

[0067]

7) When a discontinuous fiber reinforcing material is incorporated into concrete, the bending strength of the concrete can be improved, whereby the effect of an expansive material can be increased, and the bond strength can be increased.

[0068]

8) It becomes possible to thin or notch concrete, and the degree of freedom in design is widened largely.

[0069]

9) Due to synergistic effects of a mechanical stress, a chemical stress, and an ettringite generation, the strength can be increased even when a shape of a surface changes or cut out shape or an opening is provided. Therefore, a drastic design configuration can be made, and a more flexible prestressed concrete can be realized.

[0070]

10) By reducing a thickness and a weight and suppressing crack, application to a member for which a conventional concrete has not been used is possible.

[0071]

11) A prestressed concrete can be used as an alternate member for a metal member, a glass member, a hard resin member, a wood member, an impact energy absorbing member such as a damping

member or a vibration isolation member, a form material as a preceding framework, or the like.

Brief Description of Drawings

[0072]

Fig. 1 is a flow diagram showing the method for producing prestressed concrete of the present invention.

Fig. 2 is a schematic view illustrating arrangement of a tensional material in a prestressed concrete according to the present invention.

Fig. 3 is a strength test results report of concrete using industrial water used in the bond strength comparison test.

Fig. 4 is a strength test results report of concrete using seawater used in the bond strength comparison test.

Description of Embodiments

[0073]

Embodiments of the present invention will be described with reference to the drawings.

First, Fig. 1(A) to 1(C) illustrate a method for introducing [a](#) mechanical prestress by a pretension method.

[0074]

Figs. 1(A) to 1(C) are explanatory views of a pretension bed (manufacturing apparatus).

These illustrate an example in which a tension of 50 tons (490 kN) is introduced using a PC steel strand wire of ϕ 26 mm as a tensional material.

[0075]

In this example, as illustrated in Figs. 1(A) to 1(C), three prestressed concrete members are simultaneously manufactured in a longitudinal direction on a pretension bed (production apparatus) in a long line system.

[0076]

As illustrated in Fig. 1(A), the PC steel strand wire is stretched between reaction force bases and is tensed by a jack on a left side with a tensile load of 50 tons (490 kN) to add a prestress force.

[0077]

Subsequently, as illustrated in Fig. 1(B), a latticed bar (reinforcing steel) and a form are assembled while the PC steel strand wire is tensed, and a concrete is poured and cured.

[0078]

When predetermined concrete strength is obtained, as illustrated in Fig. 1(C), the tensioning jack is gradually released, the PC steel strand wire is cut, and the tension is transferred to the prestressed concrete members.

[0079]

Prestressed concrete is manufactured in this way.

[0080]

The prestressed concrete according to the present invention is achieved by a novel composition of a concrete, a tensional material, and a tensile load.

[0081]

The blending of concrete in concrete placement is shown below. (Unit: kg/m³)

Concrete Blending Example 1 (Basic Blending)

Ordinary Portland cement: 626

Seawater: 175

Fine aggregate: 809

Coarse aggregate: 818

Additive: Water reducer: 6.89

[0082]

In this example, as a mixing water, seawater is used in place of tap water. The total weight per m³ is 2,434.9 kg, and the proportion of seawater relative to the total amount is 7.2%.

[0083]

In addition, the seawater was extracted from a depth of about 100 m in the ocean off the Cape Zampa in the northern part of Okinawa, and garbage and the like were removed through a 0.5-mm mesh screen.

The components of the seawater are as follows.

Specific gravity	pH	Na ⁺	K ⁺	Ca ⁺	Mg ⁺	Cl ⁻	SO ₄ ²⁻	CO ₃ ²⁻	(ppm)
1.02	8.1	9,290	346	356	1,167	17,087	2,378	110	

[0084]

In addition, the concrete blending in the case where an expansive material was added to the above basic blending is

shown below. (Unit: kg/m³)

Concrete Blending Example 2 (Addition of Expansive Material)

Ordinary Portland cement: 606

Expansive material: 20

Seawater: 175

Fine aggregate: 809

Coarse aggregate: 818

Additive: Water reducer: 6.89

In this example, the total weight per m³ is 2,434.9 kg, and the proportion of seawater relative to the total amount is 7.2%.

