

ULTRA-THIN SEMI-PREFABRICATED CONCRETE SLAB AND MANUFACTURING METHOD THEREOF

5 FIELD OF THE INVENTION

The present invention pertains to the technical field of building materials, and relates to a cement concrete material, particularly to an ultra-thin semi-prefabricated concrete slab with high early strength, and a manufacturing method thereof.

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BACKGROUND OF THE INVENTION

At present, semi-prefabricated floor slabs are widely used in building construction. A semi-prefabricated floor slab made with the traditional concrete mix ratio must have a thickness of at least 70 mm to effectively prevent the separation between the semi-prefabricated floor slab and the cast-in-situ concrete caused by molding shrinkage. For the semi-prefabricated composite slabs with a thickness of 160 mm for common residences, the space reserved for piping arrangement in an upper cast-in-situ layer with a thickness of 90 mm is very limited.

20 To meet the space requirement on the piping arrangement, it needs to design and manufacture an ultra-thin prefabricated slab. To avoid reinforcing bars of the ultra-thin prefabricated slab being exposed, the thickness of a concrete protective layer must be reduced. However, the application scenarios of the prefabricated slab pose a higher requirement on the load bearing capacity of the prefabricated slab, such as increasing the effective depth in the case of a sagging bending moment.

25 Therefore, it is necessary to significantly increase the strength of concrete compared with the prior arts. On the other hand, a demolding stage and a lifting stage are key stages in the manufacture of the semi-prefabricated slab. In order for the slab to be demolded as early as possible and withstand the stress during handling and transportation thereof, a higher requirement is posed on the early strength of the concrete.

SUMMARY OF THE INVENTION

The present invention aims to provide an ultra-thin semi-prefabricated concrete slab with high early strength, by which while the thickness of the prefabricated slab is reduced to 50mm, sufficient strength can be still achieved to withstand the stress and support the subsequent moving, transportation, pouring, or other construction processes, so that the space reserved for piping arrangement is increased from 90 mm to 110 mm without increasing the total thickness of the slab. The present invention further aims to provide a manufacturing method for the ultra-thin semi-prefabricated concrete slab.

A technical solution of the present invention proposes a method for preparing an ultra-thin semi-prefabricated concrete slab, the ultra-thin semi-prefabricated concrete slab being made of a composition including, by weight, 45.4-49.2% of aggregate, 26.4-29.1% of stone powder, 15.6-17.7% of cement, 0.24-0.56% of super plasticizer, 1.0-2.98% of nano silica sol, and 7.41-8.78% of water. The method comprises: Step 1: mixing nano silica with water to obtain a homogeneous and stable nano sol with a mass concentration of 5-30%; Step 2: stirring and mixing aggregate, stone powder and cement uniformly to obtain a first mixture; Step 3: stirring and mixing the first mixture with water to obtain a second mixture with a final water cement ratio of 0.456 to 0.492; Step 4: stirring and mixing the super plasticizer with the second mixture to obtain a third mixture; Step 5: stirring and mixing the nano silica sol with the third mixture to obtain a concrete slurry; Step 6: injecting the concrete slurry into a mold prepared in advance, to obtain a concrete slab after curing and demolding; and Step 7: water curing the concrete slab, thus obtaining the ultra-thin semi-prefabricated concrete slab.

As a preferred solution of the present invention, the nano silica in the nano silica sol has a particle diameter of 10 nm to 30 nm.

As a preferred solution of the present invention, in Step 1, the nano silica is dispersed into

water and mechanically pre-agitated, and then treated by ultrasonic dispersion with a power of no less than 2500 W, effective amplitude of more than 40% and effective ultrasonic time of more than 10 min.

5 As a preferred solution of the present invention, the stirring in Step 2 lasts 2-3 seconds, the stirring in Steps 3 and 4 lasts at least 60-120 seconds in total, and the stirring in Step 5 lasts at least 60-120 seconds.

10 As a preferred solution of the present invention, the aggregate includes coarse aggregate with a particle size ranging from 5 mm to 20 mm, and fine aggregate with a particle size ranging from 2.36 mm to 10 mm, the weight percents of the coarse aggregate and the fine aggregate in the composition are 30.7% to 33.5% and 13.2% to 15.9%, respectively.

15 As a preferred solution of the present invention, the super plasticizer is selected from naphthalene-based high-range water reducing agents.

