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MODIFIED FINE-GRAINED CONCRETE USING RICE HUSK ASH

КҮРҮЧ КАБЫГЫН КҮЛҮН КОЛДОНУУ МЕНЕН МОДИФИКАЦИЯЛАНГАН МАЙДА ДАНДУУ БЕТОН

МОДИФИЦИРОВАННЫЙ МЕЛКОЗЕРНИСТЫЙ БЕТОН С ИСПОЛЬЗОВАНИЕМ ЗОЛЫ РИСОВОЙ ШЕЛУХИ

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Abstract

In domestic and foreign construction practice, special attention is paid to the issues of resource and energy saving. Any possibility of partial replacement of cement with cheap fillers is considered,which can include rice husk ash. Due to availability and low cost it can be a cheap alternative to imported microsilica and metakaolin. The paper presents the results of research on the use of rice husk ash in amorphous form with SiO2 content of 81.3 % as a pozzolanic additive in cement. The microstructure of rice husk ash particles,which consist of multiple agglomerates of silica nanoparticles, often ranging in size from a few tens to hundreds of nanometers, is investigated. Positive changes in the microstructure of the cement matrix are observed.The prepared rice husk ash, when added to cement, helps to improve the physical and technical performance of fine-grained concrete. At the content of rice husk ash - 6 - 8 % and superplasticizer NEOLIT 303 – 0.2...0.8 % the strength of fine-grained concrete in 90 days ≥ 30 MPa.

Keywords: rice husk ash, cement, plasticizers, aggregate, microstructure, fine-grained concrete

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Аннотация

Ата мекендик жана чет өлкөлүк курулуш практикасында ресурстарды жана энергияны үнөмдөө маселелерине өзгөчө көңүл бурулат. Цементти арзан толтургучтарга, анын ичинде күрүч кабыгынын күлүнө жарым-жартылай алмаштыруу мүмкүнчүлүгү каралууда. Жеткиликтүүлүгүнөн жана арзандыгынан улам ал импорттук микросилика жана метакаолинге арзан альтернатива боло алат.

Макалада SiO2 курамы 81,3% болгон аморфтук формадагы күрүч кабыгынын күлүн цементте пуццоландык кошумча катары колдонуу боюнча изилдөөлөрдүн натыйжалары берилген. Көбүнчө өлчөмдөрү бир нече ондогон жүздөгөн нанометрге чейинки кремний диоксиди нанобөлүкчөлөрүнүн көптөгөн агломераттарынан турган күрүч кабыгынын күл бөлүкчөлөрүнүн микроструктурасы изилденген. Цемент матрицасынын микроструктурасында позитивдуу езгеруулер бар. Даярдалган күрүч кабыгынын күлү цементке кошулганда майда бүртүкчөлүү бетондун физикалык жана техникалык мүнөздөмөлөрүн жакшыртууга жардам берет. Күрүч кабыгынын күлү 6 - 8% жана NEOLIT 303 суперпластификатор 0,2...0,8%, майда бүртүкчөлүү бетондун бекемдиги 90 күндө R90 ≥ 30 МПа.

Ачкыч сөздөр: күрүч кабыгынын күлү, цемент, пластификаторлор, толтургуч, микроструктура, майда бүртүкчөлүү бетон

МОДИФИЦИРОВАННЫЙ МЕЛКОЗЕРНИСТЫЙ БЕТОН С ИСПОЛЬЗОВАНИЕМ ЗОЛЫ РИСОВОЙ ШЕЛУХИ

Аннотация

В отечественной и зарубежной практике строительства особое внимание уделяется вопросам ресурсо- и энергосбережения. Рассматривается любая возможность частичной замены цемента дешевыми наполнителями, к которым можно отнести золу рисовой шелухи. Благодаря доступности и низкой стоимости она может являться дешевой альтернативой импортным микрокремнезему и метакаолину.

В статье представлены результаты исследований по использованию золы рисовой шелухи в аморфной форме с содержанием SiO2 - 81,3 % в качестве пуццолановой добавки в цемент. Исследована микроструктура частиц золы рисовой шелухи, которые состоят из множества агломератов наночастиц кремнезема, часто имеют размер от нескольких десятков до сотен нанометров. Отмечаются положительные изменения в микроструктуре цементной матрицы. Подготовленная зола рисовой шелухи при добавлении в цемент способствует повышению физико-технических показателей мелкозернистого бетона. При содержании золы рисовой шелухи – 6 - 8 % и суперпластификатора NEOLIT 303 - 0,2…0,8 % прочность мелкозернистого бетона в 90 суток составляет R90сж ≥ 30 МПа.

