MULTIFUNCTIONAL CONCRETES OF NEW GENERATION

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A new concept of creating concrete based on mechanochemical activation of Portland cement and modifying it to nano-cement has been proposed. Such concretes have a number of improved properties, including their complete im-permeability to liquids and gases.

INTRODUCTION

Nowadays, it is finally recognised that when developing new concretes, the focus should be not on reducing it's cost, but on creating more durable and technologically viable options. Such concretes are named multifunctional concretes (High Performance Concrete). The concept and the term covers concretes with such combination of properties that are impossible to achieve using conventional cements, traditional preparation of concrete mixes and standard methods of pouring. The new properties are, for instance, a combination of high durability and self-compacting (bulk) consistency. According to estimates by Japanese scientists, the service life of such concretes can reach 500 years. It should be noted that the requirements for multifunctional concretes have already been included in the nation The new properties are, for instance, a combination of high durability and self-compacting (bulk) consistency. al standards of some countries. The impressive example of the use of multifunctional concretes, namely, high-strength and durable, is the platform built in Norway for oil production in the North Sea. Its height - 470 meters, and it is designed for the impact of a hurricane storm with a maximum wave height of 30 meters.

Confederation Bridge, Prince Edward Island, Canada

The life of the platform is at least 100 years. Similar platforms are built on the oceanic shelf of the Arctic Ocean, which are operated in the zone of solid multiyear ice sheet, the movement of which creates enormous shear stresses. As an example, a bridge built in eastern Canada can also be cited. Its length is 13 km; the supports are immersed in water to the depth of 35 meters. Operational life is 100 years.

It should be noted that construction of concrete structures with high durability, longevity and strength is not an easy task, even with modern developments of concrete science. For this purpose, cement grade 600, washed and graded aggregates, active mineral additives (micro fillers), hyper plasticisers and some other special components must be used.

Placing and compaction of such concrete mixtures presents certain difficulties, since they have a consistency of 3 to 5 cm of cone slump, and for this reason require the use of powerful compaction equipment (poker vibrators).

In addition, such concrete contains 2 times more components than ordinary concrete, some of which are introduced into the con crete mix in very small quantities. In addition, to ensure uniform distribution of the components, the mixing plants must be equipped with additional supply paths for the components in the form of micro-dispensers, as well as special mixers.

It is well known that in concretes prepared according to traditional technology, there is a fairly strong segregation and water bleeding of concrete mixtures. This happens for a number of reasons and mainly due to the absence of a superfine fraction in the aggregate composition: from 50 to 150 microns (0.05-0.15 mm). As a result, concretes prepared according to standard technology, after hardening, have greater water absorption and, as a result, a decreased longevity.

The durability of concrete today is estimated by its frost resistance. At the same time, the determination of frost resistance by direct method takes a very long time. At that, accelerated methods are excluded from the latest edition of GOST.

Accelerated methods to determine frost resistance by indirect indicators (water absorption, ultrasound velocity, and others) are not developed sufficiently today and are not applied in practice. Thus, it should be recognized that modern concrete mix designs do not take into account its durability. In this regard, the author believes that durability of concrete is most correctly determined by its water absorption. If there is no water absorption, then there is no destruction of a concrete structure from frost and chemical aggression.

As proof of this hypothesis, it is possible to refer to the well-known data on frost resistance of concrete grade 600 on Portland cement. In a normal environment, when water absorption is equal to 3%, its frost resistance is F300, and when water absorption is 0.3%, it increases to F900. The same is observed in an aggressive environment. At water absorption of 3%, the frost resistance of concrete in aggressive environments is equal to F50, and at 0.3% it increases to F800. Nanocements allow to produce concretes with the lowest possible water absorption.

