УДК 625.825 DOI: 10.30977/BUL.2219-5548.2019.86.2.14

RESEARCH STATUS OF LIMESTONE POWDER CONCRETE

Jian Sun[1], Liyan Suo[2]
[1]Shandong Jiaotong University
[2]Inner Mongolia Bingshan Engineering Design Consulting CO. LTD

Abstract. *According to expert research and engineering application at home and abroad, this paper summarizes the basic properties of limestone powder, lime powder in cement base material, accelerate the hydration effect, active effect and particle morphology effect mechanism, and limestone powder on the working performance of concrete, durability and the influence of mechanical properties.*
Key words: *limestone powder, material, concrete, durability.*

Introduction

The performance of concrete is a requirement in infrastructure with the development of China, there is a need to improve concrete as an environmentally benign and sustainable material. Mineral mixture is a method that mixes fly ash or slag with concrete which is widely used in nowadays that can improve the performance of concrete and also cut costs.

Due to the shortage of fly ash caused by decrease of coal power enterprises, a material which is used for mix with concrete, limestone powder, widely distributed in China can replace fly ash and reduce pollution. In some developed countries, limestone powder mix with concrete is applied in many areas of engineering.

Analysis of publications

In the 1990s, Japan has been widely used in high-fluidity concrete and high-performance concrete [1].The amount of limestone powder in the concrete of the pier cable anchor solid of Akashi Kaiju Bridge in Japan is 150 kg/m^3, accounting for 36,6 % of the total powder material [2].

The aim and formulation of the task

The aim of this paper is to review basic properties of limestone powder and its hydration effect, active effect and particle morphology effect mechanism, and limestone powder on the working performance of concrete, durability and the influence of mechanical properties.

1. The function and mechanism of limestone powder in concrete

1.1 Basic properties of limestone powder.

Wei Huang [3] et al. analyzed the physical and chemical properties of Betocarb HP-OG limestone powder produced by OMYA company, and found that its density and BET specific surface area were 2200 kg/m^3 and 0,8 m^2/g, respectively, and the main component was CaCO3, with a mass fraction of 97,6 %. Its chemical composition was shown in table 1.

Table 1 – Chemical composition of limestone powder

Chemical composition of limestone powder	Percentage
SiO_2	0,07
Fe_2O_3	0,02
CaO	56,90
MgO	0,13
SO_3	0,05
Na_2O	0,07
ZrO_2	0,03
LOI (950 ℃)	42,73

Limestone powder is generally considered as an inert material with low activity and is often used as a filler. Studies have shown that limestone powder is not a completely inert material, and it can hydrate with C_3A and C_4AF in cement in concrete to form carbonic aluminate. In addition, an appropriate amount of limestone powder can be used to replace cement to improve the working performance of fresh concrete and the pore structure of hardened concrete, so as to improve its impermeability.

1.2 The action mechanism of limestone powder in cement substrate.

1.2.1 Accelerating hydration effect.

The proper amount of limestone powder can dilute the nucleating matrix of C-S-H, reduce the nucleating barrier, and accelerate the hydration of cement. Further studies have shown that the degree to which $CaCO_3$ accelerates the hydration of C_3S increases with the increase of its fineness and has a greater impact on the early hydration of C_3S.

1.2.2 Activity effect.

Limestone powder reacts with aluminum in cement to form carbon-aluminate complex with certain cementing ability, which changes some properties of cement cementing system. This effect contributes to the later strength of concrete. It should be noted that many factors of limestone powder affect the early strength of concrete, but the degree of influence is different. As long as limestone powder is added, its acceleration effect and activity effect will work at the same time, but in different degrees.

For cementing system with low C_3A content, the acceleration effect of limestone powder plays a leading role in the early strength of cementing system. For the cementing system with high C_3A content, the activation effect of limestone powder plays a leading role in the early strength of cementing system.

1.2.3 Particle morphology effect

The morphology effect of particles can be divided into morphology effect and filling effect.

Morphology effect refers to that the compact and smooth limestone particles on the surface are dispersed among cement particles, playing the role of dispersant, which can promote the disflocculation of cement particles at the initial hydration stage, thus improving the fluidity of concrete.

