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Using of Stone Flour from Some Mineral Rocks in Modern Concrete

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Abstract. There is shown the possibility of using mill ground rocks in SCC without deterioration of rheological properties of concrete mixtures. Obtained high-strength concrete of the new generation with high technical and economic indices and low unit costs per unit of cement strength.

1. Introduction

As history shows, the development of civilizations is directly related to the achievements in the field of construction. One of the reasons for the rapid development of our civilization is the invention in the mid-19th century of a building material such as cement concrete.

Modern concrete properties are significantly superior to products made from traditional concrete. Such concrete is called High Performance Concrete (HPC). The new generation concrete is usually referred to high-strength, ultra-high-strength, ultra-efficient, reactive-powdered concretes, self-compacting concrete, self-leveling and others. They consist of 7 or more optimally selected components. The properties of modern high-quality concrete significantly exceed traditional ones. In addition, they are diverse and can cover the entire scope of concrete use in construction: from ordinary and monolithic concrete with a compressive strength of not more than 50 MPa to high-quality and high-strength concrete 80-1800 MPa, as well as decorative concrete.

A feature of modern concrete is the presence in their composition of a significant amount of water-dispersed suspension (rheological matrix) consisting of cement, stone flour, fine sand and water with a superplasticizer. A large amount of rheological matrix is necessary to ensure high mobility of such concrete mixtures. The large and fine aggregate floats as if "floating" in them, without encountering obstacles and resistance, whereas in old generation concrete, with a lack of matrix, the aggregate particles interfere with each other and for the laying of such concrete one it is necessary to apply vibrocompression or add water, increasing porosity and decreasing strength.

Increasing the volume of the rheological matrix can be achieved by increasing the proportion of finely divided components, such as cement or stone flour. Increasing the proportion of cement is not rational, because it will lead to its overspending and increase in the cost of concrete, as well as to an increase in shrinkage. Thus, it is more expedient to introduce stone flour in the optimum ratio with cement.

The most common in the Russian practice of making such concretes with stone flour is pulverized quartz, i.e. Ground quartz sand. Its advantages include high rheological activity, and in concrete, when it is used, there is an increase in density, a decrease in porosity. And the strength of concretes with this finely dispersed additive can be up to 150 MPa or more with an optimally selected recipe. With all its technological merits, the microquartz also has a significant drawback - an increased cost of production, associated with the washing of sand from clay particles, subsequent drying and grinding in mills to a
high specific surface area. In this regard, pulverized quartz loses some of the advantages and is not in high demand in Russia.

2. Results and Discussions
Therefore, the aim of our research is to find an alternative to pulverized quartz in modern high-quality concretes. Its replacement will reduce the cost of such concrete, thereby making them more affordable in the market.

The novelty of the study is the proposed requirements for the rocks for the production of mineral filler used in the production of high-quality concrete.

1. The rocks must be dense in order to prevent the migration of water and dissolved superplasticizer into the pores of the particles. This requirement is more applicable to rocks of sedimentary origin, which may have not only micro-, but also nanosporosity. The porosity of dolomites, limestones, dolomitized limestones varies depending on the deposit, which obliges the conduct of primary research on porosity. Thin-grained granites, basalts, diabases and the like, which are rocks of igneous origin, have only surface water absorption due to microcracks and surface wetting. Therefore, they do not require porosity control. When grinding internal cavities are destroyed.

2. The rocks must be dispersed and ground to a microscale level of 0 to 120 μm to form a flowable disperse system. Volcanic rocks in their majority are dense (cast or crystalline structure). Those volcanic rocks that are porous: ash, tuff, pumice, have a closed porosity with aluminosilicate pore walls and when grinding fine particles do not absorb water.

3. The rocks must have a rheological activity comparable to cement activity or close to it. An increase in the water requirement of a mixture of cement with a finely divided filler is allowed up to 10-15% in comparison with pure cement.

4. Fine particle filler particles must be positively charged, because all super- and superplasticizers are anionic and negatively charged by functional groups, which contributes to the adsorption of superplasticity polyions on the particle surface, thereby increasing the mobility of the mixture. On negative-charged particles, GP ions do not precipitate and their rheological effect is insignificant. Such rocks include acid rocks - quartz sand, diatomite, and flak.

Thus, we see as an alternative to the use of micro-quartz is the use of stone-crushing wastes of dense rocks and rocks that have better grinding than quartz sand.

One of the most important signs of the suitability of rocks for use as dispersed filler in powdered and powder-activated concrete of the new generation is the porosity index, determined by the water absorption (Wm) of the rock from which they are made. The water absorption of rocks depends on their porosity and pore nature: the number of open and communicating pores assessed by effective porosity, as well as by the pore size.

As the first suitability test, in accordance with the methodology developed by us, it is necessary to determine the water absorption of grains of crushed stone fraction 15-20 mm. Depending on the water absorption by mass after 48 hours, the crushed stone is divided into the following categories:

I category - water absorption no more than 2% - is the most suitable for obtaining concretes of all grades from M200 to M1200;

II category - water absorption from 2 to 4% - can be used for obtaining concrete grades from M200 to M1000;

III category - water absorption from 4 to 6% - can be used for concrete grades from M200 to M800.

