Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejstv6n207

STUDY ON PHOSPHOGYPSUM-BASED LOW-CARBON ROAD BASE MATERIALS

Girts Sinka
Department of Building Materials and Products, Riga Technical University, Riga, Latvia.

Abstract: Phosphogypsum is a by-product emitted from the wet phosphoric acid production process. The massive accumulation of phosphogypsum occupies land resources and pollutes groundwater. Predecessors have made contributions to the utilization of phosphogypsum resources, especially the preparation of pavement base materials using phosphogypsum. It is more conducive to realizing its large-scale utilization. The paper introduces the physical and chemical properties of phosphogypsum, this review summarizes the phosphogypsum modified pavement base materials, Phosphogypsum-cement pavement base material and its hydration mechanism were analyzed. The problems existing in the research on phosphogypsum-based pavement base materials are summarized. Suggestions on resource utilization of phosphogypsum in pavement base materials were also put forward.
Keywords: Phosphogypsum; Pavement base materials; Resource; Hydration mechanism

1 PHYSICAL AND CHEMICAL PROPERTIES OF PHOSPHOGYPSUM

Phosphogypsum is a solid by-product emitted during the production of wet phosphoric acid [1]. Among them, for every 1t of phosphoric acid produced (as P_2O_5 (calculated) Emissions 4.5 ~ 5.5t off-white or off-black phosphogypsum. The main component of phosphogypsum is $CaSO_4 \cdot 2H_2O$, due to soluble phosphorus and many harmful impurities, phosphogypsum cannot be directly utilized[2]. Currently, the global stockpile of phosphogypsum reaches 6 billion tons[3]. my country is the largest by-product country of phosphogypsum, mainly distributed in the five provinces of Hubei, Yunnan, Guizhou, Sichuan, and Anhui. The stock of phosphogypsum has reached 400 million tons, and 50 million tons of phosphogypsum are added every year, but the comprehensive utilization rate is not high. to 40% [4]. The high accumulation of phosphogypsum occupies a large amount of cultivated land, and also pollutes groundwater, soil and atmospheric environment, seriously restricting the high-quality and rapid development of the phosphorus industry [5].

In order to promote the resource utilization of phosphogypsum, researchers have made contributions to the study of the utilization of phosphogypsum in the extraction of valuable components, cement retarder, production of fertilizers, soil conditioners and calcination to prepare sulfuric acid [6-10]. However, phosphogypsum has not been utilized on a large scale and its comprehensive utilization rate is still low. Pavement base material is an important part of the road construction structure and maintains the quality, performance and safety of the road [11]. Preparing pavement base material from phosphogypsum is one of the effective ways to utilize resources. The paper summarizes the physical and chemical properties of phosphogypsum, and systematically summarizes the utilization status and mechanism of phosphogypsum in pavement base materials. Finally, the existing problems in the research on phosphogypsum-based pavement base materials were discussed, and suggestions were put forward for the resource utilization of phosphogypsum low-carbon building materials in the future.

Phosphogypsum is gray-white or gray-black powdery solid particles. The bulk density of phosphogypsum is 2.27~2.4 g/cm3, the volume density is 0.9~1.7g/cm3. The main mineral phase of phosphogypsum is dihydrate gypsum $CaSO_4 \cdot 2H_2O$ (mass fraction 75% ~ 95%), moisture content 20% ~ 25%, pH value 1.5 ~ 5.5 [13]. Phosphogypsum is the product of the reaction between phosphate rock and sulfuric acid during the production of wet phosphoric acid. The main chemical components of phosphogypsum are CaO (30%~40%), SO_3 (37% ~50%), P_2O_5 (1% ~3%) and a small amount of SiO_2, MgO, Al_2O_3, Fe_2O_3, F[14].

