UDC 625.861 (045)
DOI: 10.18372/2306-1472.77.13497

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INVESTIGATION OF THE STRENGTH OF RUBBER CONCRETE ON THE BASIS OF MODEL OF THE SPECIFIC AREA OF FINE AGGREGATE

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Abstract

Based on the microscopic analysis of a large amount of rubber cement mortar, a mathematical model was established to qualitatively analyze the specific surface area of the rubber powder-sand mixed with fine aggregate. On the basis of the mechanisms of the influence of the methods of mixing the rubber powder, the size of the particles (rubber powders with a particle size of 20 mesh, 60 mesh, 80 mesh and 120 mesh were used - only 4 species, for testing the resistance of the concrete to the compression), etc., on the specific surface of the adhesion of the fine aggregate with rubber powder, the scientific explanation of the logical differences existing in the process of previous studies of rubber concrete has been given, the in-depth study of the influence of methods and mixing parameters, particle sizes and other factors on the resistance of concrete to compression has been carried out. The results show that the negative effect of replacing a fine aggregate of concrete with the same volume of rubber powder on the strength of concrete is much less than the negative impact on the strength of concrete rubber powder mixed with concrete. The size of particles in 60 mesh is a turning point, because the strength of the concrete for compression in the process of reducing the diameter initially decreases, and then increases. The main reason lies in the fact that the specific surface of the mutual contact of rubber particles in concrete is changing. In this paper, with the help of a large number of experimental studies, on the basis of the method of "model of determination of concrete surface area", which uses the coefficient of contact between the rubber mixture and the fine aggregate, an additional study and a deep study of mechanisms of influence on rubber concrete have been carried out.

Keywords: rubber concrete; specific surface; strength; mathematical model

1. Introduction

With the rapid development of society, transport plays an extremely important role in people's lives, and in the world, the number of cars increases with explosive speed. According to the statistics of the relevant institutes, the world's production of tires is about 1.5 billion tons per year, and the total number of worn tires is about 4.5 billion tons. However, every worn tire becomes "unnecessary" for the car [1]. Deprecated tires are refractory polymeric elastic materials that are difficult to recycle, and decomposition in the soil takes decades, burning can cause serious air pollution, creating a global headache for "black pollution". In most cases, thrown tires do not use their entire useful resource, and the volumes of materials used to produce tires are too large. If the tires used are directly thrown into the environment, then this will not only be a waste of resources, but also create imminent threats to environmental pollution. As a result of the rapid development of our country, in terms of the number of personal cars, it occupies a leading place in the world, is fairly considered a country with a lot of personal cars. Under these conditions, the impact of used tires on the environment becomes even more serious. Therefore, since the middle of the 20th century, the processing of waste tires through their modification and processing to obtain rubber (or) carbon products has become a problem to which scientists are of considerable interest, while concrete materials tended to increase the characteristics of elasticity and stability to aging and the like. Therefore, waste tires processed in rubber fillers, after being added to concrete materials, will have good prospects for development, especially in materials for road concrete. This article is based on many studies of scientists involved in the study of rubber concrete under a microscope for the purpose of the fastest application in production [2, 3].