20 As a preferred solution of the present invention, the mold in Step 6 is an ultra-thin mold with an internal mold thickness of 50 ± 2 mm, wherein the ultra-thin mold is pre-lined with reinforcing bars and provided with conduits, pipes and embedded parts, and molding oil is pre-applied on an inner wall of the mold, and no shear reinforcing bar is installed when the concrete slurry is poured.

As a preferred solution of the present invention, the curing in Step 6 is natural curing at $25\pm 5^{\circ}\text{C}$ for 12 ± 2 hours, or steam curing at $45\pm 10^{\circ}\text{C}$ for no more than 6 hours.

25 As a preferred solution of the present invention, in Step 7 water curing is carried out under natural conditions, with the surface of the concrete slab wet until five days after demolding.

The present invention further proposes an ultra-thin semi-prefabricated concrete slab prepared by the aforesaid method.

Compared with the prior arts, the ultra-thin semi-prefabricated concrete slab and its manufacturing method according to the present invention have the following advantages.

5 According to the present invention, the concrete formula with nano silica added is used in the concrete reaction, so that the nano silica can provide a large specific surface area to accelerate the pozzolanic reaction with calcium hydroxide, and also accelerate the cement hydration process. Meanwhile, the nano silica can also be used as fine filler to fill and compact the microstructure of the concrete, which can accelerate early strength development of the concrete, promote early
10 demolding of the semi-prefabricated slab, and improve its mechanical stability during the demolding stage and the lifting stage. Therefore, the semi-prefabricated slab can still provide sufficient strength to withstand the stress and support the subsequent moving, transportation, pouring or other construction processes, although having reduced thickness. For ordinary concrete, the demolding can only be carried out on the next day, while the semi-prefabricated slab prepared
15 by the present method can be demolded on the same day, and another round of pouring can be carried out in advance, thereby greatly shortening the construction period.

 According to the present invention, a higher water cement ratio is adopted, so that the workability of the concrete slurry is increased, and at the same time the amount of pumping agent
20 is reduced, thereby saving the cost and generating no influence on the early and long-term compressive strength properties of the concrete.

 According to the present invention, the content of stone powder is increased while that of cement is reduced, thereby saving the cost. By improving the concrete formula, the deflection of
25 the semi-prefabricated slab with nano silica does not exceed a span ratio of 250, thereby effectively improving the shrinkage performance.

 For the ultra-thin semi-prefabricated slab prepared by the manufacturing method according to the present invention, the mechanical properties of the semi-prefabricated slab are improved by

optimizing the mixing ratio of the concrete with nano silica, the cost is reduced and the shrinkage is slowed down, and the thickness is reduced from 70 mm (in the case of traditional prefabricated slab) to 50 mm, so that the height reserved for piping arrangement space in the slab is increased from 90 mm to 110 mm. Moreover, the ultra-thin semi-prefabricated concrete slab according to the present invention can be used not only for residential floors, but also for corridors and halls, so that a ratio of the floor area which can be formed by semi-prefabricated slabs can be increased to 100%.

In the traditional prefabricated slab casting method, the shear reinforcing bars have to be embedded into the prefabricated slab in advance, and extend out of the prefabricated slab to connect with the cast-in-situ concrete, which is inconvenient for storage and transportation. Compared with the traditional prefabricated slab, the ultra-thin semi-prefabricated concrete slab according to the present invention only requires the placement of a prefabricated steel cage with shear reinforcing bars directly on the top thereof during the installation stage, without involvement of shear reinforcing bars during pouring, thereby facilitating moving, transportation and installation.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a bar graph showing durability test results of Example 2 according to the present invention and Comparative Example 1.

Fig. 2 is a line graph showing dry shrinkage test results of Example 2 according to the present invention and Comparative Example 1.

Fig. 3 is a line graph showing deflection test results of Example 2 according to the present invention.

Fig. 4 is a line graph showing deflection test results of Comparative Example 1.

DETAILED DESCRIPTION OF THE EMBODIMENTS

5 The present invention will be further described in conjunction with the following embodiments.

Materials used in the embodiments are all commercially available.

10 Test methods for properties of semi-prefabricated concrete slab are as follows: a concrete compression strength test is based on a method described in BS EN 12390-3: 2009 "Testing hardened concrete. Compressive strength of test specimens"; a concrete slump test is based on a method described in BS EN 12350-2 "Testing fresh concrete. Slump-test"; concrete durability is determined based on a method described in ASTM C1202-09 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration"; and concrete dry shrinkage is
15 determined based on a method described in BS ISO 1920-8: 2009 "Testing of concrete -- Part 8: Determination of dry shrinkage of concrete for samples prepared in the field or in the laboratory".