Filling effect refers to the fact that limestone particles with smaller fineness than cement can fill the gaps between cement and fill the skeleton, so as to improve the strength and workability of concrete.

2. The influence of limestone powder on the performance of concrete

2.1 Concrete workability.

Working performance is an important index to evaluate concrete performance. Good working performance is the premise of high performance, safety and reliability of concrete. Concrete with good workability must have good fluidity and water retention, small slump loss and better segregation resistance. A large number of high-efficiency superplasticizer and mineral admixture make the cohesion and water retention of concrete and liquidity are often inversely proportional. Therefore, it is necessary to find better mineral admixtures or highly efficient water reducers with better adaptability to solve this problem. Limestone powder, due to its accelerated hydration effect and particle morphology effect, can improve the working performance of concrete, improve the slump of concrete, reduce the slump loss, increase its cohesion and water retention.

Juanhong Liu et al. [4] studied the workability of concrete with limestone composite ultrafine mineral admixture. It is found that the water consumption of concrete decreases with the increase of limestone powder content under the condition of similar slump. Limestone powder can reduce the water consumption of concrete, reduce the water-cement ratio, and ensure the workability of concrete. Hang Yuan [5] replaced cement with limestone powder with a density of 2.6g/cm^3 and 45 μm sieve residue of 0,6 % 4,6 % and 16,5 % respectively, and the replacement rate was 15 %.

Note: in Fig. 1, cement stands for common concrete, and LP1, LP2 and LP3 stand for concrete with limestone powder with three fine grades of sieve remaining 16,5 %, 4,6 % and 0,6 % respectively.

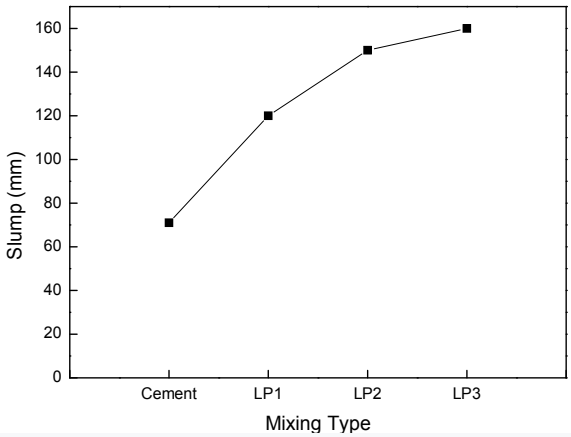

Fig. 1. Effect of limestone fineness on slump of concrete mixture

The results show that the slump of the concrete mixed with limestone powder is greater than that without limestone powder, and the slump increases with the decrease of the fineness of limestone powder.

The above two studies demonstrate the effect of form effect and filling effect of limestone powder on concrete. On the one hand, limestone powder is dispersed among cement particles to disflocculate the "flocculation structure" formed in the hydration process and play the role of "ball" among cement particles, thus improving the fluidity of concrete. On the other hand, limestone powder requires less water than cement. Replacing cement can reduce the mixing water consumption of concrete and increase the slump of concrete.

2.2 Durability of concrete.

The durability of concrete refers to its ability to resist chloride penetration, sulfate erosion, carbonization and freezing and thawing. In the use of concrete, water and air in the environment and their erosion medium often invade, produce physical and chemical reactions and gradually deteriorate. Generally speaking, as long as the concrete has a low permeability, it has a good ability to resist the invasion of water and erosion medium. The permeability is related to the porosity and pore structure of concrete. The greater the porosity and the more connected holes, the worse the permeability of concrete. Therefore, when external deterioration conditions are unavoidable, the durability of concrete can only be improved to extend its service life. The main methods to improve the durability of concrete include:

– make the concrete itself compact without the generation of original cracks through technical means;

– after hardening volume stability without shrinkage crack;

– reduce the internal erosion of concrete components.

