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Performance of Waste as Energy-saving Material

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This paper aims to explore whether the construction waste can be used as energy saving building materials and it comprehensively analyzes the energy saving properties of construction waste. The research method is that based on the concept of sustainable development, the research scope of energy-saving technology and equipment will be expanded. The analysis data of construction waste are obtained to provide a reliable basis for reducing the energy cost of buildings. The conclusion suggests that in the performance research of energy-saving building materials, the introduction of construction waste can not only maximize resource utilization, but also effectively control the building energy costs without affecting the quality of construction projects. Therefore, there is a high feasibility for construction waste to be used as energy saving building materials.

1. Introduction

With the rapid development of China's social economy and the accelerating pace of urbanization construction, a large amount of construction waste generated in the process of old house reconstruction and urban expansion has caused great damage to the environment. According to relevant data, the current amount of construction waste accounts for 40% of total city garbage in our country, and at least five hundred tons of construction waste can be produced by every 10,000 square meters of construction stage. At present, many cities in our country adopt landfill and air storage to dispose construction waste, which cannot solve the fundamental problem but take up a lot of land resources and destroy the environment again with dust problem generated in the process of push and pickup. In addition, through a large number of scientific experiments, the construction waste has a relatively high utilization value of renewable resources. If it is buried and discarded at will in the treatment process, a large amount of resources will be wasted. Instead, it will be beneficial to promote the healthy development of social economy if the construction waste is recycled and its own energy-saving function is fully played. Therefore, it is necessary to further study the safety and environmental protection performance of building materials during improving the building functions, and more energy saving technologies should be introduced by learning from foreign advanced experience in energy saving, so as to apply the construction waste with energy saving performance in building construction for reducing the construction cost as well as ensuring the quality of construction projects.

2. Literature review

Scholars Abanda and Byers believed that building energy consumption mainly included building heating, air conditioning energy consumption, lighting energy consumption, household electrical appliances energy consumption, and building operation energy consumption (such as elevators), among which building heating and air conditioning energy consumption accounted for the highest proportion of building energy consumption (Abanda and Byers, 2016). The heating energy consumption in northern China could account for more than 36% of the total energy consumption in China. The main reasons for the high energy consumption of building heating are as follows: the poor insulation of the enclosure structure and the high heat loss, low efficiency and low heat source efficiency of the heating system. It is mainly due to the poor insulation of the enclosure structure, that is, the thermal insulation performance of the building walls cannot meet the requirements.
The scholar Ahmadzadehtalatapeh held that with the rapid development of the economy and the rapid rise of the real estate industry, the housing construction entered the peak period of development, and most of the newly added buildings belonged to the non-energy saving high consumption building (Ahmadzadehtalatapeh,

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2017). These new buildings and the original non energy-efficient buildings consumed a lot of energy. With the acceleration of urbanization in China, building energy consumption would exceed the other areas to reach the first place in China's energy consumption, about 33%.

The growth of building energy consumption is bound to bring a series of problems in China, such as resources, environment and so on. If we cannot contain this trend, energy production in China is bound to be difficult to support this situation for a long time. The scholar Barbhuiya thought that building energy conservation was directly related to national energy strategy, sustainable development and environmental protection and so on, which should be paid enough attention to (Barbhuiya, 2013).

Granular materials include expanded frog stone, cement-expanded frog stone, expanded perlite and their products. The scholar Hsu believed that the expansive frog was mainly used for heat insulation and sound absorption and had good fireproof performance, but its water absorption rate was high, the acid environment was not resistant, and the construction was complex (Hsu, 2015). The cement-expanded frog stone was formed by cement and expanded frog stone. Because of the high water absorption, it was not suitable for external insulation material of exterior wall; expansion pearl rock had the advantages of light weight, low thermal conductivity and low moisture absorption rate, but the smaller the apparent density, the higher the water absorption rate.

Porous materials, including aerated concrete, microporous calcium silicate, foam glass, and so on. The scholars Jahromi and Beheshti thought that the apparent density of aerated concrete was higher than that of microporous calcium silicate and foam glass, and the strength was higher than the two and the thermal insulation performance was better, but its thermal conductivity was also higher (Jahromi and Beheshti, 2017), and the apparent density of microporous calcium silicate was lower than that of aerated concrete, but containing harmful substances; foam glass had low apparent density and thermal conductivity, and was easy to process, but its cost was high.