The semi-prefabricated concrete slab according to the present invention is made of a composition including the following materials by weight: 45.4-49.2% of aggregate, 26.4-29.1% of
20 stone powder, 15.6-17.7% of cement, 0.24-0.56% of super plasticizer, 1.0-2.98% of nano silica sol, and 7.41-8.78% of water.

The aggregate includes coarse aggregate with a particle size ranging from 5 mm to 20 mm, and fine aggregate with a particle size ranging from 2.36 mm to 10 mm. The weight percent of the
25 coarse aggregate in the composition is 30.7% to 33.5%, and that of the fine aggregate in the composition is 13.2% to 15.9%.

The super plasticizer is preferably selected from naphthalene-based high-range water reducing agents, which are commonly used additives in the production of concrete. There are

many products of super plasticizer commercially available on the market, such as that in the brand of Jiangmen Qiangliè.

The nano silica in the nano silica sol has a particle diameter of 10 nm to 30 nm.

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The method for manufacturing a semi-prefabricated concrete slab according to the present invention includes the following steps.

In Step 1, nano silica is dispersed into water, and the solution obtained is mechanically pre-agitated. The agitating method includes, but is not limited to, slurry agitation, turbine agitation, anchor agitation, or helical ribbon agitation. Then, ultrasonic dispersion is performed using a 2500 W probe-type ultrasonic machine, with an effective amplitude of more than 40% and effective ultrasonic time of more than 10 min, thus obtaining a homogeneous and stable nano sol with a mass concentration of 5%-30%.

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In Step 2, the aggregate, stone powder and cement are agitated in an agitating vessel for 2-3 seconds to be mixed uniformly, thus obtaining a first mixture.

In Step 3, the first mixture is mixed with water under agitation to obtain a second mixture, so that the final water cement ratio of the second mixture is 0.456 to 0.492.

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In Step 4, the super plasticizer is mixed with the second mixture under agitation to obtain a third mixture, wherein the sum of the agitation time of Steps 3 and 4 is at least 60 to 120 seconds.

In Step 5, the nano silica sol is mixed with the third mixture under agitation for at least 60 to 120 seconds, thus obtaining concrete slurry.

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In Step 6, the concrete slurry is injected into an ultra-thin mold with a thickness of 50 ± 2 mm, wherein the ultra-thin mold is pre-lined with reinforcing bars and provided with conduits, pipes

and embedded parts, and molding oil is pre-applied on the inner wall of the mold. After a natural curing at $25\pm 5^{\circ}\text{C}$ for 12 ± 2 hours, or a steam curing at $45\pm 10^{\circ}\text{C}$ for no more than 6 hours (the specific curing time is determined by the weather conditions of the day), the mold is opened to obtain a concrete slab.

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In Step 7, a water curing is performed on the demolded concrete slab under natural conditions, with the surface wet until five days after pouring, thus obtaining the ultra-thin semi-prefabricated concrete slab.

10 Several examples of the present invention are described below.

Example 1

15 The composition includes the following ingredients (by weight): 17.0% of cement, 7.8% of water, 27.9% of stone powder, 32.97% of coarse aggregate, 13.53% of fine aggregate, 0.34% of nano silica (powder, with a particle diameter of 30 nm), and 0.43% of super plasticizer.

20 The nano silica powder is dispersed in water to prepare a nano silica sol with a mass concentration of 6%. The coarse aggregate, fine aggregate, stone powder and cement are added successively to the agitating vessel, and the dry powder is pre-agitated. The weighed water and super plasticizer are poured in the agitating vessel and stirred uniformly. The homogeneous and stable nano silica sol is poured into the above-mentioned concrete slurry under continuous agitation. The concrete slurry obtained has a slump of 70 mm.

25 The above-mentioned concrete slurry is poured into a mold, subjected to a natural curing at room temperature ($25\pm 5^{\circ}\text{C}$) for 12 hours and then demolded, thus obtaining a semi-prefabricated concrete slab with high early strength of more than 15 MPa.

Example 2

The composition includes the following ingredients (by weight): 15.9% of cement, 6.7% of water, 28.7% of stone powder, 31.8% of coarse aggregate, 15.2% of fine aggregate, 1.06% of nano silica sol (with a particle diameter of 12 nm, the nano silica having a mass concentration of 30%), and 0.56% of super plasticizer.