Basic principles of the new technology

The goal of many years of the research done by the author as well as by other scientists working on this problem was and remains the creation of a simple and affordable technology for producing multifunctional concretes (High Performance Concrete). This article will consider one of the varieties of multifunctional concretes, namely, super-durable heavy-duty concrete from self-compacted mixtures using mechanochemical processing of cement. In the course of creating such concrete, we have tried various ways to solve the problem, starting with water magnetisation and ending with a grinding of cement in liquid nitrogen. As a result of the long-term research, it was found that the task can be successfully accomplished by mechanochemical treatment of ordinary Portland cement in a special installation. Such a technology was first called cement activation technology, then renamed to its modern version: the nano-cement technology.
Concretes manufactured according to the proposed technology can be considered as 5th generation concretes, bearing in mind that the concrete of the first generation contained only cement, aggregates and water.

The second generation additionally contained the simplest plasticisers, the third generation concretes (most common today) contain super plasticisers, and the fourth (High Performance Concrete) additionally contain a hyper plasticiser and a micro filler. The proposed technology includes mechanochemical treatment of Portland cement and its modification into nano cement. The author proposes to consider concretes manufactured on the basis of nanocements as fifth generation concretes.
The main difference and critical advantage of the technology of mechanochemical activation of cement is that for the first time in the world it was possible to introduce into cement concrete an increased (up to 10%) amount of plasticiser. It turned out that, depending on the amount of plasticiser, the grains of cement are covered with either continuous or partial plasticiser shell. The thickness of such shell, calculated theoretically at the initial stage of technology development, was estimated by us at 20-150 nanometers. In 2012, the thickness of this shell was experimentally measured and ranged from 50 to 100 nanometers, which is in line with our initial calculations.

A variety of devices for cement mechanochemical activation was tried during the research: planetary, jet and vibratory mills, dismembrators and a number of other devices. The use of a conventional ball mill, used in the production of Portland cement, was considered the best implementation of the technology.

The developed technology provides for self-compacting self-leveling concrete mixes (cone slump of 22-24 cm) and at the same time lowers the water-cement ratio of concrete mixes by more than 2 times (to 0.20 - 0.22). This makes it possible to abandon the mandatory use of cement M600, hyper plasticisers and high quality aggregates and, ultimately, allows to make almost ever lasting concrete.

Application of new generation concretes

One of the most important tasks of modern concrete engineering is protection of reinforced concrete structures from corrosion. It is generally recognised, that this task will be solved, if permeability function of chloride salts and other substances aggressive to concrete and reinforcement, is reduced by a factor of ten or more. Concretes on nano-cements have a complete waterproofing capacity and reduced ability to capillary absorption of aqueous solutions of salts. Such concretes can be used in burial of toxic and radioactive waste, preservation of

spent nuclear power units and nuclear facilities, and in other cases where it is necessary to ensure that structures are impermeable for a very long time.

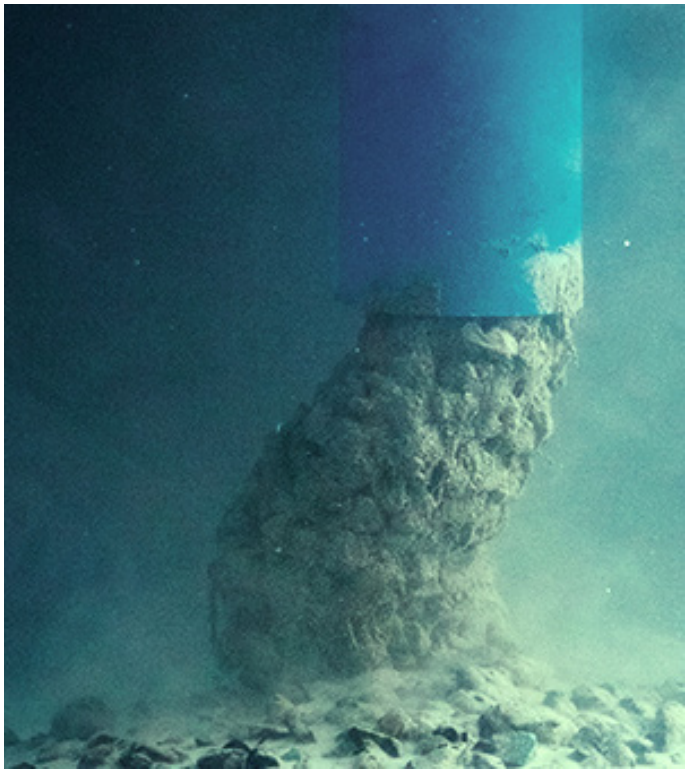
The mechanochemical activation of Portland cement and its modification into nano-cement dramatically improve such characteristics of concrete as strength (up to 200 MPa), sulphate resistance (up to 90-98%), frost-resistance (up to F2000) and water resistance (up to W50). According to the results of research conducted by the author, the use of nanocement significantly increases durability of material in sulphate media. The advantages of concretes on nanocements with a strength of 150 MPa are shown in Table 1.