2. Analysis of researches

A large number of scientists have already carried out research on the mechanical properties of cement based materials on rubber powders. It is known that the unreasonable addition of rubber powder reduces the useful mechanical properties of cement composites. Wang Hailong and others [4] studied the effect of different sizes particle and dosage of the used rubber powder on the compressive strength and bending of the cement mortar. The results of comparing the compression and bending strength over 3 d (d = 1 day), 7 d, 14 d, 21 d, and 28 d show that when the size of the rubber particles is the same, the rubber powder content is inversely proportional to the compressive and bending strength of the cement mortar. For the same dose, the particle size is directly proportional to the compression and bending strength. Similarly, Xu I [5], experimentally studying three layers of pure cement mortar, cement-sand mortar and concrete, conducted an experimental analysis of the physical and mechanical properties of a composite material based on concrete with different contents of rubber powder and the size of rubber powder particles. He has concluded that "with the increase in the content of rubber powder, the time of coagulation (hardening) of composite concrete increases, and while provided the same content of rubber powder, the smaller the size of the particles of rubber powder, the less time to cement for hardening, as well as the strength of pure cement mortar, cement-sand mortar and the concrete decreases as the size of the particles of the rubber powder decreases. Lu Shasha [6] and others conducted a comparative analysis of the influence of the amount of rubber particles, the size of the particles on the strength of rubber concrete, and obtained the experimental conclusion "provided the same amount of rubber powder, with the increase in the size of the particles of rubber, the strength of concrete compression decreases". Comparing the experimental conclusions of Lu Shashi and Xu I, we can also find that the conclusions about the experimental results related to the size of the particles are completely inverse. Therefore, Shi Guanglin and Zhang Haibo conducted a pilot study on concrete and cement-sand solution simultaneously [7]. His results showed that with the same amount of replacement, the compressive strength of the sand-cement solution with the addition of rubber powder with a particle size of 5 mesh always exceeds the strength of a similar solution with the size of particles of 100 mesh. But for rubber concrete with a lower level of replacement, the compressive strength of 100-mesh rubber concrete is higher than that of 5-meshe rubber concrete. On reaching a certain amount of replacement, the compressive strength of 100-meshe rubber concrete, on the contrary, is lower than the 5-mesh. There is a pivotal mass of substitution, for a different age of durability, the pivotal mass of substitution is different. For the durability of the age of 28 d, the compressive strength difference between 100 mesh and 5 mesh of rubber concrete is not obvious when the weight of the substitution is more than 50%.

According to the existing research results on materials from cement with the addition of rubber powder, we observe that different experimental methods give different conclusions, especially in regard to the size of the particles of difference are relatively large, and the reasons for the differences remain unclear. In terms of mixing techniques, the effect of different methods of mixing on rubber concrete is obviously different. Including, the rubber filler according to the size and shape is divided into a rubber block and rubber powder, respectively. The rubber block is usually used as a coarse aggregate that replaces the materials, and fine particles of rubber are mixed into concrete in the following three ways: (1) External mixing of concrete (external mixing used in the sources [5-6, 8-9]); (2) internal equal-mass substitution of a filler (the equal-mass mixing used in sources [10-11]); (3) internal equal-volume mixing of a fine filler (internal equal-volume mixing is used in sources [12-16]).

Cement is a typical inorganic non-metallic material, rubber powder belongs to organic polymer composite materials, the chemical composition of these two materials is very different, the compatibility of contact surfaces is poor. The inclusion of rubber powder in cement composites will not lead to a chemical reaction with water, but will prevent the hydration of cement and water, freezing of cement with sand and gravel, will lead not only to increase the hardening time, but also to a significant reduction in the mechanical strength of composite material on the basis of cement with rubber powder. With the help of a large number of experiments, it has been shown that these phenomena are due to different size of the contact area of the fine filler and rubber.

In this work, from the point of view of the specific surface area, the differences in the conclusions regarding the mechanics of composites on the basis of cement and rubber powders, determined by different methods of making a mixture, the size of the particles of rubber powder and the morphological properties of the rubber powder have been investigated. First of all, with the help of granulometric analysis, the theoretical foundations for the model of the specific surface were created, as well as mathematical models of the specific surface of the three types of mixing were created, after which quantitatively analyzing are the methods of the change of the specific surface in three types of mixing from different macroscopic and microscopic points of view of quantitative analysis. Then, based on experimental results and existing theories, the differences in the mechanics of cement-based composites with the addition of rubber powder were explained and analyzed. Finally, rubber particles of four sizes (20 mesh, 60 mesh, 80 mesh, 120 mesh) were used, with which the strength of compression of concrete was investigated with the external mixing of small aggregates with masses of 3%, 6% and 9%; the mechanism of influence of these factors on the cement base with rubber powder was determined, the influence of the size of rubber particles on the strength of concrete on compression was revealed.