The coarse aggregate, fine aggregate, stone powder and cement are added successively to the agitating vessel and pre-agitated. The weighed water and super plasticizer are poured in the agitating vessel and stirred uniformly. Then, the nano silica sol is poured, and concrete slurry is obtained after continuous agitation. The concrete slurry obtained has a slump of 120 mm.

The above-mentioned concrete slurry is poured into a mold, subjected to a natural curing at room temperature ($25\pm 5^{\circ}\text{C}$) for 12 hours, and then demolded.

The demolded ultra-thin concrete slab with high early strength is subjected to a water curing for five days to obtain an ultra-thin semi-prefabricated concrete slab that meets the application requirements.

Example 3

The composition includes the following ingredients (by weight): 16.4% of cement, 5.2% of water, 27.3% of stone powder, 32.9% of coarse aggregate, 15.7% of fine aggregate, 2.71% of nano silica sol (with a particle diameter of 30 nm, the nano silica having a mass concentration of 6%), and 0.26% of super plasticizer.

The coarse aggregate, fine aggregate, stone powder and cement are added successively to the agitating vessel, and the dry powder is pre-agitated. The weighed water and super plasticizer are poured in the agitating vessel and stirred uniformly. Then, the homogeneous and stable nano silica

sol is poured into the above-mentioned concrete slurry under continuous agitation. The concrete slurry obtained has a slump of 45 mm.

The above-mentioned concrete slurry is poured into a mold, subjected to a natural curing at room temperature ($25\pm 5^{\circ}\text{C}$) for 12 hours and then demolded, thus obtaining a semi-prefabricated concrete slab with high early strength of more than 15 MPa.

It should note that water in the compositions in the three embodiments described above does not include water in nano silica sol.

Comparative Example 1

The composition includes the following ingredients (by weight): 17.1% of cement, 7.8% of water, 27.6% of stone powder, 47.5% of aggregate, and 0.09% of super plasticizer.

The aggregate, stone powder and cement are added successively to the agitating vessel, and the dry powder is pre-agitated. Then, the weighed water and super plasticizer are poured therein and stirred uniformly. The concrete slurry obtained has a slump of 60 mm.

The above-mentioned concrete slurry is poured into a mold, subjected to a natural curing at room temperature ($25\pm 5^{\circ}\text{C}$) for 12 hours and then demolded, thus obtaining an ordinary semi-prefabricated concrete slab.

Comparative Example 2

The composition includes the following ingredients (by weight): 16.0% of cement, 7.1% of water, 28.4% of stone powder, 47.1% of aggregate, 1.1% of nano silica sol (with a particle diameter of 12 nm, the nano silica having a mass concentration of 30%), and 0.36% of super

plasticizer.

The aggregate, stone powder and cement are added successively to the agitating vessel and pre-agitated. Then, the nano silica sol, super plasticizer and water are poured therein and stirred to
5 obtain concrete slurry. The concrete slurry obtained is has a slump of 50 mm.

The above-mentioned concrete slurry is poured into a mold, subjected to a natural curing at room temperature ($25\pm 5^{\circ}\text{C}$) for 12 hours and then demolded, thus obtaining an ordinary semi-prefabricated concrete slab.

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Effect analysis

The properties of the semi-prefabricated concrete slabs prepared in Examples 1, 2 and 3 and Comparative Examples 1 and 2 of the present invention and comparison results thereof are shown
15 as follows:

Table 1 Comparison of compressive strength test results

Compressive strength (MPa)					
	12 hours	1 day	3 days	7 days	28 days
Example 1	18.1	31.9	53.4	58.4	70.1
Example 2	15.6	22.4	34.5	43.5	49.7
Example 3	16.6	26.7	47.8	58.5	68.5
Comparative Example 1	10.3	24.0	42.8	57.4	69.3
Comparative Example 2	11.4	18.8	29.1	36.2	44.9

Table 1 shows comparison of the compressive strength test results of Examples 1, 2, and 3

and Comparative Examples 1 and 2 of the present invention. It can be seen that in Examples 1, 2, and 3 of the present invention, wherein nano silica is added, an optimized formula and a strict material adding sequence are adopted, the semi-prefabricated slab can reach strength of 15 MPa after 12 hours, which can meet the requirement of early demolding. By contrast, the strength after 12 hours for the products prepared by Comparative Examples 1 and 2 does not exceed 12 MPa, and early demolding is impossible.