An assessment of the suitability of rocks for water absorption showed that magmatic and dense carbonate rocks (dolomite, calcareous limestone) with a water absorption Wm = 0.09-0.8% are most suitable, but a flak and a diatomite are not suitable Wm = 60-120%. In the Penza region, a suitable rock is the Salovsky Sandstone (Wm = 1.4%). The Yessin limestone and the Nikolsky sandstone are conditionally suitable (Wm = 5-16%). Therefore, it was required to check their rheological activity in comparison with cement.

The final assessment of the quality of stone flour is to ensure the necessary dilution of the aqueous suspension from it in a mixture with cement and superplasticizer. The criterion for evaluation is the water-reducing effect (table 1). It is determined by the formula:

\[ \text{Effect} = \frac{\text{Water required with filler} - \text{Water required with cement}}{\text{Water required with cement}} \times 100 \]
where \((W/H)_{unpl}\), \((W/H)_{pl}\) water-aggregate ratio of unplasticized and plastified slurries with the same dissolution from the Hegermann cone (280-320 mm).

**Table 1.** Rheological activity of flour from rocks by the water-reducing effect \(W_{eff}\).

| Composition of a slurry | Type of stone flour |
|-------------------------|---------------------|
|                         | Limestone | Sandstone |
| Cement: Stone flour 100:0| 2,10      | 2,10      |
| Cement: Stone flour 67:33| 2,25      | 2,09      |
| Cement: Stone flour 50:50| 2,37      | 2,05      |

As can be seen, limestone enhances the rheological properties of the suspension, and sandstone slightly worsens.

To assess the effectiveness of the use of stone flour in modern concrete, powder, powder-activated sand and gravely concrete were made.

It is proposed to determine the quality of recipe and raw material selection by the specific consumption of cement per unit compressive strength (kg/MPa):

\[
C_{R_{comp.str.}}^{sp} = \frac{C}{R_{comp.str.}}
\]  

(2)

This evaluation criterion is generalizing: technical, economic and environmental.

**Table 2.** Indicators of samples from powdered concrete.

| №  | Cement, kg/m\(^3\) | Type of stone flour | W/H | W/C | \(\rho_{hum}\), [kg/m\(^3\)] | \(R_{comp.str.}\), [MPa] | \(C_{R_{comp.str.}}^{sp}\), [kg/MPa] | \(W_m^3\), [%] |
|----|-------------------|---------------------|-----|-----|-----------------------------|----------------------|-----------------------------|--------------|
| 1  | 681               | Dusty quartz        | 0,124| 0,386| 2333                        | 103,7                | 6,57                        | 2,94         |
| 2  | 655               | Limestone (Issa)    | 0,116| 0,361| 2302                        | 110,5                | 5,93                        | 2,11         |
| 3  | 680               | Dolomite            | 0,106| 0,328| 2324                        | 110,5                | 6,15                        | 2,52         |
| 4  | 669               | Limestone (Togliatti)| 0,123| 0,383| 2318                        | 113,9                | 5,87                        | 2,97         |
| 5  | 677               | Sandstone (Nikolsk)| 0,154| 0,479| 2095                        | 85,0                 | 8,00                        | 5,89         |
| 6  | 657               | Sandstone (Salovka)| 0,123| 0,383| 2234                        | 103,7                | 6,34                        | 2,69         |
| 7  | 660               | Diabase             | 0,123| 0,383| 2305                        | 107,1                | 6,16                        | 2,81         |
| 8  | 690               | Granite             | 0,115| 0,347| 2302                        | 108,8                | 6,34                        | 2,17         |

Note: Cement brand CEM I 52.5

**Nomenclature:**

\(W/H\) – water-aggregate ratio

\(W/C\) – water-cement ratio

\(\rho_{hum}\) – density of humid concrete

\(W_m^3\) – water absorption after 3 days

**Table 3.** Indicators of samples from powder-activated sand and gravel concrete.

| №  | Cement, kg/m\(^3\) | Type of stone flour | W/H | W/C | \(\rho_{hum}\), [kg/m\(^3\)] | \(R_{comp.str.}\), [MPa] | \(C_{R_{comp.str.}}^{sp}\), [kg/MPa] | \(W_m^3\), [%] |
|----|-------------------|---------------------|-----|-----|-----------------------------|----------------------|-----------------------------|--------------|
| 1  | 623               | Sandstone (Nikolsk)| 0,128| 0,379| 2296                        | 107,2                | 5,81                        | 1,69         |
| 2  | 643               | Limestone (Issa)   | 0,096| 0,314| 2303                        | 105,4                | 6,10                        | 1,76         |

**Powder-activated crushed stone concrete**
3. Conclusions

1. It has been established that ground rocks of various chemical and mineralogical composition and genetic origin are highly effective dispersed additives which, introduced in significant amounts from 40 to 100% of the mass of cement, allow producing concrete with compressive strength from 54 to 110 MPa depending on from the content of cement and the type of concrete.

2. It is established that the specific consumption of cement per unit compressive strength, which is a comprehensive evaluation criterion for all concretes produced, is in the range from 3.3 to 6.6 kg / MPa, which is much lower than in old and transitional generations with SP.

3. The water absorption of the new generation of concrete is determined, which ranges from 1.7 to 3.0%, depending on the type of concrete, which guarantees high water resistance, low water permeability and frost resistance, and determines their durability. Considering that self-packing concrete is a step towards the future, the transition to the technology of their production guarantees high technical and economic indicators of new-generation concrete.

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