3. Mathematical model

One can not be underestimated is the influence of the factors of the mesoscopic form of rubber particles on the formation and mechanical properties of cement-based composites. In this section, we use the dynamic particle analyzer BT-1800 to monitor the shape, size and other factors of rubber particles. Because of the wrong form of rubber particles, the macroscopic description can not really reflect the characteristics of these particles, therefore, in this document from a microscopic point of view, a quantitative-qualitative analysis of the contact between the rubber particles and concrete fillers is carried out. Figure 1 shows the results of testing sphericity and the ratio of length to diameter of rubber particles 80 mesh.

From Fig. 1 on the right, the result of the analysis can be concluded: when the spherical ratio of rubber particles is less than 0.75, then the total particles are 5.1%; when the spherical ratio reaches 0.85, then the total particles make up 66.79%.

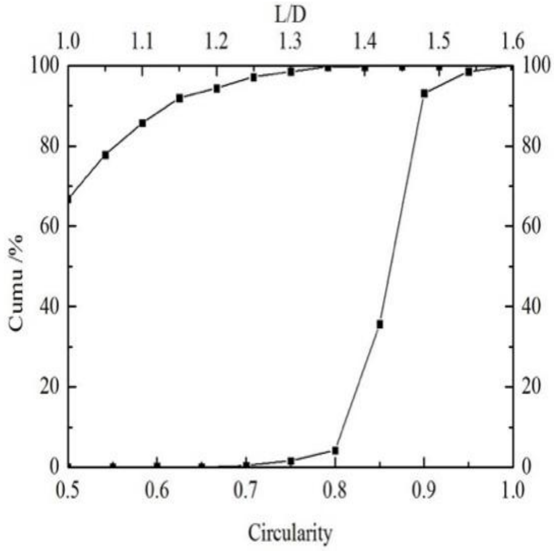

Fig. 1. Circular ity and length to diameter ratio of rubber particles

As a result, the average ratio of length to diameter 1.58 was obtained, which provided good research conditions for the calculation of the specific surface area of the modified rubber and sand filler.

4. Analysis of examples of calculations

For the experiment used a rubber powder, that was produced by a rubber powder plant "Hebei Taishan Highway", performance indicators are presented in Table 1; as a fine aggregate, the river sand of zone II of the standard 2.55, the apparent density of 2546 kg/m^3, the norm of the residue of sifting and accumulated residue of sifting is shown in Table 2.

As an example, a rubber powder of 20 mesh, 60 mesh, 80 mesh, 120 mesh is taken and mixed with 6%, as well as a rubber powder of 60 mesh for 3%, 6% and 9% impurities, then the specific surface area of fine filler of sand and rubber powder is calculated according to the following three methods of mixing: (1) external concrete mixing; (2) internal mixing of a fine filler with a egual-mass substitute; (3) internal mixing of fine aggregate with equal-volume substitution.

Calculation of the rate of change of the specific surface area of the sand-rubber filler see in Table 3. From Table 3 it is possible to intuitively establish that for each kind of mixing, increasing the amount of mixing or reducing the size of the particles will increase the specific surface area. By comparing the external mixing of the concrete and the internal mixing with the equal-mass replacement of the fine filler, the increase in the surface area in the first method is slightly less than in the second one, but in both cases it is much larger than with the internal mixing method with the equal-volume substitution of the fine filler. When the size of the particles of the residue of the discharge of the river sand and the selected rubber powder is the same, in the method of even-volume internal mixing, when the particle size is reduced, the specific area is smaller than with the standard value of the fine filler.