Lee and other scholars believed that organic thermal insulation materials were mainly polystyrene foam, rigid polyethylene foam, rigid polyurethane foam plastics, and phenolic foam plastics and so on. Polystyrene foam had the characteristics of light quality, heat preservation, sound absorption, low temperature resistance, easy cutting, and low water absorption and so on, but its fireproof performance was poor, and it was easy to soften the deformation at high temperature (Lee et al., 2017). Ran and other scholars held that polythene foam had the characteristics of low toxicity and low water absorption, but its fire resistance was poor, and the use conditions were more severe (Ran et al., 2017). Polyurethane foam had low toxicity and good thermal insulation effect, but its cost was very expensive. Phenolic foam had good fire resistance, light quality, low price and so on, but its strength was low, and its hygroscopicity was high. These weaknesses could be improved by structure improvement and by adding filler.

Foam concrete is a kind of porous lightweight, thermal insulation and insulation material, which is stirred, foamed and cured by cement, foaming agent, admixture or fly ash, gypsum, foaming agent and so on. The apparent density is about 300~500kg/m^3, and the thermal conductivity is about 0.082~0.186W/ (m·K). Aerated concrete is a thermal insulation material made of cement, gypsum, fly ash, hair gas and other materials. It has the advantages of good heat insulation and heat insulation performance as well as excellent fire resistance. The apparent density is about 300~850kg/m^3. Silicate insulation products are formed from diatomite or silica with lime, mixing, molding, and hydrothermal treatment. The apparent density is between 140~270kg/m3 and the thermal conductivity is 0.058~0.075W/ (m·K).

Xia and other scholars thought that organic thermal insulation materials were lighter than inorganic thermal insulation materials, it had lower thermal conductivity and better thermal insulation performance, but there were shortcomings of low strength, flammable, and so on (Xia et al., 2017). Before the 80s of last century, only a few thermal insulation materials factories in China could produce some expanded perlite, expansive frogs, microporous calcium silicate and other products. The variety and quality could not be compared with the foreign ones, and they could not meet the needs of national construction. After the reform and opening up, China's thermal insulation materials have made great progress. Especially in the development of product varieties and quality improvement, many high-quality thermal insulation materials have been greatly improved, and the quantity and scope of application are expanding continuously. The social effect and economic benefits produced by the application of building energy saving projects are gradually accepted and recognized by people. However, compared with foreign advanced technology and mature market, China still has a great distance from it because of the lost control of the market macro adjustment and the changing market demand.

Traditional thermal insulation materials are divided into organic thermal insulation materials and inorganic thermal insulation materials. Organic thermal insulation material has good heat preservation effect and light quality, but it has shortcomings such as easy aging and poor fireproof performance. Inorganic thermal insulation material has the disadvantages of high temperature resistance, good fire resistance, high water absorption and poor machinability, and the development trend of modern thermal insulation material is to combine the advantages of the two and form a composite type thermal insulation material. With the continuous improvement of people's living standards, more and more attention has been paid to green environmental protection. Therefore, the thermal insulation materials harmful for environment and human are gradually restricted or eliminated, and environment-friendly thermal insulation materials have gradually become hot spots.

To sum up, the above research work is mainly aimed at silicate insulation and energy saving materials with advantages of high strength, good heat insulation, low water absorption, high fire protection grade, acid alkali resistance, aging resistance and convenient construction. It fully conforms to the development trend of thermal insulation material in China at the present stage, and has great engineering application potential and good prospects for development. Therefore, based on the above research status, this paper mainly aims at the increasing construction waste in China, and then applies it to the system of silicate insulation after refining the crushing ball milling of building garbage, and studies the influence of the type and content of building garbage on the mechanical strength of the material. Moreover, it provides the theory and data support for the next step of the construction waste system silicate insulation materials.

3. Research method

This study aims to use construction waste to produce energy-saving building materials and discuss the factors influencing energy saving performance. After refining through the ball mill, the construction waste is used as the aggregate of silicate thermal insulation materials. Since silicate cement belongs to cementing materials, by adding proper amount of additive, a new silicate thermal insulation material from construction waste can be produced through in-situ assembly. This paper also analyzes the factors influencing material mechanical properties and the corresponding reasons by changing the combination and mixing amount of cementing material, filling material, construction waste, reinforcing fiber and admixture. By comparing the heat conductivity coefficients of the material under different bulk density and pore size, the effect on the thermal insulation performance of the material is analyzed. In order to improve the comprehensive utilization level of resources and solve the dilemma of construction waste siege cities, a kind of lightweight composite self-insulation block with excellent performance, multiple functions and good durability has been produced through ecological design after years of unremitting efforts. In addition, by taking this kind of block as the core, project transformation has been conducted firstly and a pilot production base that produces of 5*104 m^3 lightweight composite self-insulation blocks has been built. By using the domestic initiative cleaner production technologies such as low-energy consumption and non-polluting, this kind of block consumes no natural resources and the waste utilization rate reaches 85%. Thus, the company has become the first enterprise in China to develop and produce energy-saving and ecological new type wall materials, which substantially recycles solid waste such as construction waste. The project has passed the achievements and product appraisal presided over by the Provincial Science and Technology Department, the Provincial Economic Commission and the Provincial Construction Department, and the technology has reached the leading level in China. The project made a major breakthrough in the way of recycling, processing technology, the selection of solid waste, combination technology, mixed preparation technology, product structure design, molding technique, thermal insulation performance and the curing technology. It also provides important technical support for construction waste recycling, reduction, harmlessness and commercialization, and it’s rated as "National Key New Product" by five national ministries such as Ministry of Science and Technology. As the winner of “Science and Technology Progress Award in National Building Materials”.

