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Study on the influence of different dosage of fly ash on the physical mechanical properties and pore structure of foamed concrete

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ABSTRACT

With the development of the society, the urbanization level improved unceasingly, the building floors are becoming higher and higher, the use of concrete is becoming more and more widely, and with the continuous improvement of living standards, the quality of concrete requirements are also rising. But in real life, buildings such as roads, bridges, houses and others often appear phenomenon that the concrete quality can not reach the standard, many concrete cracked within the service life, in order to deal with these problems, high performance concrete is being produced. In the 1980s, the fly ash was used as concrete activity material and improves the performance of concrete, from now on the research for adding fly ash into concrete has become a hot topic. China has a rich resource of fly ash, but the development and utilization of fly ash is very low. It not only takes up a large amount of storage area, but also brings bad influence to the environment. Fly ash can improve the physical mechanical properties of cement, the application of comprehensive exploitation and utilization of fly ash in concrete is the main direction of future development. And in the consideration of sustainable development, the use of fly ash can bring good economic benefits and social benefits for China. This study analyzes the physical chemical properties of fly ash and its utilization, and has the exploration on the influence of different dosage of fly ash on the physical mechanical properties and pore structure of foamed concrete. As for the pore structure, with the increasing amount of dosage of fly ash, porosity is becoming more and more even, the aperture is small increased. For the physical mechanical properties, when the dosage of fly ash is 20%, the compressive strength of foamed concrete achieves the best level.

KEYWORDS

Concrete; Fly ash; Economic benefit; Compressive strength.



INTRODUCTION

In the production process of cement, there will produce large amounts of toxic and harmful gases, the production of every ton of Portland cement will produce one ton of carbon dioxide gas, and will consume large amounts of nonrenewable resources. As shown in TABLE 1, it is the cement output table of every country all over the world. TABLE 1 shows that the cement output of China has always been the first in the global rankings, what's more it is easy to know that the carbon dioxide from cement production has serious effect on atmospheric conditions in China, and also brings increasingly serious shortage of resources, so improve the green environmental protection of the cement has become a growing concern. Fly ash is a by-product of the thermal power industry, with the development of the coal industry, coal-fired power plants developed very fast, it drove the economy, but at the same time also produced a large amount of fly ash, and some large power plants must build large ashfield to store the fly ash. With huge coal resources in China, it can be expected that in 2030 the Chinese amount of coal may reach more than 4 billion tons, and the resulting flow of fly ash is also expected to reach billions of tons. In other countries, fly ash is widely used in concrete and more and more fly ash replace cement, and this kind of mixing fly ash cement is widely used in the construction in reality, which brought them considerable economic benefits and social benefits. The application of comprehensive exploitation and utilization of fly ash in concrete is the main direction of the future development. This paper studies different dosage of fly ash on the physical mechanical properties and pore structure of foamed concrete, and makes a research on the influence of different dosage of fly ash on the physical mechanical properties and pore structure of foamed concrete.

TABLE 1 : Cement output in the world

Number	Country	2008	2009	2010
1	China	145000	162000	188191
2	India	17500	20500	20686
3	America	8100	6490	6445
The world's total output		285700	306000	330000

AN OVERVIEW OF THE FLY ASH AND ITS UTILIZATION SITUATION

Physical and chemical properties of fly ash

Fly ash is the solid waste produced by coal-fired power plants grinded fine pulverized coal combustion.

The physical properties of fly ash

Fly ash has a similar appearance with cement, which is a mixture formed by a variety of particles, the content as well as the variety of types of fly ash particles have an important influence on the activity of fly ash. According to relevant statistics, the physical properties of fly ash are shown in TABLE 2.