Table 1

Property of rubber powder

Powder type	20mesh	40mesh	60mesh	80mesh	100mesh	120mesh
Screen specifications /mm	0.9	0.45	0.3	0.2	0.15	0.125
Apparent density /kg·m^{-3}	483	483	483	483	483	483
Stacking density / kg·m^{-3}	341	351	367	376	382	387

Table 2

Particle size distribution of river sand

Screening standard(No.)	1	2	3	4	5	6	7	8
	4.75~2.36 mm	2.36~0.9 mm	0.9~0.45 mm	0.45~0.3 mm	0.3~0.2 mm	0.2~0.15 mm	0.15~0.125 mm	<0.125m m
Grade retained	0.8%	25.7%	28.8%	20.7%	11.4%	5.7%	2.4%	4.5%
Accumulated retained	0.8%	26.5%	55.3%	76.0%	87.4%	93.1%	95.5%	100.0%

Table 3

Test results of specific surface area

Specific area /cm2·g^{-1}	(1)	(2)	(3)
20-6%	3.70%	4.00%	-4.10%
60-6%	22.50%	23.90%	-0.30%
80-6%	36.60%	38.80%	2.50%
120-6%	62.00%	65.70%	7.60%
60-3%	11.6%	11.9%	-0.2%
60-6%	22.5%	23.9%	-0.3%
60-9%	32.9%	35.8%	-0.5%

5. The process of calculating the model of a specific area

First, the actual sieve sand residue is determined according to the required sizing interval (Table 2), (i = 1, 2, 3, ..., m). Calculate the size of the rubber particle used for similar screen sand according to the size of the particles from large to small sequentially and note j (j = 1,2,3, ..., n).

Secondly, through research and analysis we make the following assumptions:

(1) all rubber powder and sand - is the correct spherical shape;

(2) rubber powder and sand tightly arranged intermittently;

(3) it is established that the upper limit of each interval of the grain of sand should be considered as the radius r_i, and the upper limit of each interval of the rubber particle should be considered as the radius r_j .

However, the surface area and the volume of each spherical fraction of rubber powder and sand, respectively:

$$S_i = 4\pi r_i^2 \quad (1)$$

$$S_j = 4\pi r_j^2 \quad (2)$$

$$V_i = \frac{4}{3} \cdot \pi r_i^3 \quad (3)$$

$$V_j = \frac{4}{3} \cdot \pi r_j^3 \quad (4)$$

In unit volume v_0 (in this article 1cm^3) i – interval of screening, j – total amount of rubber particles n_i, n_j equals (mode notes rounding):

$$n_i = \frac{v_0 - \mathrm{mod}(v_0, v_i)}{v_i} \quad (5)$$

$$n_j = \frac{v_0 - \mathrm{mod}(v_0, v_j)}{v_j} \quad (6)$$

Therefore, according to different apparent density of sands and rubber powders ρ_{sand}, ρ_{RP} specific area of the i-interval of screening S_i and the specific surface area of the rubber powder S_j in accordance:

$$S_i = \frac{n_i \cdot s_i}{\rho_{sand}} \quad (7)$$

$$S_j = \frac{n_j \cdot s_j}{\rho_{RP}} \quad (8)$$

In accordance with the law on the ratio of the size of the filler particles and surface area [16], got a specific area of the surface of the river sand S_w a_i for the appropriate withdrawal residues:

$$S_w = S_i \cdot a_i \quad (9)$$

Relative insufficiency of fine filler of rubber powder:

(1) after external mixing of j-rubber particles w% the rate of change in the surface area of a sand-rubber filler $S_{ixj}^{(1)}$:

$$S_{ixj}^{(1)} = \left(\frac{S_j}{S_w} - 1 \right) \cdot \frac{w}{w+100} \cdot 100\% \quad (10)$$

(2) after equal-mass internal mixing of j-rubber particles w % the rate of change in the surface area of a sand-rubber filler $S_{ixj}^{(2)}$:

$$S_{ixj}^{(2)} = \left(\frac{S_j}{S_w} - 1 \right) \cdot w\% \quad (11)$$

(3) after equal-volume internal mixing of j-rubber particles w% the rate of change in the surface area of a sand-rubber filler $S_{ixj}^{(3)}$:

$$S_{ixj}^{(3)} = \left(\frac{S_j}{S_w} \cdot \frac{\rho_{RP}}{\rho_{sand}} - 1 \right) \cdot w\% \quad (12)$$