4. Results and discussion

4.1 Test materials

(1) Cementing material

Ordinary silicate cement: Lafarge cement (p-type cement) produced by Du Jiangyan Rui’an Cement Plant (P.042.5R type) in Chengdu is adopted. The physical performance indexes of the cement are shown in Table1.

Table 1: Physical performance of silicate cement

Specific surface area (m2/kg)	Setting time（min）		The compressive strength (MPa)			Flexural strength (MPa)		
380	Initial setting	Final set	1d	3d	28d	1d	3d	28d
	35	120	38.3	46.1	56.6	7.1	7.3	7.8

Early-strength sulphoaluminate cement: Early-strength sulphoaluminate cement (K-type cement) produced by Leshan Fuqiang Cement Plant (R? SAC 42.5 type) in Chengdu is adopted. The physical performance indexes of the cement are shown in Table 2.

Table 2: Physical performance of sulphoaluminate cement

Fineness (%)	stability	Setting time (min)		The compressive strength (MPa)		Flexural strength (MPa)	
3.2	qualified	Initial setting	Final set	3d	28d	3d	28d
		95	160	24.6	48.5	4.5	7.2

Gypsum: High strength gypsum powder (A-type semihydrate gypsum) produced by Shanghai Huaxing Special Gypsum Plant and special gypsum powder for construction (P-type semihydrate gypsum) produced by Chengdu Lecheng Paint Factory are adopted.
(2) Filling materials
Fly ash: The chemical compositions of fly ash of grade n and above produced by Chengdu Thermal Power Plant are shown in Table 3:

Table 3: Chemical compositions of fly ash

component	Si02	Ca O	MgO	AI2O3	Fez Oa	SO_3	R2O	Ignition loss
%	44.98	3.90	2.46	27.05	12.37	1.04	1.24	6.0

Table 4: Physical performance of PP fiber

The density of (g/cm^)	The compressive strength (MPa)	Modulus of elasticity (MPa)	Color	Elongation at break	Melting point (°C)	Flash point (°C)
0.90-0.95	>340	>3500	white	]0-35%	165	560

Table 5: Chemical compositions of glass fiber

Chemical composition	$Si0_2$	AI_2O_3	MgO	Li_2O	Fez Os	B_2O_3	CeO_2
%	50?60	23.5-26.5	10-19.5	0?1.0	0.5~1.5	0-4	0.5-8.0

(3) Construction waste
Common construction wastes in the construction site include concrete blocks, bricks, tile, foam concrete blocks, and the waste generated by the production of silicate heat insulation materials. After the preliminary crushing of jaw crusher, those construction wastes are refined in the ball mill respectively and dried for next step.
(4) Admixtures
a) Water-reducing agents purchased in the market; b) Self-made drilling agent; c) The viscosity regulator purchased in the market for adjusting the viscosity of various materials during mixing; d) Self-made foam stabilizer; e) Foaming agents purchased in the market; f) Anti-seepage agent produced by Chengdu Longhu Science and Technology Company for removing and reducing minor cracks in products; g) Alumina produced by Chengdu Jinshan Chemical Reagent Company.
(5) Reinforcing fiber
PP fiber (3mm, 6mm, 19mm) and glass fiber (6mm) produced by Chengdu Ao’neng Company are adopted, and their physical performance indexes are shown in Table 4 and 5:

4.2 Test design and equipment

(1) Test scheme design
According to the diagram of pore and skeleton structure of silicate base porous thermal insulation material, the material is composed of a large amount of three-dimensional closed pore structures, and skeleton structures that form and support those closed pores. The mechanism of pore structure formation is that after putting cementing material, filling material, admixture and pore forming agent into a stirred tank according to certain proportion, the liquid slurry is formed, and by pouring foaming agent in the slurry, gas is produced and it swells continuously until a gas-liquid interface is formed. When the gas passes through the liquid, the surface of the liquid shrinks automatically due to the surface tension, and a liquid film is wrapped around the gas, forming a special "bubble", in which the pressure rises continuously until it exceeds the surface tension of the liquid, and then the bubble bursts and the gas inside escapes. At the same time, since the minerals and their products