Ключевые слова: зола рисовой шелухи, цемент, пластификатов, наполнитель, микроструктура, мелкозернистый бетон

Introduction

In accordance with modern quality standards for building materials, special attention should be paid to the environmental sustainability and economic efficiency of scientific developments. Scientists consider any possibility of replacing natural resources with man-made raw materials. Partial replacement of cement with cheap fillers, such as rice husk ash (RHA) will allow without loss of basic properties of binder and concrete to increase technical and economic performance and solve environmental problems.

About 100 million tons of rice husk by-products are produced worldwide, which are often disposed of in nonenvironmental ways: incineration or landfilling.

RHA consists mainly of silica SiO_2, has a very low bulk density of 90 to 150 kg/m³, has good reactivity and can be effectively used as pozzolanic filler for cements and concretes [1, 2, 3].

The works [4, 5] show the possibility of obtaining modified concrete with the required performance characteristics through the joint use of organic-mineral additives-modifiers of cement and concrete structure. During cement hardening, containing amorphous silica RHA forms additionally low-basic calcium hydrosilicates of CSH type, compacting the concrete structure. Such concretes have increased frost resistance, water resistance and resistance to chemical influences. Studies have shown that rice husk ash, when added to cement, increases the strength of concrete by 32% at the age of 28 days and water resistance by one or two grades.

Due to the availability and low cost of raw materials, RHA can be a cheap alternative to imported microsilica. This will reduce the consumption of cement in concrete mix without loss of strength and allow for more environmentally friendly construction.

Materials and methods. The purpose of this research: to study the possibility of modification of fine-grained concrete with fine silica additive in the form of rice husk ash from the southern region of the Kyrgyz Republic.

The fine-grained concrete specimens were used for the manufacture of the samples: Portland cement - M400 D20 GOST 10178-85, 30515-97, NG- 26.25; compressive strength of 28 days of hardening - 36.6 MPa; density ρ - 3.1 g/m3. Sand - coarseness modulus Mk =3.38. Rice husk ash, chemical composition: %: SiO_2 – 81.3; Al_2O_3 - 4; CaO -5; Na_2O -1.5; MgO -3; Fe_2O_3 -4; K_2O -1.2. Superplasticizer - Neolit 303, pH 3.5 - 5.5 of the solution, density 1120 ± 30 kg/m3. For this research, the structure of rice husk ash was previously studied using a VEGA3 TESCAN scanning electron microscope (Fig. 1a, b).

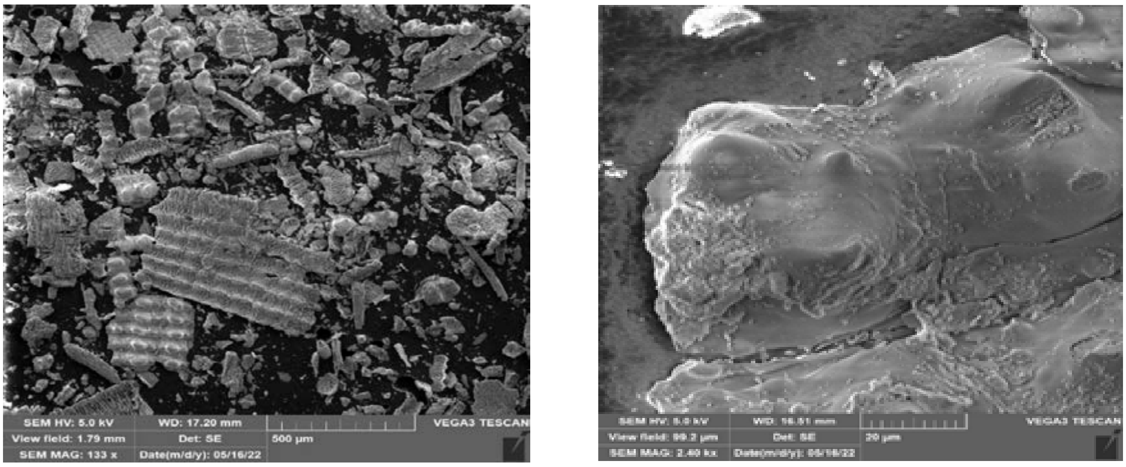

Fig.1. Microstructure of rice husk ash (a) at magnification (×133) and (b) at magnification (×2400)

Results and Discussion

The microstructure of rice husk ash (RHA) particles is unique due to the content of amorphous silica. It can be seen that the rice husk ash consists of chaotically scattered small porous particles of irregular shape. At low magnification (×133), a porous surface with microcracks and small granular particles can be seen (Fig.1a). At high magnification (×2400) (Figure 1b), the microstructure of rice husk ash (RHA) particles is represented by amorphous silica and has a porous structure. At this magnification level, amorphous (disordered) areas of silica are visible and do not have a clear geometric shape, which confirms the absence of crystalline structure. The RHA particles consist of multiple agglomerates of silica nanoparticles, often ranging in size from several tens to hundreds of nanometers.

