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The research of the basic properties of Ceramisite concrete

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Abstract. This paper expounds the ceramisite concrete fine characteristic, the development history, present situation and the existing problems. Using orthogonal design to study on the internal and external factors of compressive strength and dry apparent density and specific strength of ceramisite concrete. At the same time, using the professional Image analysis software of Image-pro plus to analysis and evaluate the uniformity of ceramisite concrete and its influencing factors were discussed.

Introduction

Definition of light weight aggregate concrete is that new building materials' density is not more than 1950 kg/m^3 by using small density aggregate.

Ceramisite is a kind of artificial building light weight aggregate. According to different kind of the material it can be divided into shale ceramisite, clay ceramisite, fly ash ceramisite and coal gangue ceramisite. The ceramisite concrete which is made from ceramisite, lightweight sand (or ordinary sand), cement and water is a kind of light weight aggregate concrete

Compared with ordinary concrete, ceramisite concrete and its products hold 'lightweight' and the 'energy efficiency' properties, it can be widely used in thermal insulation material, artificial floating island, bearing structure, wall material and so on . In present society with the increasing needs of building energy efficiency and environmental protection, ceramisite concrete has the broad development prospects inevitably.

Ceramisite concrete's excellent property

(1) Lightweight and high-strength: Compared with ordinary concrete its density reduces about 20%-40%, the density is about 1550-1950 kg/m3. We can use ceramisite concrete to make building unit just like wall, girder and pillar and so on. It can not only reduce self-weight 10%-20% but also save the quantity of steel bar. The strength of ceramisite concrete can reach the level of common concrete.

(2) Good performance of thermal insulation: Air void of ceramisite concrete can reach 30%-60% as well as 10%-20% in air void of ordinary concrete, big air void that lead to the coefficient of thermal conductivity is much lower than the ordinary concrete, ceramisite concrete's coefficient of thermal conductivity is about 0.208~0.420 W/(m·K).

(3) Good performance of fire resistance: ceramisite is the porous material that undergo a process of high temperature, it have a low coefficient of thermal conductivity, coefficient of linear expansion and the good performance of thermal property.

(4) Good performance of crack resistance: Ceramisite concrete's coefficient of thermal conductivity and modulus of elasticity are both less than the ordinary concrete's, so that the tensile stress caused by effect of cold-contraction and shrinkage is less than ordinary concrete's either. Meanwhile, the rough texture on ceramisite's surface can increase friction coefficient of the aggregate surface, it also can prevent relative motion in particles of aggregate. These properties make crack resistance of ceramisite concrete be superior to ordinary concrete's crack resistance.

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(5) Good performance of durability: Because the ceramisite in ceramisite concrete is the porous structure, this structure can alleviate the expansive pressure produced by freezing, this makes it has a good performance of frost resistance. Compared with ordinary concrete, the microporous structure of ceramisite makes the bond of aggregate interface maintain good state, also improves the permeability resistance of lightweight aggregate concrete. At the same time, ceramisite can effectively avoid alkali aggregate reaction in concrete and maintain the stability and security of structure and function.

(6) Good performance of synthesis technique and economic efficiency: Ceramisite concrete can make effective use of industrial waste residue, coal gangue and fly ash from coal-fired power plants. We can change waste material into things of value, save resources and protect the environment and have a good performance of synthesis technique and economic efficiency.

Ceramisite concrete's historical development and current situation

Ceramisite concrete development can be traced back to the 1920s. As early as in 1913, The United States succeeded in developing shale ceramisite, and use it made of ceramisite concrete applications in the shipbuilding and bridge engineering. But Ceramisite concrete long-term as a non-structural material, the range of applications has been largely restricted.

In the 1950s, Japan began to study and produce ceramisite concrete, and then developed rapidly. Before and after the 1970s the peak of ceramisite concrete occurred. Ceramisite concrete in Japan was not only for the improvement of building structural performance, but also used in gardens, flowerbeds and other facilities and achieved remarkable results. In the 1990s , ceramisite concrete began the stage of rapid development, Successful development of self- compacting ceramisite concrete indicated Ceramisite concrete began a comprehensive development application stage.

Compared with European countries, the development and application of Ceramisite concrete was relatively late in our country. Until the late 1990s, at home and abroad Ceramisite concrete technology was rapid development and in promoting building energy efficiency and environmental protection requirements, Research and application of China's high strength ceramisite concrete has been an unprecedented development, have been well used in high-rise buildings and large span bridges.

In 1990s Japan, some European and American researchers on the basis of experimental and theoretical study of ordinary concrete, studied in-depth high strength, high-performance ceramisite concrete and achieved certain results, including the study of ceramisite concrete materials, configuration, production process, mechanical properties, and material properties and so on.