6. Experimental researches

Selection of cement material Jidong P O42.5 - ordinary Portland cement; the choice of performance indicators for rubber powders, as shown in Table 1; the use of small fillers described in paragraph 2.3; water - tap water. In accordance with the provisions of the national standard "Technical regulations for light aggregates of concrete" (JGJ51-2002) the composition is calculated and a test mixture is made, as concrete standard is concrete with light fillers without rubber powder, with the strength of C30, the coefficient of aqueous adhesives 43%, sand factor 0.43, for all concrete test blocks the same ratio of water, cement, sand, and pumice is strictly maintained (W: C: S: G = 1280: 2960: 5760: 4080).

Combining the interconnection of various factors and the "specific surface" of a rubber cement solution, the following experiments were carried out:

1. (Quantitative Mixing and Volume Experiment). The basic requirements of concrete, mixing and modification are absolutely identical, in the appropriate range of sizes separately, in accordance with the weight ratio of 3%, 6% and 9%, a fine aggregate of concrete was mixed with rubber powder, then the concrete components were created, and tests were conducted on compression resistance, results are given in Table 4.

2. (Experiment of variable particle sizes). The basic requirements for mixing the concrete are exactly the same, the mixing methods and modifications are absolutely the same, and the ratio of the mass of the rubber powder to the concrete is 3%, 6% and 9% respectively. The compression test was carried out on four different sizes of rubber powder particles of 20-30 mesh, 50-60 mesh, 80-90 mesh and 110-120 mesh. The results are summarized in Table 4.

3. (Experiment to change the mixing methods). The basic requirements of mixing concrete are exactly the same, the parameters are all for 3%, absolutely the same way of modification. Accordingly, for each range of particle size, 3 experiments with concrete were carried out, namely, external mixing, equal-mass internal mixing with the replacement of a fine filler, an equal-volume internal mixing with the replacement of the filler, which were separately named experiment A, experiment B, experiment C The results are summarized in Table 5.

Table 4

Mix proportions of concrete test block and the result

Sample No.	Cement /g	River sand /g	Water /g	Rubber Powder /g	Gravel /g	Water Reducer /g	Compressive Strength /MPa
MRC20-30-1	2960	5760	1280	88.8	4080	6.4	24.50
MRC20-30-2	2960	5760	1280	177.6	4080	6.4	24.99
MRC20-30-3	2960	5760	1280	266.4	4080	6.4	19.54
MRC50-60-1	2960	5760	1280	88.8	4080	6.4	23.39
MRC50-60-2	2960	5760	1280	177.6	4080	6.4	21.54
MRC50-60-3	2960	5760	1280	266.4	4080	6.4	17.62
MRC80-90-1	2960	5760	1280	88.8	4080	6.4	24.59
MRC80-90-2	2960	5760	1280	177.6	4080	6.4	23.50
MRC80-90-3	2960	5760	1280	266.4	4080	6.4	23.58
MRC100-120-1	2960	5760	1280	88.8	4080	6.4	25.08
MRC100-120-2	2960	5760	1280	177.6	4080	6.4	23.63
MRC100-120-3	2960	5760	1280	266.4	4080	6.4	23.51
无	2960	5760	1280	无	4080	6.4	33.31

Table 5

Mix proportions of concrete test block and the result

Sample No.	Ceme nt /g	River sand /g	Water /g	Rubber Powder /g	Gravel /g	Water Reducer /g	Compressive Strength /MPa
MRC20-A	2960	5760	1280	88.8	4080	6.4	19.50
MRC20-B	2960	5760	1280	88.8	4080	6.4	23.60
MRC20-C	2960	5760	1280	88.8	4080	6.4	24.60
MRC60-A	2960	5760	1280	88.8	4080	6.4	20.30
MRC60-B	2960	5760	1280	88.8	4080	6.4	21.54
MRC60-C	2960	5760	1280	88.8	4080	6.4	23.29
MRC80-A	2960	5760	1280	88.8	4080	6.4	19.10
MRC80-B	2960	5760	1280	88.8	4080	6.4	22.53
MRC80-C	2960	5760	1280	88.8	4080	6.4	24.52
MRC120-A	2960	5760	1280	88.8	4080	6.4	17.92
MRC120-B	2960	5760	1280	88.8	4080	6.4	23.63
MRC120-C	2960	5760	1280	88.8	4080	6.4	25.12

7. Experimental analysis

Complex experiment 1 and complex experiment 2 are as follows.