When RHA is used in cement, strength is increased due to its unique properties. The porous structure of RHA provides increased adsorption properties, which reduces water and increases the strength of the cement stone. RHA introduces positive changes in the microstructure of the cement matrix. Prepared RHA in amorphous form as well as coal combustion ash when added to cement promotes the increase of concrete compressive strength at the age of 28 days by 32 % and water resistance by one or two grades [1, 2, 3].

In these studies, the active fine admixture used for the modification of FGC as an active fine admixture was RHA from the southern region of Kyrgyzstan. In order to reduce water consumption, it is necessary to use water-reducing additives, which will affect the strength properties of concrete.

To evaluate the effectiveness of using rice husk ash in concrete, a 2-factor experiment was conducted. Variable factors: rice husk ash -X1 = 4 ± 4% and X2 = 0.4 ± 0.4% - Neolit 303 additive (relative to the amount of cement M400 D20). The rest is cement. The following parameters were selected as output parameters: fctk and fck.cube compressive and flexural strength after 7, 28 and 90 days of curing, density ρ 28 day, water-cement ratio B/C, degradation factor Kd. Mathematical models (Table 1) and their graphical images of fine-grained concrete (FGC) properties were obtained based on the experimental results (Fig. 1 - 4).

Table 1. Coefficients of models of the main properties of fine-grained concrete

№	Properties of FGC	1	2	3	4	5	6
		b0	b1	b11	b2	b22	b12
1.	f_{ctk}^{7}	10.95	-2.04	2.21	-1.2	-1.88	0.37
2.	f_{ctk}^{28}	14.09	-1.94	0.69	-1.67	0.05	1.0
3.	f_{ctk}^{90}	21.97	0.28	0.86	0.85	0.00	0.02
4.	$f_{ck.cube}^{7}$	15.4	-1.5	2.37	-1.3	-0.63	0.26
5.	$f_{ck.cube}2^{8}$	22.15	-5.37	4.4	0.28	3.6	0.36
6.	$f_{ck.cube}^{90}$	30.91	-0.96	-0.22	0.61	-1.53	-0.98
7.	ρ^{28}	2.41	-0.026	-0.001	-0.009	0.022	-0.004
8.	ρ^{90}	2.392	0.101	-0.032	0.066	0.017	-0.031
9.	W/C	0.525	0.025	-0.014	-0.051	0.012	-0.002
10.	K_d^{90}	0.697	0.036	0.34	0.19	0.056	0.043

According to the model (1) it can be noted that RH ash at its maximum amount (8%) x1 = 1 reduces the strength to a certain concentration, linear coefficient b1 = - 2.04 and quadratic b11 = 2.21. On the nomogram where the strength decreases from 18 to 12 MPa at the content of RH ash 6-8 % and the optimal concentration of chemical additive 0.2 ... 0.6 % (Fig.1a).

a) b) c)

Fig. 2. Nomograms of FGC flexural strength after (a) 7 days fctk7 (b) fctk28 and (c) 90 days fctk90

Analysis of the coefficients of the model fctk28 showed that at the maximum filling of cement with fly ash and the amount of plasticizer to x1 and x2 = +1, the strength of FGC after 28 days of curing slightly decreases b1 = - 1.94 and b2 = – 1.67. The nomogram (Fig.2 b) shows that with simultaneous increase in the amount of RH ash and plasticizer, there is a sharp decrease in the strength of fctk28 from 19 to 12 MPa.

Since RH ash as a pozzolanic additive lengthens the setting time of cement, the processes of structure formation on 28 days are not yet completed, it can be seen on the nomogram (Fig.1c) that increasing the plasticizer to 0.8 % and the optimal amount of RH ash 2...6 % provides the maximum strength fctk90 to 23.6 MPa.

From the compressive strength models of FGC (4-6), it can be observed that the maximum cement filling of RHA 8% (x1 = 1) acts negatively. There is a linear effect at x1 = 1 for fck.cube7 (b1 = – -1.5), for fck.cube28 (b1 = – 5.37) and for fck.cube90 (b1 = – 0.96). The quadratic effects of the models indicate the search for the optimum concentration of RHA in concrete. At factor (x1), the quadratic coefficient is (b11 = 2.37) for fck.cube7, for fck.cube28 (b1 = 4.4) and for fck.cube90 (b1 = – 0.22).

a) b) c)