Ceramisite concrete's problems in application development

Today, the yield and quality of the ceramisite concrete also far from being able to meet the rapid development of the construction industry demand, and there are many problems. How to improve the quality of ceramisite concrete to promote the application of ceramisite concrete have not formed a complete set of theories. So, the research work on the basic performance is particularly important. Although the domestic and foreign scholars did a lot of trials and studies of the performance of ceramisite concrete, but there are still many problems in practical applications, the lack of some of the basic performance of ceramisite concrete guidelines. Therefore, the research of the performance of ceramisite concrete is very urgent.

Test methods and results analysis

Materials: Grade 42.5 Ordinary Portland cement produced by Yangzhou luyang cement，river sand with 2.5~2.6 fineness modulus, ceramisite with particle size range from 5~10mm,were used in the study. Tap water and poly-carboxylic acid water reducer were prepared for the test.

Testing methods: Many factors that affect the basic performance of ceramisite concrete, select the appropriate number of control factors. The orthogonal design was used to arrange the test, the use of standardized orthogonal table, reasonable arrangements for the test, do a small test you can get the right conclusions and better results for selected factors. Experiment with water-cement ratio, sand ratio and poly-carboxylic acid water reducer doped rate as the three factors. Test factor and level as shown in Table 1.

Table 1 Test factor and level

factor	level		
	1	2	3
W/C（A）	0.32	0.35	0.39
Sand rate(B)	0.40	0.42	0.44
Water-reducing admixture(C)	1.1%	1.3%	1.5%

Water-cement ratio (A), sand rate (B), Water-reducing admixture ratio(C) as a factor for consideration. Among them, the water-cement ratio taken the 0.32, 0.35, 0.39 three level; sand ratio taken 0.40, 0.42, 0.45 three level; the Water-reducing admixture ratio is 1.1%, 1.3%, 1.5% (percentage of total cementitious material quality) three levels. Test using 100mm × 100mm × 100mm concrete cube specimen, by 28 days cube compressive strength, ceramisite concrete dry apparent density, 28d compressive strength and ceramisite concrete dry apparent density ratio (specific strength) and test-components section ceramisite distribution analysis of the results of the evaluation of test as the basis. The concrete mix proportions are presented in table 2.

Table 2 Mix proportion of concrete kg/m^3

number	cement	water	sand	ceramisite	Water-reducing
1	400.0	112.6	677.6	343.2	4.40
2	450.0	126.7	711.5	331.8	5.85
3	500.0	140.8	745.4	320.3	7.50
4	450.0	138.6	677.6	343.2	6.75
5	500.0	154.0	711.5	331.8	5.50
6	400.0	123.2	745.4	320.3	5.20
7	500.0	171.6	677.6	343.2	6.50
8	400.0	137.2	711.5	331.8	6.00
9	450.0	154.4	745.4	320.3	4.95

Compressive strength, dry apparent density, specific strength analysis.

This experiment measured the compressive strength of Ceramisite concrete at 28 days, dry apparent density and specific strength. Compressive strength of concrete cube with its dry apparent density ratio is called the specific strength. The specific data showed in Table 3.

Table 3 The performance of ceramisite concrete

	1	2	3	4	5	6	7	8	9
Compressive strength [MPa]	17.7	21.6	20.2	27.0	24.7	25.6	18.4	21.9	24.0
Dry apparent density [kg/m^3]	1706	1780	1754	1754	1705	1855	1671	1727	1767
specific strength [10^{-2}]	10.3	12.1	11.5	15.3	14.4	13.8	11.0	12.6	13.6

The orthogonal test range analysis in Table 4 shows:

Water-cement ratio is one of the main factors that affect the ceramisite concrete strength. Due to the increase of the water-cement ratio, the increase in free water in the concrete. When the water evaporates, the mortar internal to the formation of many tiny pores, thereby reducing the bond strength between the mortar density and ceramisite quickly reduces the strength of concrete.

Water-reducing admixture ratio and sand ratio is an important factor to affect the strength of ceramisite concrete. Ceramisite concrete mixed with the right amount of Water-reducing can reduce the amount of cement to reduce the water-cement ratio, thus affecting the strength of ceramisite concrete. A reasonable rate of sand can effectively improve the ceramisite concrete strength. If the sand ratio is too small, the gap between the aggregate is not filled with dense will reduce ceramisite concrete strength. With sand ratio of the increases, porosity decreases, ceramisite concrete becomes denser, thus increasing its strength. But if the sand was too large, the same amount of cement, the amount of coarse aggregate reduced and the ceramisite cement paste interface strength and mechanical bite force decreased, the strength of the concrete will drop.