[0085]

In addition, the concrete blending in the case where fly ash was added to the above basic blending is shown below. (Unit: kg/m³)

Concrete Blending Example 3 (Addition of Fly Ash)

Ordinary Portland cement: 563

Fly ash: 63

Seawater: 175

Fine aggregate: 798

Coarse aggregate: 810

Additive: Water reducer: 6.89

In this example, the total weight per m³ is 2,381.5 kg, and the proportion of seawater relative to the total amount is 7.3%.

[0086]

In addition, the concrete blending in the case where an expansive material, fly ash, and a fiber-reinforced material were added to the above basic blending is shown below. (Unit: kg/m³)

Concrete Blending Example 4 (Addition of Expansive Material + Fly Ash + Fiber-Reinforced Material)

Ordinary Portland cement: 621

Expansive material: 20

Fly ash: 71

Fiber-reinforced material: 9.1

Seawater: 185

Fine aggregate: 1,205

Coarse aggregate: 267

Additive: Water reducer: 11.38

In this example, the total weight per m³ is 2,381.5 kg, and the proportion of seawater relative to the total amount is 7.3%.

[0087]

In all the above Concrete Blending Examples 1 to 4, the amount of sulfate ions in the mixing water and seawater is 2,378 ppm.

[0088]

In addition, the concrete may also be prestressed concrete having a decreased plate of its thickness.

[0089]

For example, it is possible that a strand made of a carbon fiber-reinforced polymer (CFRP) material 12.5 mm in diameter, which is a rust-resistant wire and a continuous fiber-reinforcing wire, is used as a tensional material, the size of each prestressed concrete volume is 3 m × 2.4 m × 36 mm, and five tensional materials are disposed at intervals of 500 mm in the transverse direction.

[0090]

Fig. 2 shows the disposition of a tensional material.

The thickness T of the prestressed concrete 1 is 36 mm, and a tensional material 2 of $\phi 12.5$ mm was disposed in the center of the plate thickness.

[0091]

Latticed bars 3 were disposed on the top face of the tensional material. The covering depth is about 7 mm.

[0092]

In the concrete composition described above, the tensional material was disposed, and a tensile load of 18 kN was introduced per tensional material.

[0093]

After curing for about 24 hours, the tension force was released.

[0094]

The compressive strength after the manufacturing of

prestressed concrete was 60 MPa or more, meeting the strength standard.

[0095]

The plate thickness of the prestressed concrete of this example is 36 mm. In the case of conventional prestressed concrete using a tensional material made of steel ($\phi 12.5$ mm), considering the problem of rusting and the like, a covering depth of about 30 mm is required. Therefore, the plate thickness has to be larger than the prestressed concrete of the present invention by the difference in covering depth (30 mm minus 7 mm), that is, about 23 mm each side.

[0096]

In addition, the weight of the prestressed concrete of this example was 648 kg.

[0097]

In the case of prestressed concrete using a tensional material of steel, the plate thickness is 82 mm considering the covering depth. When calculated as the estimated weight of general reinforced concrete (calculated as 2.5 tons per m³), the weight is about 1,476 kg, indicating a weight reduction of 50% or more.

[0098]

In the prestressed concrete, the concrete's weakness of being weak to tensile stress is compensated with mechanical prestress by a tensional material, and cracking due to tensile

stress, for example, can be prevented.

[0099]

In order for the capability of prestress to be sufficiently exerted, the bond strength between the concrete and the tensional material is important. In the case where the bond strength is insufficient, slipping occurs between the concrete and the tensional material, whereby mechanical prestress cannot be exerted.

[0100]

In the present invention, sulfate ions or seawater is mixed with a mixing water to generate ettringite, which exerts an expansion effect at the time of concrete hardening, making the concrete be dense and exert an expansion force; as a result, the bond strength between the tensional material and the concrete is increased.

[0101]

Hereinafter, a bond strength comparison test using seawater will be shown.