TABLE 2 : The physical properties of fly ash

Item	Range	Mean Value
Density (g/m ³)	1.9-2.9	2.1
Bulk Density(g/m ³)	531-1261	780
Specific Area(m ² /g)	2900-4000	3400
Granularity (μm)	2.5-300	40
Color	Level 5-9	-

Chemical properties of fly ash

Because the conditions and degree of combustion in the process of fly ash production is different, so the chemical composition of fly ash is rather complex and the fluctuation of its content is obvious. The main chemical composition of fly ash in China is shown in TABLE 3. The main composition of fly ash is SiO₂ and Al₂O₃, these two parts accounted for 50% -- 95%, and may also contain a small amount of Fe₂O₃, MgO, CaO, as well as some rare elements and trace elements. Because of the large content of SiO₂ and Al₂O₃ in the fly ash and the irregular glass shape, there are many pore structure on the surface, porosity in form is high, specific surface area is large, and for a variety of pollutants has a good adsorption. What's more, because of the particular chemical composition in fly ash, it is capable to remove the polycyclic aromatic hydrocarbons and cyanide.

TABLE 3 : The main chemical composition of fly ash

Composition	Mean Value	Wave Range (%)
SiO ₂	50.6	33.9-59.7
Al ₂ O ₃	27.1	16.5-35.1
Fe ₂ O ₃	7.1	1.5-19.7
CaO	2.8	0.8-10.4
MgO	1.2	0.7-1.9
Na ₂ O	0.5	0.2-1.1
K ₂ O	1.3	0.6-2.9
SO ₃	0.3	0.0-1.1
Burning Vector	8.2	1.2-23.6

The mineral composition of fly ash

The mineral group of fly ash can be divided into two parts: amorphous phase and crystallization phase. The amorphous phase is mainly composed of glass phase and amorphous carbon, and the crystallization phase is mainly composed of mullite, quartz, graphite, magnetite, hematite and other parts, as shown in TABLE 4 is the likely part of the crystal phase in fly ash. Depending on the mineral content and different composition the fly ash can be divided into high calcium fly ash and low calcium fly ash. Level of the activity of fly ash are mainly depends on the proportion of the vitreous and the crystals in the ash, the more vitreous content, the higher chemical activity.

TABLE 4 : Mineral composition of fly ash

	Vitreous	Mullite	Quartz
Range(%)	69.4-84.4	7.8-18.2	5.4-11.5
Mean Value(5)	77.6	12.2	8.5

The damage of fly ash

As a major coal-producing country, firepower electricity production accounts for a large proportion in China, but inevitably the fire electricity production produced a large amount of fly ash. Related studies show that expected in 2030 China's coal quantity may reach more than 4 billion tons, and the resulting flow of fly ash may also reach billions of tons, which is more than the amount of urban living garbage. It brought a lot of trouble to the processing of fly ash, which need a large area to complete the fly ash piling up, what's more, the composition of the fly ash has great damage to atmosphere, soil, water source, etc. At present, the utilization of fly ash in China is relatively lower, for the processing method of fly ash is mainly backfill. But because of containing a variety of poisonous and harmful components in the fly ash, the way of backfill will have irreversible effects on the environment, and will produce serious pollution to groundwater and soil. The fly ash particles are very small and fine, in the process of handling, the fly ash will produce dust diffusing in the air, when the content reaches a certain amount, it will cause air pollution. Investigations show that the fly ash contains more than 20 kinds of harmful heavy metals and compounds. Therefore, the improvement of the processing method of fly ash and the study of the recycling of fly ash become the problem what we cannot ignore.

The application of fly ash

Because of the recyclability of fly ash, experts and scholars now pay much attention in material, environment and other fields. The fly ash now is mainly used in the field of construction industry, as filling agent of cement. Additionally, fly ash is also applied in agriculture and environmental protection, etc. The effective utilization of fly ash has an important significance for resources recycling and environmental protection in China.

The application in construction industry

The application of fly ash in construction industry is mainly used as building materials, which account for about 35% of the country's total utilization^[1]. In cement industry, fly ash is mainly used as a substitute for clay or pan, because of its advantages of surface effect and filling effect, it can effectively improve the technical performance in physic property of concrete^[2-3], at the same time the uncompleted combustion coal in fly ash can provide energy in the process of cement production, consequently reducing energy consumption. At present, there are a lot of studies on the substitute incorporation of fly ash for concrete cement, and many of them are put into use in the construction in reality^[4]. The application of fly ash in cement production can improve the compressive strength and bending strength of cement, and also reduce the problems such as permeable, dissociation like common cement, and this will have a certain economic benefits and social benefits.