The sand rate is one of the main factors of ceramisite concrete dry apparent density. Because sufficient mortar can be completely wrapped ceramisite surface and fill the gap between the ceramisite to make concrete workability, compacting increased. As the sand ratio improved, Ceramisite concrete dry apparent density gradually increased.

For ceramisite concrete strength, water-cement ratio is the main factors, followed by the rate of Water-reducing admixture ratio. Because the specific strength is the ratio of compressive strength and dry apparent density, dry apparent density changes by less than the compressive strength. For the above reasons, the intensity of the main controlling factors of water-cement ratio and Water-reducing admixture ratio to become the strength of the main factors.

It can be seen from the Range R in Table 4, in this experiment, the impact of primary and secondary order is that: 28d compressive strength: water-cement ratio > Water-reducing admixture ratio > sand ratio; Dry apparent density: sand ratio > Water-reducing admixture ratio > water-cement ratio; Strength: water-cement ratio > Water-reducing admixture ratio > sand ratio.

Table 4 The Range analysis table of compressive strength, dry apparent density and specific strength.

factor	W/C	sand rate	Water-reducing admixture ratio	Compressive strength [MPa]	Dry apparent density [kg/m^3]	specific strength [10^{-2}]
1	1	1	1	17.7	1706	10.3
2	1	2	2	21.6	1780	12.1
3	1	3	3	20.2	1754	11.5
4	2	1	2	27.0	1754	15.3
5	2	2	3	24.7	1705	14.4
6	2	3	1	25.6	1855	13.8
7	3	1	3	18.4	1671	11.0
8	3	2	1	21.9	1727	12.6
9	3	3	2	24.0	1767	13.6
Mean 1	19.8	21.0	21.7	-	-	-
Mean 2	25.8	22.7	24.2	-	-	-
Mean 3	21.4	23.3	21.1	-	-	-
Range R	5.9	2.2	3.1	-	-	-
Mean 1	1747	1710	1727	-	-	-
Mean 2	1771	1737	1767	-	-	-
Mean 3	1722	1792	1710	-	-	-
Range R	49.7	82.0	57.1	-	-	-
Mean 1	11.3	12.2	12.2	-	-	-
Mean 2	14.5	13.0	13.7	-	-	-
Mean 3	12.4	13.0	12.3	-	-	-
Range R	3.2	0.8	1.4	-	-	-

Homogeneity analysis

Today, homogeneous studies have become a research direction of ceramisite concrete, because poor homogeneous will take an adverse impact to mechanical properties and durability of hardened concrete, which set the obstacle of high-performance ceramisite concrete obstacles. According to the ceramisite floating in the vibration process, this article uses the Image- pro Plus Professional image analysis software to analyze the test block's sections of the orthogonal test of ceramisite concrete, through the section Ceramisite distribution to evaluate the homogeneity of ceramisite concrete.

To enter the photo of the first half section and the second half section of the test block to the professional image analysis software of Image-pro plus, measure the ceramisite area of the first half section and the second half section for S1, S2, and Evaluate the homogeneity of ceramisite concrete by means of Calculated uniform coefficient of KS.

Calculated uniform coefficient of KS:

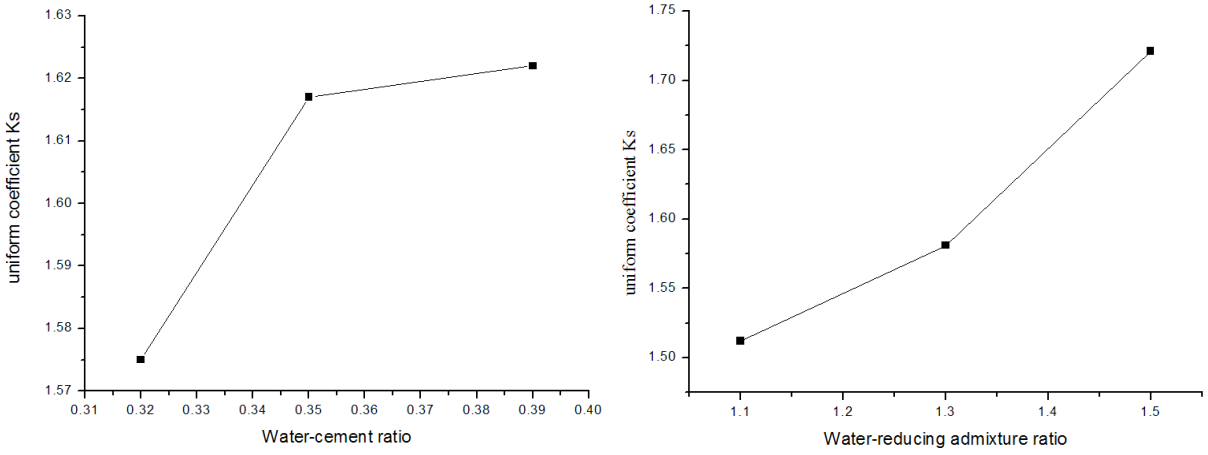
$$KS=S1/S2 \quad (1)$$

For: KS is a uniform coefficient of ceramisite concrete , S1 and S2 is the ceramisite area of the first half section and the second half section, usually $KS \geq 1$， when the KS is more close to 1, that ceramisite floating will become more smaller.