[0102]

<Bond Strength Comparison Test>

A bond strength comparison test was performed on conventional concrete using industrial water (industrial water C) and concrete using seawater (seawater C).

[0103]

The test method and evaluation are based on "Method of

Test for Bond Strength between Concrete and Steel Reinforcement by Pull-Out Test (JSTM C 2101)" of the Japan Testing Center for Construction Materials. The bond stress at a slippage of 0.002 D (Diameter) and the maximum bond stress at break were subjected to comparison.

[0104]

<Test Specimen>

1) Industrial water C, three volumes

Mixing water: Industrial water

Specific gravity: 1.0

Sulfate ions: 7.0 mg/L (7 ppm)

2) Seawater C, three volumes

Mixing water: Seawater from Yomitan village

Specific gravity: 1.02

Sulfate ions: 2,090 mg/L (2,132 ppm)

3) Test specimen conditions

- Test specimen size

Cubic test specimen: 200 mm × 200 mm × 200 mm

Reinforcing steel rod diameter: 13 mm (SD295A D13)

Site of bonding: 50 mm

- Concrete blending ratio

Ordinary Portland cement: 621

Expansive material: 20

Seawater or industrial water: 185

Fine aggregate: 1,205

Coarse aggregate: 267

Additive (water reducer): 11.38

Fly ash: 71

Carbon fiber: 9.1

- Strength test: Material age: 28 days (see Fig. 3 and Fig. 4)

Compressive strength: Industrial water concrete: 99.1

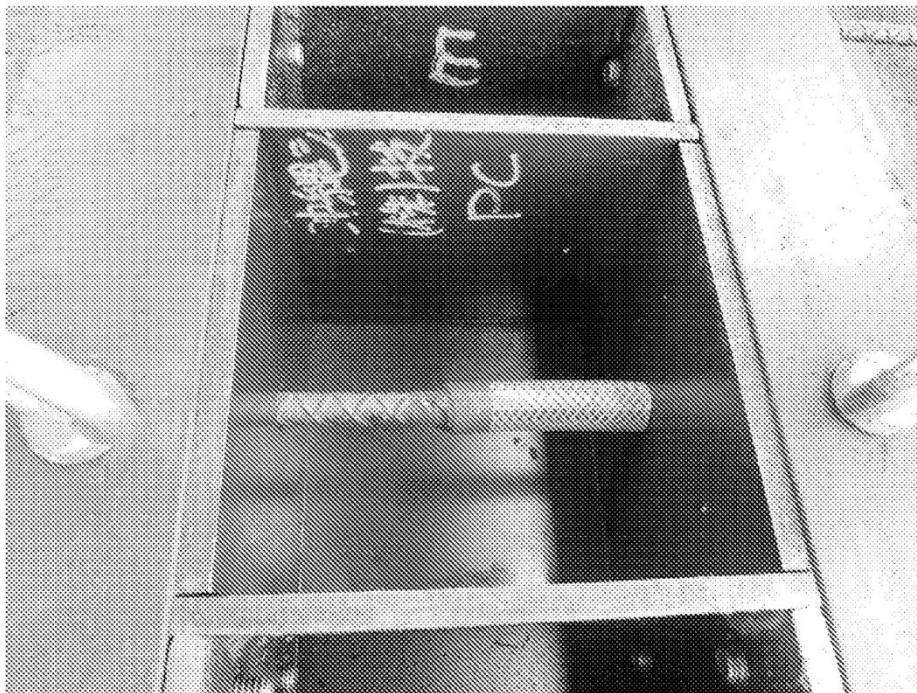
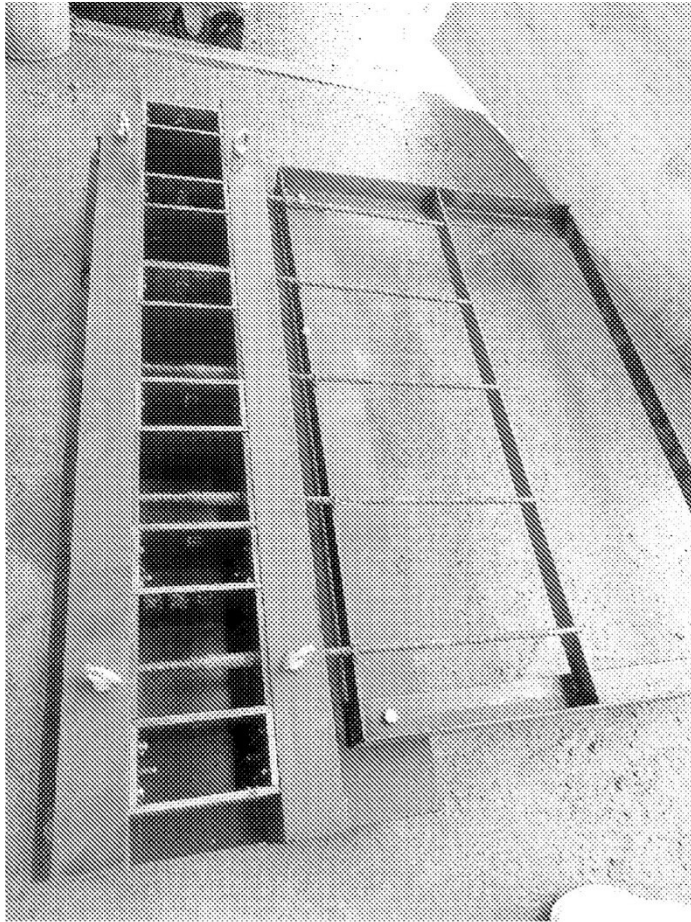
N/mm²