According to the results of the 28-d compression strength test, a linear diagram is shown in Figure 2. According to the figure, we find: 1. With the increase in the mixing of rubber, the compressive strength of concrete components shows a tendency to decrease. 2. At the same dose of mixing, starting at 60 mesh as a turning point, the compressive strength at the decrease in the size of the rubber particles initially decreases, and then increases. Based on the analysis presented in section 2, this test proves that the strength of rubber concrete 60 mesh and below is mainly influenced by factors such as the bond strength between the rubber particles and the cement matrix, as well as the actual ratio of water and cement mix, due to the change in the surface area of the fine filler. However, the factors of integrated strength of rubber concrete 80 mesh and above have changed, there is no longer any interaction with the specific surface.

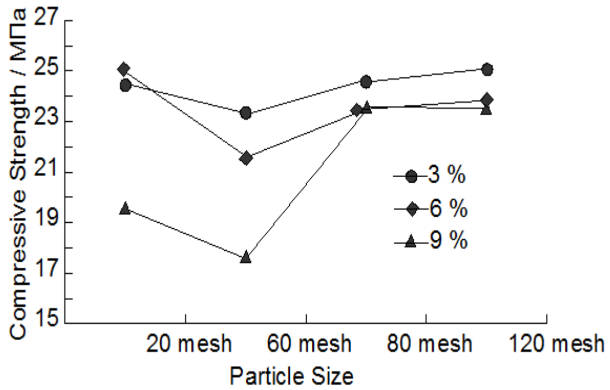

Fig. 2. The change of the particle size of 28d rubber concrete with the same amount rate

From the figure, we also found:

1. With a decrease in the size of the particles, the reduction of the strength of rubber concrete, caused by the mixing of rubber, shows a tendency to decrease.

2. According to the calculation of the model of the surface area, with a decrease in the particle size, the change in the specific area caused by the change in the rubber content is gradually increasing. This shows that the smaller is the size of the particles of the rubber powder, the smaller are the specific surface affects the strength of the concrete, the influence of the contact surface of the rubber particles on the strength of their bond with the cement matrix also decreases. The aforementioned phenomenon shows that the contact surface of small particles of rubber in concrete has little effect on strength, without revealing obvious features of the extra-elasticity.

Analysis of complex experiment 3:

1. Based on the test result in conjunction with the calculation of the model of the second section, it can be seen that the growth of the "specific surface" of the contact of rubber and fine material is greater in experiments A and B than in C.

2. The results of the experiment show that the strength of the material in the method of equal-volume substituting of fine filler with internal mixing is better than in the other two experiments. Section 2, "Calculation of the model of a specific area" also shows that this method of mixing has the best contact coefficient of a specific area. This means that the more a specific area of the surface, the higher the compressive strength.

Thanks to microanalysis we can easily conclude that the reason for the above results is:

1. Rubber is a poorly soluble polymer, which has a very bad affinity with water. On the one hand, the external way of mixing prevents the affinity between water and fine aggregates of concrete, increases the internal vulnerability of concrete. On the other hand, when external mixing, the total surface area of the rubber powder is excessively increased, so that the water molecules, that must be included in the concrete reaction, are attached to the surface of the rubber powder and interfere with the normal reaction of the concrete.

2. At the same time, in the method of internal mixing with the replacement of equal-volume of increase of the specific surface of rubber and fine aggregates of concrete has a mild good effect, therefore the method of even-volume internal mixing has greater advantages.