2.2.1 Effects of sulfate resistance.

Yao Li et al. [6] carried out sulfate erosion experiments on concrete with limestone powder with specific surface area of 2000 m^2/kg at 5 %, 10 % and 20 % substitution rates. The weight loss of each group of concrete shows a decreasing trend with the increase of limestone powder content, and the weight loss is lower than that of blank concrete. Mingnan Pan et al. [7] used the same test method to reach a consistent conclusion under the same specific surface area and the same substitution rate. Through the above research, it can be concluded that the addition of ultra-fine limestone powder can greatly improve the resistance of concrete to sulfuric acid erosion.

2.2.2 Effects on frost resistance

The addition of limestone powder in an appropriate range can improve the frost resistance of concrete. With the increase of limestone powder content, the frost resistance of concrete decreases, even lower than that of benchmark concrete. Songqi Mei et al. [8] concluded in the test that the concrete with 5 % limestone powder has the best frost resistance, while the concrete with 20 % limestone powder has the worst frost resistance. Therefore, a small amount of limestone powder can improve the frost resistance of concrete, and a large amount of limestone powder (more than 10 %) is harmful to the frost resistance of concrete. However, Qingwei Sun et al. [9] found that the frost resistance of concrete improved with the increase of limestone powder content, but the effect was limited. By reducing the water-cement ratio, the frost resistance of concrete can be significantly improved.

2.2.3 Influence on the permeability of chloride ions.

At present, the influence of the addition of limestone powder on the impermeability of concrete is still controversial. Some people think that the filling effect of limestone powder improves the porosity and pore structure of concrete, so it improves the impermeability. Some researchers also think that limestone powder will reduce the chloride resistance of concrete permeability, but limestone powder and fly ash can certainly improve the chloride resistance of concrete permeability.

Dehui Wang et al. [10] measured the diffusion coefficient of chloride ion with limestone powder with a specific surface area of 500 m^2/kg and 650 m^2/kg at different mixing amounts. When the specific surface area of limestone powder is 650 m^2/kg and the content is 15 %, the chloride diffusion coefficient of concrete is the smallest. Baosheng Zeng [11] pointed out in the literature that in the concrete with a single mixture of limestone powder, the permeability of chloride resistance increases with the growth of concrete curing age. When limestone powder and fly ash are mixed, the chloride penetration resistance of concrete is greatly improved. S.Sivilis et al. [12] found that the addition of limestone powder is conducive to improving the permeability of concrete, but not conducive to improving the permeability of chloride ions. Therefore, it is necessary to study the chloride resistance and permeability resistance of the concrete with limestone powder.

2.2.4 Resist the influence of carbonization ability.

Carbonization mechanism of concrete:

$$CO_2+H_2O\rightarrow H_2CO_3. \quad (1)$$

$$Ca(OH)_2+H_2CO_3\rightarrow CaCO_3+2H_2O. \quad (2)$$

$$3CaO\cdot 2SiO_2\cdot 3H_2O+3H_2CO_3\rightarrow \rightarrow 3CaCO_3+2SiO_2+6H_2O. \quad (3)$$

$$2CaO\cdot SiO_2\cdot 4H_2O+2H_2CO_3\rightarrow \rightarrow 2CaCO_3+SiO_2+6H_2O. \quad (4)$$

Tingting Ren [13] et al. studied the carbonization resistance of ordinary concrete with dif-

ferent limestone powder content (0, 10 %, 20 %, 30 %) and concluded that the carbonization depth of concrete increases with the increase of limestone powder content in ordinary concrete. This shows that adding limestone powder to ordinary concrete will reduce its carbonization resistance, and the larger the content is, the more obvious it is. The main reasons are as follows:

– the addition of limestone powder, reduce the amount of cement, increase the porosity, at the same time in the hydration product $Ca(OH)_2$ content also decreases, leading to the reduction of the alkalinity inside the concrete;

– with the increase of limestone powder content, the content of $Ca(OH)_2$ decreases further, and the alkalinity of concrete also decreases, resulting in more and more serious carbonization.

2.3 Mechanical properties of concrete

Strength is one of the most important indexes to measure the quality of concrete. The basic strength indexes of concrete mainly include compressive strength, tensile strength and shear strength. With the needs of engineering and the development of science and technology, concrete strength index has developed rapidly. The influence of limestone powder on concrete strength is mainly manifested through three major effects.