Compressive strength: Seawater concrete: 88.5 N/mm²

[0105]

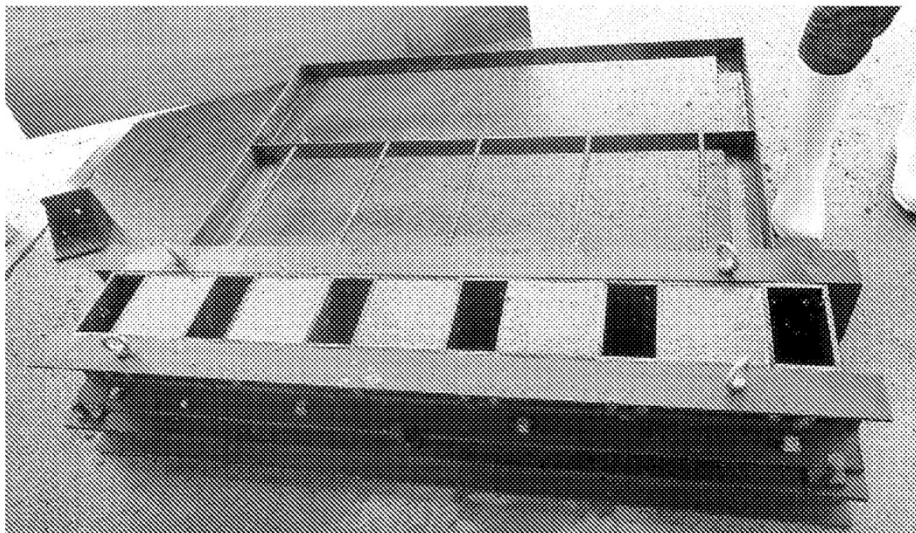
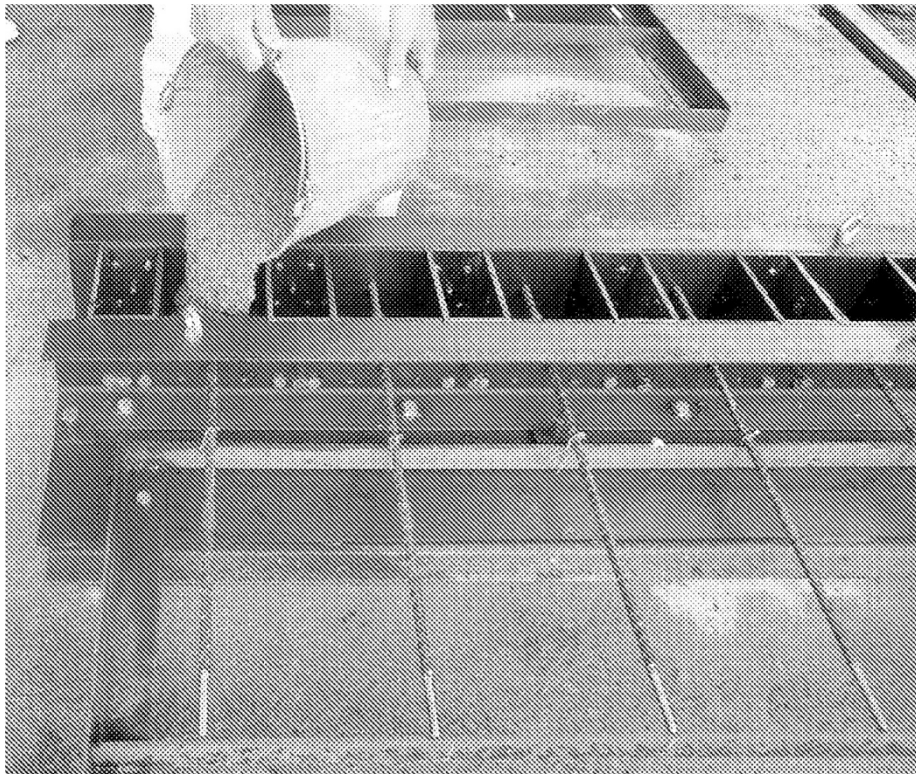
<Test Specimen Manufacturing Conditions>