According to the author, such concretes can also be widely used in the construction of bridges, roads and marine structures: berths, offshore platforms, etc. It is necessary to state that it is practically impossible to achieve these parameters on existing materials and using old technologies. The nano cement technology will allow to make even acid-resistant concrete on the basis of ordinary Portland cement without the use of liquid glass and quartz micro filler.

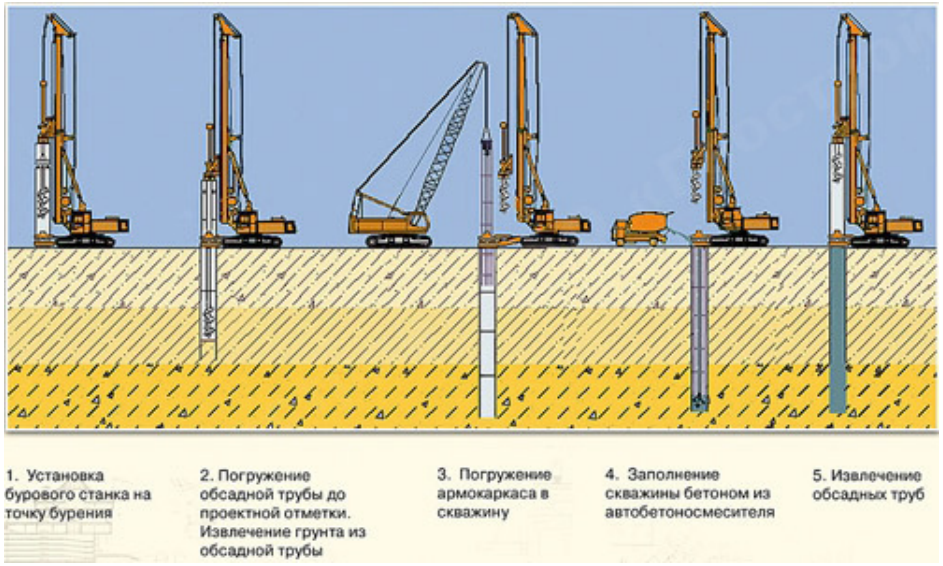
Thus, the technology of mechanochemical activation allows to obtain concrete, which can be attributed to the multifunctional in terms of water impermeability, high resistance in sulphate environments and frost resistance (along with high high strength). The use of this technology can be considered a solution to the problem of creating concrete that

Underwater concrete

In this case, the following properties are the priority: the concrete mix must resist wash out and have high cohesion. The nano-cement technology allows to mix only the activated cement and normal aggregates with water in a standard mixer. The presence of nano-cement eliminates the use of M600 cement, micro silica, special polymer and hyper plasticizer in a concrete mix. Also, no dispensers for adding minerals and chemical additives are needed for concrete mixing equipment.