The application in road construction

Because the fly ash has similar properties with cement, it can be applied in road construction. It can be used for road surface and can improve the antiwear property of the road. Therefore the durability improved, and also the quality of the project improved. Due to its good water stability, good impermeability^[5], light weight and other characteristics, the fly ash has been widely applied in embankment engineering.

The application in agricultural

Because the fly ash has the characteristics of large specific surface area and large porosity, it can improve the structure and physical properties of cohesive soil if it is added to the soil. What's more, the fly ash can provide certain rare elements and trace elements for the soil, and has the function of guaranteeing the effectiveness of the phosphorus in the soil and increasing the activity of microorganisms in the soil. The application of fly ash in agriculture is to use directly as fertilizer, or to be used to produce fertilizer, and to fill the ash in the land, etc.

The application in environmental protection

The specific surface area and porosity of fly ash is large, and contains the active group such as SiO_2 and Al_2O_3 , which has good adsorption for some pollutants, so the fly ash can be used to treat wastewater and sulfur-containing gas, etc. As the characteristics of fly ash, it can be made into molecular sieve, white carbon black, flocculant, Molecular hoof, etc, and many of them are used by other industries^[6], which brings them economic benefits at the same time reduces their pollution to the environment.

EXPERIMENT OF CONCRETE WITH DIFFERENT DOSAGE OF FLY ASH

The experiment materials

Cement: Level-52.5 common Portland cement produced by Qufu cement factory.

Fly ash: III fly ash produced by Nanchang power plant.

Accelerator: Sanli PCS - 4 Shanxi accelerator.

Fiber: 11% polypropylene fiber in length produced by Beijing ZhongFang fiber technology co., LTD.

Foaming agent: hydrogen peroxide with 50% concentration produced by Shanxi Xilong chemical co., LTD.

Determination of physical and chemical properties of fly ash

The results of the determination of physical and chemical properties of fly ash are shown in TABLE 5, and the data shows that the content of the chemical composition of fly ash in China is basically identical.

TABLE 5 : The physical and chemical properties of fly ash produced by Nanchang power plant

Type	Density (g/m^3)	Specific Area (m^2/g)
Fly Ash	2.38	3690

The results of the determination of chemical composition of fly ash are shown in TABLE 6, and the data shows that the content of the chemical composition of fly ash in China is basically identical.

TABLE 6 : The chemical composition of fly ash produced by Nanchang power plant

Content	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	SO_3	Burning Vector
Fly Ash	52.2	30.6	6.0	1.0	5.9	0.4	1.8

Testing methods on different dosage of fly ash of foamed concrete

Preparation of foamed concrete

The key factor to prepare high performance foamed cement is to make the setting and hardening rate of slurry and foaming rate of foaming agent to achieve a dynamic balance^[7]. The preparation way is that according to certain proportion, prepare cement, fly ash, aggregate, blending agent, admixture, fiber and water, then stir the mixture evenly with high speed mixer and the mixing time is 150 s. The next step is to add certain amount of foaming agent with mixing time 50 s, then paste into the model to foam off after 24 h, and then conserve 28 d under the condition of airproof.

Ingredient composition

Maintain the amount of other raw materials, select 10%, 15%, 20%, 25%, and 30% of dosage of fly ash to prepare foamed concrete with density of $250 \text{ kg}/\text{m}^3$. The amount of ingredients is shown in TABLE 7.