Form Frame Condition



(Bonding Site Enlargement Condition)

Placing Condition



[0106]

<Test Specimen>

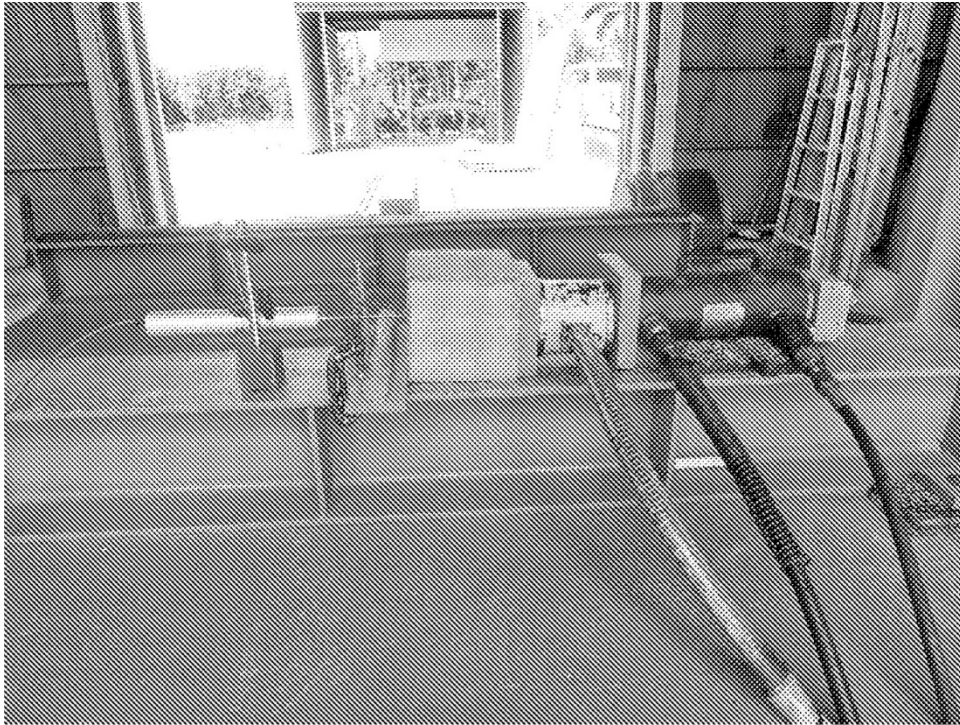


[0107]

<Test Apparatus>



(Whole Appearance of Test Apparatus)