Auger-cast grout piles



Here, the following properties of concrete are the most important:

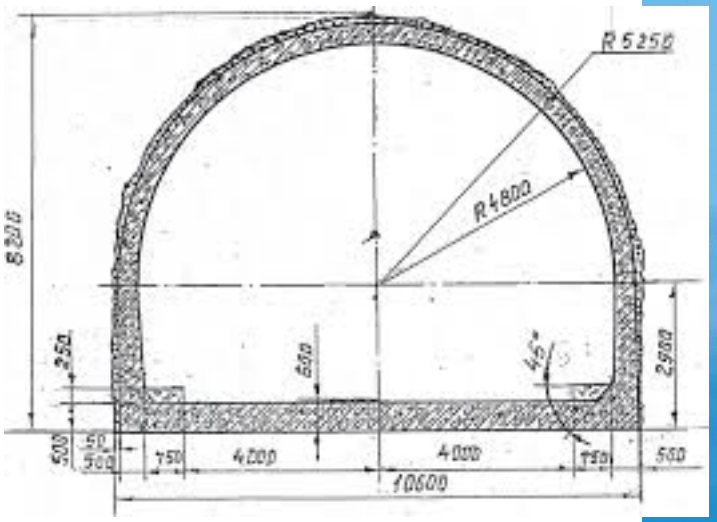
Almost complete absence of concrete segregation and water bleeding. The proposed nano-cement technology makes it possible to ensure early strength, even during the autumn-winter period, and at the same time to increase piles' load bearing capacity. The presence of nano-cement eliminates the use of M600 cement, micro silica, special polymer and hyper plasticizer in a concrete mix. Also, no dispensers for adding minerals and

Table 1. Requirements to concrete mix, comparison of concrete parameters: OPC vs Nano cement.

Ingredients	High Performance Concrete technology	Mechano chemical activation technology	Results achieved when using nano-cement
Cement	M600 and higher grade. Must be without mineral additives; the content of tricalcium aluminate should not exceed 6%	Nanocement of all classes	Availability of materials. Cost reduction
Sand	3 fractions. Must be washed. The content of dust particles should not exceed 0.5%	1 fraction. Unwashed with dust content up to 10%.	
Aggregate	2 fractions. Rough and washed with the content of dust particles no more than 0.5%. Flakiness no more than 10%	1 fraction. Unwashed with the content of dust particles up to 5%. Flakiness up to 30%	
Plasticizer with water reducing additive.	At least 40%	At least 20%	
Silica fume	yes	no	Simplification of mix design. Reduced cost
Cone slump, cm	1 - 2 2 - 5	60 - 75 22 - 25	Guaranteed absence voids when pouring, even in densely reinforced structures
Water bleeding,%	1 - 2	0.01 – 0.02	Uniformity of properties. Resistibility to wash out of concrete mix in water.
Strength at 1 day, MPa	30	70	Acceleration of construction process
Water resistance	25	50	Extended operational life in saline water up to 100 years
Gas permeability coefficient, g/м*h*Pa	0.01	0.001	Long-term storage of highly toxic waste and materials
Maximum frost resistance, cycles	1000	2000	Extended operational life up to 200 years

Shaft domes in mining

The impact of permafrost adds to the aggressive effects of mine waters containing hydrogen sulfide. Our technology and nano-cement make it possible to abandon the use of any special cements (including sulphate-resistant) and, as a result, to reduce the cost of mining.



Marine terminals and offshore drilling platforms supports operations

One of the qualities of concretes on nanocements is extremely high resistance to saline seawater. The proposed technology and nano-cements make it possible to abandon the use of sulfate-resistant cement and at the same time provide concretes with extremely high resistance to sulfate aggression.

Findings

1. A simple and reliable technology has been developed for the production of the fifth generation concrete - super-durable High Performance Concrete. The strength of such concretes based on nanocements can reach up to 200 MPa.

2. The fifth generation concrete can be produced using the existing equipment of concrete plants without additional feeders for mineral and chemical additives.

3. High durability of concrete can be ensured on nano-cement without the use of hyper plasticizers and air-entraining additives. The resistance of concrete on nano-cements to the effects of aggressive media is provided without the use of special cements, including sulphate-resistant and chemical-resistant.

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