are polar molecules, and water also belongs to polar molecule, but the gas is not polar molecule, the escaping gas wouldn't adsorb the minerals in the system. Hence the minerals will have a precipitation tendency and form an unstable coexistence system of "solid-liquid-gas", in which solid tends to precipitate, liquid tends to separate out, and gas tends to escape. Therefore, it’s hard to form a uniform porous dispersed system. In order to solve this problem, the stable foam agent is introduced into the system to improve the surface tension of liquid-gas interface, stabilize the bubble and attract solid particles to adhere around the bubble under the influence of the initiator. Thus the precipitation of solid particles can be avoided and a uniform stable coexistence system of "solid - liquid - gas" can be formed around the bubbles. When the solid is solidified, the liquid separates out, and the bubbles are firmly wrapped between the solid, forming closed porous silicate thermal insulation materials.

(2) Process flow

After weighing cementing material, filling material, fine aggregate of construction waste, fiber, pore forming agent and so on in a certain proportion, pour the admixtures such as fiber and pore forming agent into a certain amount of water and stir for about 1 minute; Then pour silicate cement and fly ash and stir for 2 minutes to form a uniform charge. After adding the pore forming agent, the material is poured into the forming mould, and the porous material is formed by in situ self-assembly. The material is naturally preserved and dried, and finally the sample is produced.

(3) Test equipment

In situ self-assembly mould (220mmx230mmx80mm); SDF-400 high speed dispersing agitator; JSM7001F scanning electron microscope used for morphology analysis; WDW3100 microcomputer controlled electronic universal pressure testing machine for testing compressive strength.

4.3 Principles for material property test

(1) Thermal conductivity coefficient

According to the structural principle of double plate method, two identical samples are placed between the cold plate and the hot plate, and the heat shield ring plate is used to surround the main heater. Since the heat generated by the main heater is blocked by the heat shield ring plate, the heat can only be exported along the direction of samples on both sides. When the temperature T1 on one side of the hot plate and T2 on the other side of the cold plate reach equilibrium without changing with time, the whole system reaches a one-dimensional heat conduction state.

(2) Compressive strength

According to the structural principle of WDW3100 microcomputer controlled electronic universal pressure testing machine, samples are put into the oven to dry after been cutting and grinding into 70 mm x 70mm x 70mm cubes. After the processed samples are put between the upper and lower plates, the device should be launched to start the load test, and the biggest pressure F that the sample can bear is recorded to calculate its maximum compressive strength.

4.4 Test results

It is found that since the recycled concrete aggregate comes from broken bricks, the fluidity and cohesion is too poor for molding. As the broken aggregate has many edges and rough surface, the slippage effect between the aggregate is not as good as that of the natural aggregate concrete since a large friction resistance is formed and the ease and fluidity are obviously poor. By adding proper plasticizer and fly ash, and taking technical measures such as wetting aggregate, this paper greatly improves the working performance of the mixture such as cohesion, water retention, mobility and so on, which satisfies the requirements of molding techniques. The results show that the recycled concrete aggregate adopting water reducing agent with high efficiency and active mineral raw materials can prepare recycled concrete aggregate 28d with strength of 40 MPa ~ 50 MPa, in which low density and good durability are technically feasible. It is an ideal lightweight aggregate concrete material with high strength and good water stability.

4.5 Study on lightweight composite thermal insulation concrete block

The characteristics of various solid wastes and the cohesive strength of cementing materials used in this project are of vital importance to the performance of lightweight aggregate concrete. Due to the material variety, there are many restriction and influence factors and the structural system is complex, thus the formation of a stable structure system which meets the quality requirements of production has become the focus of technology development. Through a lot of exploration and testing, the matching technology which meets the quality requirements of production was found. The research shows that the concrete is light, and has high intensity, small shrinkage, good durability such as antifreeze performance, which is a good light aggregate concrete that completely satisfies the technical requirements of the product design of lightweight aggregate concrete

5. Conclusion

(1) By in situ self-assembly method, taking admixtures, construction waste, filling materials, cementing materials as raw materials for the preparation of energy saving building material, which is combined with construction waste by adopting quantitative method, takes the initiative in our country. It has a positive impact on the orderly implementation of energy conservation and emission reduction activities; (2) When construction waste is applied in silicate thermal insulation materials, as a kind of recycled aggregates, it produce a strength directly relating to the strength of the material, that is, higher the higher the aggregate strength is, the greater the strength of the material is; (3) In the experiment, the surfactant dosage will not significantly influence the strength of the silicate thermal insulation materials, and the addition of proper amount of anti-seepage agents can improve the strength of the silicate thermal insulation materials. Therefore, the development of new type high strength, energy saving environmental protection building material with thermal insulation performance has become an important issue in the developmental process of building materials industry, which is also an urgent need for the construction of energy saving buildings.

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