(Condition of Test Specimen Part)

[0108]

<Break Condition>



(Break Condition in Threaded Part)

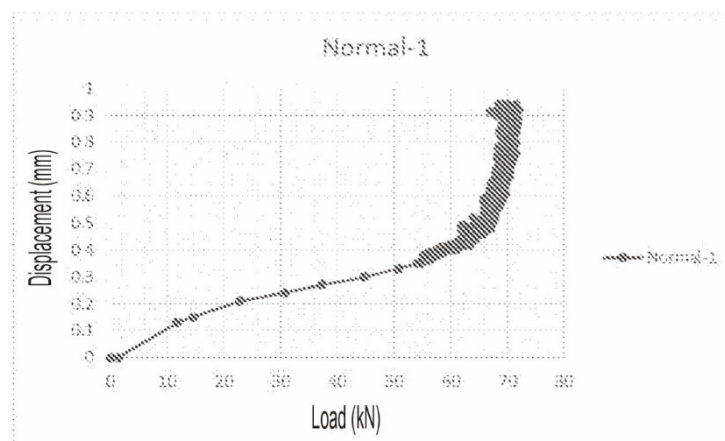


(Break Condition in Reinforcing Steel Part)

[0109]

<Test Results>

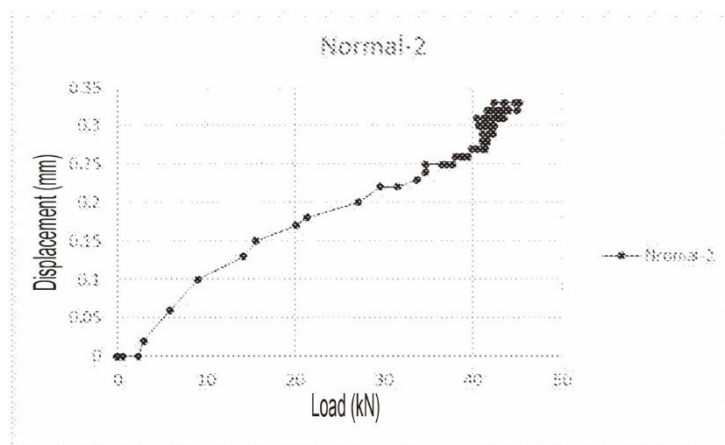
Industrial water C-1



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	2.092	kN
	MAX	:	$P =$	72.05	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	99.1	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.303	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	0.298	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	10.28	N/mm ²		

[0110]

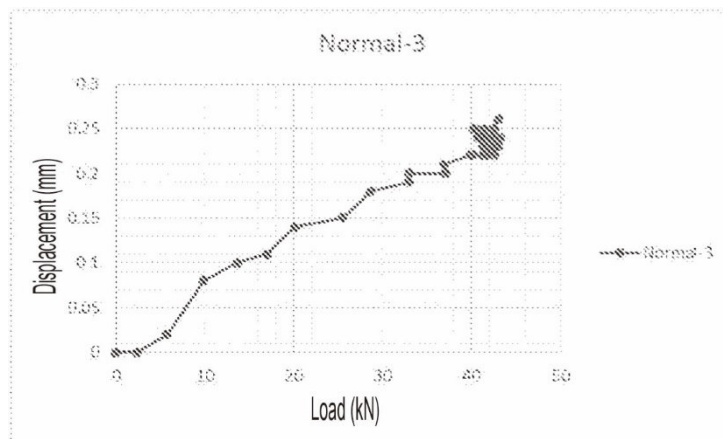
Industrial water C-2



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	1.924	kN
	MAX	:	$P =$	45.2	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	99.1	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.303	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	0.275	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	6.449	N/mm ²		

[0111]