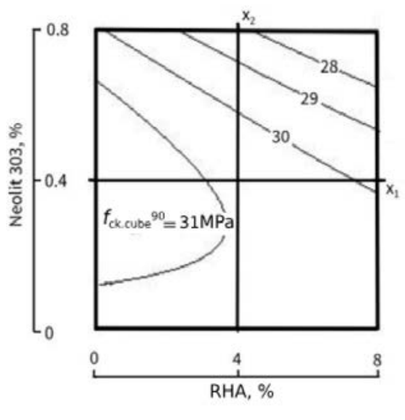

Fig. 3: Nomograms of FGC compressive strength after (a) 7 days fck.cube7, (b) 28 days fck.cube28 and (c) 90 days fck.cube90

More clearly the change of compressive strength of FGC at different curing times can be seen on nomograms of Fig. 3. In the early terms there is a significant decrease in strength as the cement is filled with RHA the index of fck.cube7 decreases from 20 to 14 MPa, for fck.cube28 from 30 to 18 MPa. However, 90 days of curing the change in strength is insignificant and depends on the concentration of plasticizer fck.cube90 from 32 to 28 MPa.

The values where the strength fck.cube28 $\geq$ 30 MPa are in the region of formulations x1 = -1...- 0.9 (RH ash 0...1%) and x2 = -0.8...0.8 (SP 0.2...0.6). At 90 days of curing, the region where the strength fck.cube90 $\geq$ 30 MPa is much wider. Here the amount of RHA in cement increases up to 6 % at an additive concentration of 0.4...0.6 % (Fig. 3c).

Concrete density values can vary depending on various factors. The amount of RHA in cement, its dispersibility, pozzolanic activity. By reducing the number of pores in the concrete structure, it can increase. Due to the lower density of RHA particles compared to cement particles, the density of fresh concrete may decrease. The density of fresh concrete may also decrease at high dosages of RHA. The density of the concrete may increase due to the reduction of the total porosity, due to the active interaction of the RHA with the hydration products. In spite of the density decrease, due to its pozzolanic activity, ash ash promotes the densification of concrete structure and allows to improve its performance characteristics (water resistance and durability). In the model ρ28 at x1 the linear coefficient b1 = - 0.026. With increasing the amount of RH ash, the density practically does not decrease from 2.45 to 2.4 kg/m3.

As the curing of concrete with RH ash continues for a long period of time its structure changes due to the formation of additional amount of hydrosilicates. The density model ρ90 shows that it depends first of all on the concentration of chemical admixture and then on the filling of cement with fly ash. At the maximum concentration of X2 - NEOLIT 303 - 0.8 % (Fig. 3b), the density of RHA is ρ90 = = 2.425 kg/m3. The additional introduction of RHA reduces the density to 2.35 kg/m3.

The quality of concrete is also affected by the W/C ratio. The higher the W/C ratio, the greater the number of capillary pores formed in the concrete structure. The effect of the RHA and chemical admixture on the water-cement ratio W/C was evaluated by the model W/C = f (x1, x2). The analysis of model (9) showed that RHA (x1) slightly increases W/C (b1 = + 0.025), but up to a certain point (b11 = 0.014). The positive influence of superplasticizer (x2) is more significant, here (b2 = - 0.051) and (b22 = + 0.012). Thus, at RHA = 4%, W/C decreases as the concentration of superplasticizer increases from 0.58 to 0.48 % (Fig. 4a).

Conclusion. When designing the composition of fine-grained concrete, attention should be paid not only to the quality of raw materials, but also to the formation of a homogeneous concrete structure.Its homogeneity can be judged by the ratio between the flexural strength and compressive strength, the so-called coefficient of destruction of the structure. And the higher this coefficient Kd = fctk / fck.cube, the more homogeneous the structure and the higher the ability of the material to resist irregular disturbances and deformations. At 90 days the processes of structure formation are almost attenuated and according to the coefficient of destruction of concrete it can be noted that the introduction of RH ash, due to its pozzolanic activity improves the microstructure of concrete. At the concentration of chemical admixture 0.4 ... 0.6 % depending on the filling of RHA 0...8 % Kd increases from 0.7 to 0. (Fig.4 b). Thus, studies have confirmed the possibility of using rice husk ash as an active mineral admixture in cement for the manufacture of fine-grained concrete. Due to high silica content in amorphous form (SiO_2 - 81 %) Rice husk ash exhibits pozzolanic activity. Organo-mineral modification improves the microstructure of cement stone and consequently increases the durability of fine-grained concrete. The strength of concrete at 90-day hardening / fck.cube90 ≥ 30 MPa is achieved at the content of RHA - 6 - 8 % and concentration of superplasticizer NEOLIT 303 – 0.2...0.8 %. Density ρ90 day is in the range of 2.35...2.43 kg/m3. Destruction coefficient Kd increases from 0.7 to 0.9, which indicates the homogeneity and resistance of concrete to various types of loads. The use of RHA will reduce the consumption of cement in the concrete mixture without loss of strength and contribute to more environmentally friendly construction.

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