Fei Xiao, Hongtao Cui [14] et al., with a contrast surface area of 2000 cm^2/g, 12000 cm^2/g and 21000 cm^2/g, respectively conducted strength tests with three dosages of 5 %, 10 % and 20 %. The results show that the fineness and admixture of limestone powder have great influence on the mechanical properties of concrete. When the surface area is 2000 cm^2/g, it is not conducive to the growth of compressive strength of concrete, and the effect of compressive strength is not significant. When the specific surface area is 12000 cm^2/g and 21000 cm^2/g, and the mixing amount is 5 % and 10 %, the early and late strength of concrete is improved. Although with the increase of surface area, the later strength of concrete increases more obviously. When the content is 20 %, the compressive strength of concrete is lower than that of blank specimen. With the admixture of 5 %, 10 % and 20 %, the bending compression ratio of concrete for 28d is higher than the blank time. This shows that adding limestone powder with certain fineness can reduce the brittleness of hardened concrete and increase the toughness of concrete to some extent.

Yuxia Guo et al. [15] also found that when limestone powder is added, the strength of concrete at each age increases first and then decreases with the increase of adding amount. When the admixture is 20 %, concrete 3d, 7d and 28d have the highest compressive strength. However, when the limestone powder content exceeds 20 %, the compressive strength of concrete decreases. This is due to the excessive amount of limestone powder, unreasonable concrete gradation, the content of coarse aggregate is relatively reduced, the skeleton effect is weakened. When limestone powder is added, the strength of concrete decreases obviously with the increase of the quality of limestone powder replacing cement. When the content is 10 %, the strength decreases significantly with the increase of age, indicating that the early strength loss of concrete is less when limestone powder replaces cement.

Conclusion

At present, there are still some disputes on the activation effect of limestone powder in concrete, and the chemical reaction equation of chalky phase between limestone powder and cement has not been concluded, so further discussion is needed.

The morphology effect of limestone powder particles (morphology effect and filling effect) can reduce the water consumption of the mixture, but it will increase the viscosity of the mixture under the condition of low water-cement ratio. It is suggested to be used in the middle and low strength grade concrete to improve the performance of the mixture, reduce the amount of cement and reduce the material cost.

The durability of concrete is improved by adding limestone powder. With the increase of limestone powder content, its durability is improved. However, it is necessary to study the chloride resistance and permeability resistance of concrete with limestone powder.

The content and fineness of limestone powder have a great influence on the working performance and compressive strength of concrete. Appropriately increasing the fineness of limestone powder can improve the working performance of concrete and improve the early strength. But when the content exceeds 20 %, the strength of concrete decreases.

References

1. Houcheng Tu. Application of limestone powder [J]. Foreign Building Materials Science And Technology, 1999. 20 (40): 19-20.
2. P.K.Mehta Advancements in Concrete Technology [J]. Concrete International. June 1999.