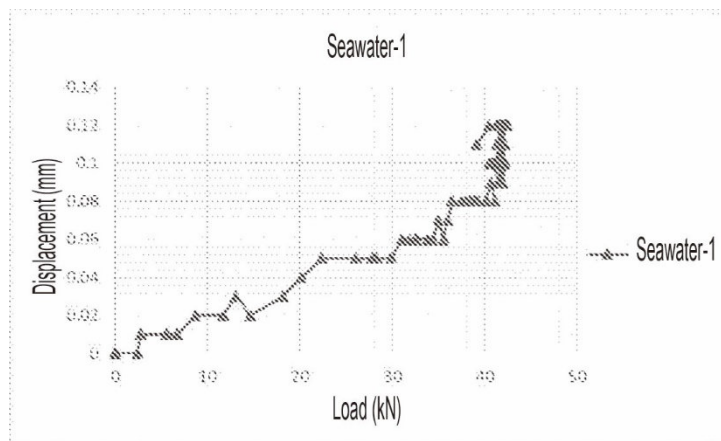
Industrial water C-3



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	1.798333	kN
	MAX	:	$P =$	43.23	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	99.1	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.303	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	0.257	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	6.168	N/mm ²		

[0112]

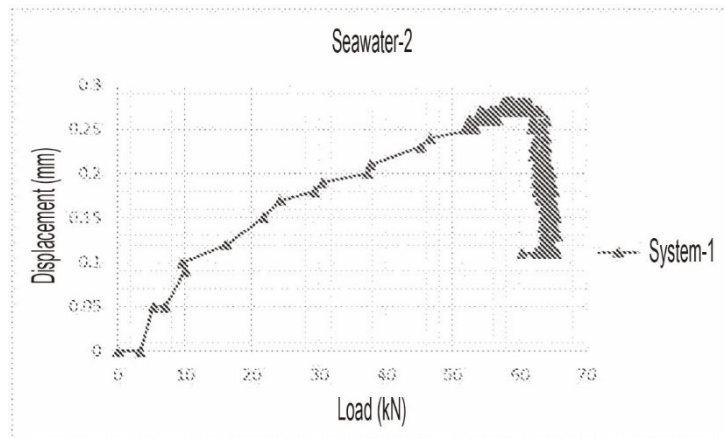
Seawater C-1



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	9.23	kN
	MAX	:	$P =$	42.44	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	88.5	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.339	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	1.473	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	6.775	N/mm ²		

[0113]

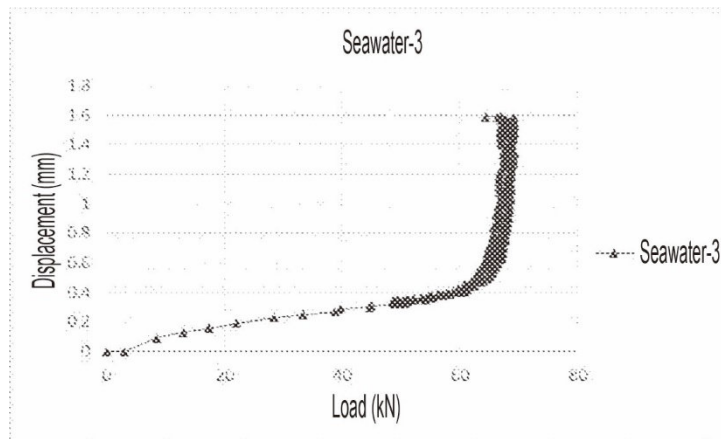
Seawater C-2



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	1.0244	kN
	MAX	:	$P =$	65.54	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	88.5	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.339	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	0.164	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	10.462	N/mm ²		

[0114]

Seawater C-3



Bond stress		:	$\tau =$		
Slippage		:	$0.002D =$	0.026	mm
Tensile strength	0.002D	:	$P =$	1.597556	kN
	MAX	:	$P =$	69.29	kN
Reinforcing steel diameter		:	$D =$	13	mm
Compressive strength		:	$\sigma_c =$	88.5	N/mm ²
Correction factor		:	$\alpha = 30/\sigma_c$	0.339	
at 0.002 D	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	0.255	N/mm ²		
at MAX	$\tau =$	$P \cdot \alpha / (4\pi D^2)$			
	=	11.06	N/mm ²		

[0115]

<Comparison of Bond Stress>

Table 1. Pull-Out Test Results (Bond Stress)