TABLE 7 : The amount of ingredients

Number	Normal cement	Portland cement	Fly ash	Accelerating agent	Fiber	Waterproof agent	Hydrogen peroxide	Water
1	64	6	30	0.20	0.36	0.50	Appropriate amount	Appropriate amount
2	69	6	25	0.20	0.36	0.50	Appropriate amount	Appropriate amount
3	74	6	20	0.20	0.36	0.50	Appropriate amount	Appropriate amount
4	79	6	15	0.20	0.36	0.50	Appropriate amount	Appropriate amount
5	84	6	10	0.20	0.36	0.50	Appropriate amount	Appropriate amount

Analysis of test results

Influence of fly ash on the pore structure of foamed concrete

Foaming mechanism of the foamed concrete is that the slurry is mixing and pouring with chemical reaction to produce calcium hydroxide to form an alkaline environment, so that the hydrogen peroxide generated gas with the formation of numerous gas sources. After the increasing of the gas source pressure it started to swell and to form bubbles. Because of the addition of flocculant, the consistency of slurry increased the slurry swelling with the expansion of the bubble. When hydrogen peroxide runs out, the bubbles will no longer expand. And concrete start to harden again, eventually the gas will be fixed in concrete to form porosity.

Through the text it is easy to found that the porosity of the foamed concrete is becoming more and more uniform with the increase of the dosage of fly ash, and the aperture increased slightly. This is because the fly ash can improve the adhesiveness of slurry, so that the slurry has an appropriate consistency which may guarantee the uniform distribution of bubble in slurry, so that the bubbles of the foamed concrete will become more uniform. Aperture increases because with the increasing amount of the addition of fly ash, the rate of slurry thickening slow down, the resistance to overcome the bubble decreases and resulting in the enlargement of pore diameter.

The influence of fly ash on compressive strength of the foamed concrete

The relationship between dosage of fly ash and compressive strength of foamed concrete is shown in Figure 1. The diagram shows that the compressive strength of foamed concrete increases with the increase of the dosage of fly ash, and when the dosage of fly ash is 20% it reaches the maximum, and then declined, but the downward trend is not obvious. This is because the increase of the dosage of fly ash may make the strength of concrete reduce, while the fly ash has potential activity. Strength increased by fly ash activity will make an interaction with strength reduced by the concrete, so that the compressive strength of foamed concrete is not significantly reduced. Through the analysis it is easy to know that the best dosage of fly ash is 20%.

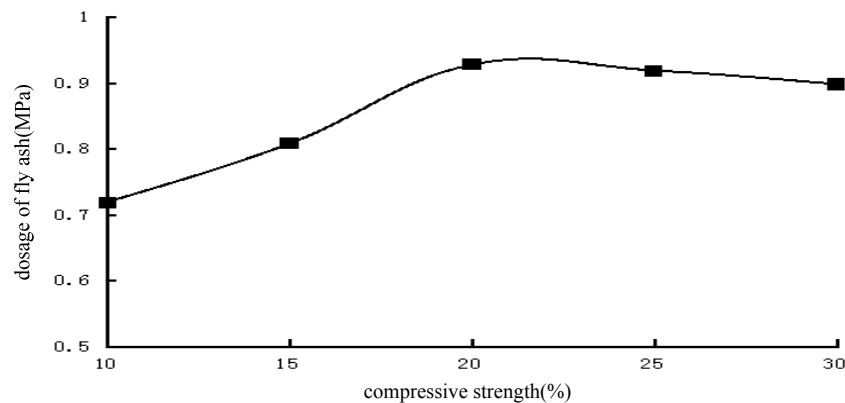


Figure 1 : Relationship between dosage of fly ash and compressive strength of foamed concrete

CONCLUSION

Because of their recyclability, now the experts and scholars in the field of material, environment and so on pay much attention on fly ash. According to the characteristics of fly ash, this study analyzes the physical and chemical properties of fly ash, and describes the problems of high productivity and low utilization rate of fly ash in China. In China, there exists the

situation that fly ash occupies the storage site, and pollutes the atmosphere, water source in the environment. The study also analyzes the application range of the fly ash and the influence of different dosage of fly ash on the physical mechanical properties and pore structure of foamed concrete. In the end, the study makes a conclusion that the porosity of the foamed concrete is becoming more and more uniform with the increase of the dosage of fly ash, and the aperture increased slightly. The compressive strength of foamed concrete may reach a best level when the dosage of fly ash is 20%.

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