Fig. 1 is a comparison diagram of durability test results of Example 2 and Comparative Example 1 of the present invention. It can be seen that by adding the nano silica and adopting the optimized formula, chloride ion penetration can be effectively reduced, and the durability of the concrete slab can be improved.

Fig. 2 is a comparison diagram of dry shrinkage test results of Example 2 and Comparative Example 1 of the present invention. It can be seen that by adding the nano silica and adopting the optimized formula, the dry shrinkage of the concrete can be effectively reduced, and the stability of spatial size of the concrete is improved.

From deflection test data of Figs. 3 and 4 it can be seen that the deformation amount can be controlled more effectively in Embodiment 2 of the present invention in which the nano silica is added and the optimized formula is used, as compared with the semi-prefabricated concrete slab in Comparative Example 1 manufactured by using a traditional method.

Although the present invention has been described with reference to the embodiments of the present invention, those skilled in the art should understand that various modifications can be made without departing from the true spirit and scope of the present invention. In addition, many modifications can be made to the subject matter, spirit, and scope of the invention so as to adapt to particular circumstances, materials, materials compositions and methods. All such modifications are encompassed within the scope of the claims of the present invention.

Claims

1. A method for preparing an ultra-thin semi-prefabricated concrete slab, the ultra-thin semi-prefabricated concrete slab being made of a composition including, by weight, 45.4-49.2% of aggregate, 26.4-29.1% of stone powder, 15.6-17.7% of cement, 0.24-0.56% of super plasticizer, 1.0-2.98% of nano silica sol, and 7.41-8.78% of water,

wherein the method comprises:

Step 1: mixing nano silica with water to obtain a homogeneous and stable nano sol with a mass concentration of 5-30%;

Step 2: stirring and mixing aggregate, stone powder and cement uniformly to obtain a first mixture;

Step 3: stirring and mixing the first mixture with water to obtain a second mixture with a final water cement ratio of 0.456 to 0.492;

Step 4: stirring and mixing the super plasticizer with the second mixture to obtain a third mixture;

Step 5: stirring and mixing the nano silica sol with the third mixture to obtain a concrete slurry;

Step 6: injecting the concrete slurry into a mold prepared in advance, to obtain a concrete slab after curing and demolding; and

Step 7: water curing the concrete slab, thus obtaining the ultra-thin semi-prefabricated concrete slab.

2. The method according to claim 1, wherein the nano silica in the nano silica sol has a particle diameter of 10 nm to 30 nm.

3. The method according to claim 2, wherein in Step 1, the nano silica is dispersed into water and mechanically pre-agitated, and then treated by ultrasonic dispersion with a power of no less than 2500 W, effective amplitude of more than 40%, and effective ultrasonic time of more than 10 min.

4. The method according to any one of claims 1 to 3, wherein the stirring in Step 2 lasts 2-3 seconds, the stirring in Steps 3 and 4 lasts at least 60-120 seconds in total, and the stirring in Step 5 lasts at least 60-120 seconds.

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5. The method according to any one of claims 1 to 3, wherein the aggregate includes coarse aggregate with a particle size ranging from 5 mm to 20 mm, and fine aggregate with a particle size ranging from 2.36 mm to 10 mm, the weight percents of the coarse aggregate and the fine aggregate in the composition are 30.7% to 33.5% and 13.2% to 15.9%, respectively.

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6. The method according to any one of claims 1 to 3, wherein the super plasticizer is selected from naphthalene-based high-range water reducing agents.

7. The method according to any one of claims 1 to 3, wherein the mold in Step 6 is an ultra-thin mold with an internal mold thickness of 50 ± 2 mm, wherein the ultra-thin mold is pre-lined with reinforcing bars and provided with conduits, pipes and embedded parts, and molding oil is pre-applied on an inner wall of the mold, and no shear reinforcing bar is installed when the concrete slurry is poured.

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8. The method according to any one of claims 1 to 3, wherein the curing in Step 6 is natural curing at $25\pm 5^{\circ}\text{C}$ for 12 ± 2 hours, or steam curing at $45\pm 10^{\circ}\text{C}$ for no more than 6 hours.

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9. The method according to any one of claims 1 to 3, wherein in Step 7 water curing is carried out under natural conditions, with the surface of the concrete slab being kept wet until five days after demolding.

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10. An ultra-thin semi-prefabricated concrete slab prepared by the method according to any one of claims 1 to 9.