	Strength test N/mm2	Bond stress N/mm2 Slippage: 0.002 D			
	Material age: 28 days	Test 1	Test 2	Test 3	Average
Industrial water	99.1	0.298	0.275	0.257	0.277
Seawater	88.5	1.473	0.164	0.255	0.631
Difference	-10.6	1.18	-0.11	0.00	0.35
Proportion (%)	89.3%	494.3%	59.6%	99.2%	228.0%

Table 2. Pull-Out Test Results (Maximum Bond Stress)

	Strength test N/mm ²	Bond stress N/mm ²		
	Material age: 28 days	Reinforcing steel break	Threading break	Overall average
Industrial water	99.1	10.28	6.31	7.63
Seawater	88.5	10.76	6.78	9.43
Difference	-10.6	0.48	0.47	1.80
Proportion (%)	89.3%	104.7%	107.4%	123.6%

[0116]

In the strength test at a material age of 28 days, the strength value of the concrete using seawater was as low as 89.3% relative to the concrete using industrial water. However, with respect to the bond stress (Table 1), as a whole, the strength value of the seawater C was as extremely high as 228.0% relative to the industrial water C. (Although the seawater C showed a lower value in the test specimen 2, considering the strength test, the bond stress is excellent.)

[0117]

In addition, with respect to the maximum bond stress, the strength value of the seawater C was as high as 123.6% relative to the industrial water C. From these results, it was confirmed that use of seawater in a concrete mixing water results in an increase in bond stress.

[0118]

Therefore, as a result of mixing seawater with a mixing water, an increase in bond strength can be seen, and the

performance of prestressed concrete by prestress introduction can be increased.

Reference Signs List

[0119]

- 1: Prestressed concrete
- 2: Tensional material
- 3: Latticed bar

CLAIMS

1. A method for producing prestressed concrete, comprising introducing mechanical stress by a tensional material and chemical stress by an expansive material,
characterized in that in the production, a cement material excluding alumina cement is used, and sulfate ions are mixed with a mixing water in a proportion of 1,000 to 5,000 ppm per unit mass of the mixing water.
2. The method for producing prestressed concrete according to claim 1, wherein seawater is used as the sulfate ions mixed with the mixing water.
3. The method for producing prestressed concrete according to claim 1 or 2, wherein the tensional material is a rust-resistant wire.
4. The method for producing prestressed concrete according to claim 1 or 2, wherein the tensional material is a continuous fiber-reinforcing wire.
5. The method for producing prestressed concrete according to claim 4, wherein the continuous fiber reinforcing wire is a reinforced fiber wire including one or more kinds of fiber

selected from a metal fiber, a aramid fiber, a carbon fiber, a glass fiber, and a poly-p-phenylenebenzobisoxazole fiber.

6. The method for producing prestressed concrete according to any one of claim 1 to claim 5, wherein the expansive material is a mixture of one or more kinds selected from a lime-based expansive material such as quick lime, a calcium sulfoaluminate, an ettringite-based expansive material, an ettringite-lime composite-based expansive material, an iron powder-based expansive material, a magnesium-based expansive material, an aluminum powder-based expansive material, a shale-based expansive material, and a silica-based expansive material.

7. The method for producing prestressed concrete according to any one of claim 2 to claim 6, wherein the seawater for use as the mixing water is used in an amount of 50 to 200 wt% relative to the total weight of the mixing water.

8. The method for producing prestressed concrete according to any one of claim 2 to claim 7, wherein sulfate ions contained in the seawater are contained in a proportion of 1,500 to 3,000 ppm per unit mass of the seawater.

9. The method for producing prestressed concrete according to any one of claim 2 to claim 8, wherein the seawater for use

as a mixing water is seawater from which chlorine ions have been removed.

10. The method for producing prestressed concrete according to any one of claim 1 to claim 9, wherein a discontinuous fiber-reinforcing material has been incorporated at a time of concrete placement.

11. The method for producing prestressed concrete according to claim 10, wherein the discontinuous fiber-reinforcing material is a reinforced fiber material including one or more kinds of fiber selected from a metal fiber, a carbon fiber, a glass fiber and a resin fiber.