Table 5 Test findings of ceramisite concrete homogeneity

number	S1[mm^2]	S2[mm^2]	KS
1	3088	2067	1.49
2	3012	1945	1.55
3	3209	1906	1.68
4	3268	1914	1.71
5	3021	2010	1.50
6	3307	2015	1.64
7	3221	2072	1.55
8	3835	2165	1.77
9	2910	1890	1.54

It can be seen from the data in Table 5： the ceramisite area of ceramisite concrete on the first half of section generally larger than the area of the second half of section. Uniform coefficient of KS is greater than 1, and the ceramisite floating widespread. When the Ceramisite concrete molding, Ceramics and water floating, Cement paste is sinking, resulting concrete mixture layered segregation phenomenon.



(a) (b)

Fig. 1 (a) Water-cement ratio - uniform coefficient of KS, (b) Water-reducing admixture ratio - uniform coefficient of KS.

From Fig. 1, (a) and (b) shows that the water-cement ratio and Water-reducing admixture ratio is an important factor in ceramisite concrete homogeneous. With the water-cement ratio increases, the uniformity coefficient KS gradually increased, ceramisite concrete homogeneous gradually reduced. Water-cement ratio is small; the mixture viscosity is large, uniform coefficient KS smaller, relatively good homogeneity. The water-cement ratio increases, the fluidity of the mixture increased, the fresh concrete hierarchical degrees and Uniform coefficient KS are increased, Ceramisite concrete homogeneous reduction. When the Water-reducing admixture increases, both the Uniform coefficient of KS gradually increased, Ceramisite concrete homogeneity is significantly reduced. This is due to water-reducing agent can not only improve the fluidity of concrete and has the role of lubrication, reducing the cohesion between the aggregate and the matrix material, and promote the hierarchical segregation of the concrete mixture. Reasonable dosage of Water-reducing admixture ratio can raise ceramisite concrete homogeneity.

Conclusions

(1) Because of its lightweight, high strength, good thermal performance, good durability and other excellent features Ceramisite concrete has broad prospects for development. But, in the practical application, ceramisite concrete's collapsed slump of great loss, pump ability poor, separation of segregation and other performance issues. How to make ceramisite concrete to fully efficient application still requires a lot of theoretical analysis and experimental research.

(2) Water-cement ratio, sand ratio and Water-reducing admixture ratio are the important factors to affect the basic performance of ceramisite concrete. Water-cement ratio is the most significant factor of compressive strength and specific strength of ceramisite concrete. With increasing water-cement ratio, the compressive strength and specific strength of ceramisite concrete decrease. Sand ratio is the most significant factor of Ceramisite concrete's dry apparent density, Ceramisite concrete's dry apparent density increases gradually with the increase of sand ratio.

(3) Professional image analysis by Image-pro plus software on the specimen cross-section analysis can be seen: When Ceramisite concrete forming, ceramisite floating problems are endemic, making the concrete structure of homogeneous variance. The water-cement ratio and Water-reducing admixture ratio have significant effects of Ceramisite concrete's homogeneity, with the water-cement ratio increases, the homogeneous of ceramisite concrete decreased; and Water-reducing admixture increases, the homogeneity will be significantly reduced.

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References:

[1] İlker Bekir Topçu, Burak Işīkdağ. Effect of expanded perlite aggregate on the properties of lightweight concrete. Journal of materials processing technology, 2008, (204): 34-38.

[2] Burcu Akcay, Mehmet Ali Tasdemir. Optimisation of using lightweight aggregates in mitigating autogenously deformation of concrete. Construction and Building Materials, 2009, 23 (1): 353-363.

[3] Lifang Liu. Homogeneity of lightweight aggregate concrete. Heilongjiang: Harbin Institute of Technology, In Chinese, 2006.

[4] Payam Shafigh, Mohd Zamin Jumaat, Hilmi Bin Mahmud, Norjidah Anjang Abd Hamid. Lightweight concrete made from crushed oil palm shell: Tensile strength and effect of initial curing on compressive strength. Construction and Building Materials, 2012, (27): 252-258.