3. Wei Huang, Wei Sun. Influence of limestone powder content on hydration evolution of ultra-high performance concrete [J]. Journal Of South-east University (natural science edition), 2017, no. 47 (4):751-759.
4. Juanhong Liu, Ye Wen, Shaomin Song. Study on the influence of limestone composite ultrafine mineral admixture on workability and strength of concrete [J]. Comprehensive Utilization Of Fly Ash, 2011 (05): 27-30.
5. Hang Yuan. Influence of limestone powder on concrete performance [D]. Changsha: Central South University, 2009:2-3.
6. Yao Li, Liqing Su, XueliangYan. Research on preparation of high strength high-performance concrete with ultra-fine limestone powder (J). Jiangsu Building Materials, 2008 (03): 28-31.
7. Mingnan Pan, Meiyun Duan, Guixiang Zhang. Influence of ultra-fine limestone powder on performance of high strength high-performance concrete [J]. Shanxi Architecture, 2008 (30): 187-188.
8. Songqi Mei, Jin Fan. Experimental study on the effect of limestone powder on concrete performance [J]. Traffic Science Engineering, 2018, vol. 34 (2): 12-17.
9. Qingwei Sun, Han Zhu, Zhenglong Cui. Study on preparation of high-performance concrete with low-quality fly ash and ultra-fine limestone powder [J]. Nonmetallic Minerals, 2012,35(03):5-8.
10. Dehui Wang, CaijunShi, Huangfei Jia et al. Effect of limestone powder on durability of concrete [J]. Journal of Fuzhou University (natural science edition), 2018, no. 46 (6):874-880.
11. Baosheng Zeng. On the influence of limestone powder on concrete [J]. Sichuan Cement, 2019, (2): 319.
12. S. Tsivilis, G. Batis, E. Chaniotakis, D. Theodossis.Properties and behaviors of limestone and concrete and mortar [J].Cement And Contrete Res, 2000, 30:1679-1683.
13. Tingting Ren , Hongyan Shi . Effect of limestone powder on the durability of ordinary concrete [J]. Sichuan Building Materials,2015,41(02):1-2.
14. Fei Xiao, Hongtao Cui, Jianxiong Chen, Hanbin Chen. Research on ultra-fine limestone powder high-strength concrete [J]. Bulletin Of Silicate,2010,29(06):1303-1307.
15. Yuxia Guo, Jinxin Gong, ulrich. Influence of stone powder content on mechanical properties and durability of concrete [J]. Journal Of Building Materials,2009,12(03):266-271.

Jian Sun, Shandong Jiaotong University, 1586118851@qq.com, tel. +8613141467900,
5001 Haitang Road,Changqing district, Jinan city,Shandong Province, China
Liyan Suo, Deputy senior engineer, Inner Mongolia Bingshan Engineering Design Consulting CO. LTD, MinozBoGum@gmail.com, tel. +8615848929937,
801,Block B,Shenghai Building,Century 7 Road,Jinqiao Development Zone, Hohhot.

Исследование состояния известнякового порошка в бетоне

Аннотация. *Проанализированы исследования посвященные изучению свойств известнякового порошка в составе цементного материала. Известняковый порошок в цементном материале, ускоряет гидротационный механизм, влияет на эффект твердения, прочностные характеристики бетона, долговечность и механические свойства.*

Ключевые слова: *известняковый порошок, материал, бетон, долговечность.*

Джиан Сан, университет Шаньдун Джаотонг, 1586118851@qq.com, тел. +8613141467900,
5001 Хайтен роад, район Чанцин, Город Цзинань, провинция Шаньдун, Китай
Лиян Суо, заместитель старшего инженера, Консалтинга инженеров проектировщиков,
MinozBoGum@gmail.com, тел. +8615848929937
Внутренняя Монголия, Китай

Дослідження стану вапнякового порошку в бетоні

Анотація. *Бетон є екологічним та міцним будівельним матеріалом. Виконання бетону в будівництві є обов'язковою умовою розвитку інфраструктури Китаю, тому є необхідність вдосконалення міцнісних параметрів бетону.*
Міцність – один з найважливіших показників для вимірювання якості бетону. До основних показників міцності бетону в основному відносяться міцність на стиск, міцність на розрив та міцність на зсув. Проаналізовано дослідження присвячені вивченню властивостей вапнякового порошку в складі цементного матеріалу. Вапняковий порошок в цементному матеріалі, прискорює гідротаціоні механізми, впливає на ефект твердіння, міцнісні характеристики бетону, довговічність і механічні властивості.
Вміст і розмір вапняного порошку мають великий вплив на працездатність та міцність на стиск бетону. Належне збільшення розміру вапняноkам'яного порошку дозволяє поліпшити робочі характеристики бетону та покращити ранні показники міцності. Але коли вміст перевищує 20 %, міцність бетону зменшується.

Ключові слова: *вапняковий порошок, матеріал, бетон, довговічність.*

Джиан Сан, університет Шаньдун Джаотонг, 1586118851@qq.com, тел. +8613141467900,
5001 Хайт роад, район Чанцин, Місто Цзинань, провінція Шаньдун, Китай
Ліян Суо, заступник старшого інженера, Консалтингу інженерів проектувальників,
MinozBoGum@gmail.com, тел. +8615848929937
Внутрішня Монголія, Китай