3. In addition, according to the quantitative analysis of the model, we see that with an increase in the proportion of rubber powder, the total area of contact between the rubber powder and the filler is increasing, but the area of contact of the small filler decreases. Since the fine filler is a major component, and the rubber powder is only an impregnated material, so the stress intensity tends to weaken.

8. Conclusion

(1) The mathematical model used to calculate the surface area of a fine filler determines the models for calculating of three types of mixing of rubber powder and a specific area of fine filler. The method of equal-mass substitution of a fine filler had the greatest effect for increasing the specific surface area, followed by an external mixing method of concrete. With regard to the effect of the method of equal-volume substitution of a fine filler on the change of the specific surface area, it shows various effects in accordance with the size of the particles, but in general, the changes are insignificant. With the same dose of mixing and particle size, the equal-volume method has a greater effect on the strength of the concrete than the equal-mass method and the method of external mixing.

(2) When the particle size increases, the compressive force increases, and because the specific surface of the fillers determines the mutual contact and chemical bonding, but all these facts have a range of relevant conditions and factors. Therefore, when the particle size is less than 60 mesh, an anomaly appears because the combination of very fine rubber particles and fillers has peculiarities.

(3) With the increase in rubber composition, the compressive strength of concrete components tends

to decrease, as the rubber powder is part of the included fillers. When the ratio of rubber powders increases, although the total contact area of rubber powder and fine filler is increasing, but the contact area of the small filler itself is decreasing, therefore the strength of the resistances tends to decrease.

(4) The method of mixing rubber powders, the amount of mixing and the size of the particles seriously affect the strength of rubber concrete. In this work, using the model of calculation of the specific area, deep researches and conclusions on the research of rubber concrete have been made, problems of contradictory analysis in previous studies have been solved, this model may be applied in the future to investigate other properties of concrete.

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Дослідження міцності гумового бетону на основі моделі визначеної області дрібного агрегату

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Стаття присвячена актуальним питанням дослідження міцності гумового бетону. Ґрунтуючись на мікроскопічному аналізі великої кількості гумового цементного розчину, була створена математична модель для якісного аналізу питомої поверхні гумового порошку, змішаного з дрібним агрегатом. На основі механізмів впливу методів змішування гумового порошку використовували різні розміри частинок для виконання випробування по визначенню опору бетону на стиск. Надано наукове пояснення логічних відмінностей, що існували в процесі попередніх досліджень гумового бетону. Проведено поглиблене дослідження впливу методів та параметрів змішування, розмірів частинок та інших факторів на стійкість бетону до стиснення. У даній роботі за допомогою великої кількості експериментальних досліджень на основі методу «Модель визначення площі поверхні бетону», який враховує коефіцієнт контакту між гумовою сумішшю та дрібним агрегатом, проведено глибоке вивчення механізмів впливу на гумовий бетон.

Ключові слова:гумовий бетон; питома поверхня; міцність; стиск; математична модель

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Исследование прочности резинового бетона на основе модели определенной области тонкого агрегата

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Статья посвящена актуальным вопросам исследования прочности резинового бетона. Основываясь на микроскопическом анализе большого количества резинового цементного раствора, была создана математическая модель для анализа удельной поверхности резинового порошка, смешанного с мелким агрегатом. На основе механизмов влияния методов смешивания резинового порошка использовали различные размеры частиц для выполнения испытания по определению сопротивления бетона на сжатие. Предоставлено научное объяснение логических различий, существовавших в процессе предыдущих исследований резинового бетона. Проведено углубленное исследование влияния методов и параметров смешивания, размеров частиц и других факторов на устойчивость бетона к сжатию. В данной работе с помощью большого количества экспериментальных исследований на основе метода «Модель определения площади поверхности бетона», который учитывает коэффициент контакта между резиновой смесью и мелким агрегатом, проведено глубокое изучение механизмов влияния на резиновый бетон.

Ключевые слова: резиновый бетон; удельная поверхность; прочность; сжатие; математическая модель

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