2 RESEARCH STATUS OF PHOSPHOGYPSUM-BASED PAVEMENT BASE MATERIALS

Phosphogypsum is a solid waste produced in the wet phosphoric acid leaching process. Its efficient utilization of resources can reduce environmental pressure and is also an important way for my country to achieve sustainable development. In order to comprehensively understand the research progress of phosphogypsum in road base materials, the relevant research status was systematically summarized.

2.1 Phosphogypsum Modified Pavement base Material

The performance of pavement base materials can be improved by using the modification function of phosphogypsum. For example, Shen Weiguo et al. [15] studied the performance of phosphogypsum-modified lime pavement base materials. The results show that phosphogypsum modification can greatly improve the performance of pavement base materials. early strength and water stability, while maintaining stable development of later strength. The erosion resistance of the pavement base material after modification by phosphogypsum is greatly improved, so the performance

of the pavement base material modified by phosphogypsum is good. Wu Kaiquan et al. [16] explored the use of waste phosphogypsum to modify lime gravel pavement base material. The results show that compared with the conventional lime pavement base material using phosphogypsum modified lime pavement base material, its strength development, water stability, and erosion resistance have been greatly improved. In addition, material costs and environmental pollution are reduced, which has social and economic benefits. Shen Weiguo et al. [17] studied the mix proportion design method of phosphogypsum modified lime pavement base material. The results show that through experimental research on the mix ratio of phosphogypsum-based pavement base materials, and based on the strength formation principle of phosphogypsum-modified pavement base materials, a mix proportion design method based on volume analysis method was developed. The above calculation method can basically determine the mix ratio of phosphogypsum modified pavement base material, its maximum dry density and optimal moisture content, which can make up for the shortcomings of complex experimental work in conventional design.

2.2 Phosphogypsum-Cement Pavement base Material

The synergistic utilization of phosphogypsum and cement can prepare green and low-carbon pavement base materials. Liu Chao et al. [18] studied phosphogypsum-cement stabilized gravel pavement base material. The results show that suitable phosphogypsum fine aggregate is beneficial to filling pores, causing the pavement base material to form a high-density skeleton structure. Phosphogypsum can also promote the synthesis of expanded ettringite (AFt). When the phosphogypsum content is 8%, compared with conventional cement-stabilized gravel road base materials, the strength of the cement-phosphogypsum pavement base material after curing for 7 days increased by 26.7%, and the dry shrinkage strain decreased by 40.3% at 28 days. Du Tingting et al. [19] studied phosphogypsum-cement pavement base material. The results show that the phosphogypsum-cement pavement base material prepared from modified or improved phosphogypsum has good water stability and the unconfined compressive strength is significantly improved. The improved phosphogypsum-cement pavement base material can meet the requirements of different levels of traffic. Strength requirements. Zhou Mingkai et al. [20] studied the properties of phosphogypsum-cement pavement base material. The results show that the phosphogypsum content of 8%, the cement content of 1%, and reducing the aggregate gradation are beneficial to improving the strength of the phosphogypsum-cement pavement base material. Compared with conventional cement-stabilized gravel materials, phosphogypsum-cement-based pavement base materials have excellent properties. Wu Shangfeng et al. [21] studied the application of phosphogypsum-cement pavement base material on highways. The results show that when the ratio of phosphogypsum:cement:gravel in the phosphogypsum-cement pavement base material is 40:7:60, its unconfined compressive strength meets the industry standard requirements. Phosphogypsum-cement pavement base material (40% phosphogypsum) saves about 20% in material cost compared with conventional pavement base materials, and slows down the accumulation of phosphogypsum.

2.3 Hydration Reaction Mechanism of Phosphogypsum-Based Pavement base Material

Xu Fang et al. [22] studied the microstructure and mechanical properties of perthion gypsum slag cement pavement base material. The results show that the main mineral phases of phosphorus gypsum slag cement are quartz (α-SiO_2), dihydrate gypsum ($CaSO_4 \cdot 2H_2O$) and the hydration product ettringite. These mineral components and microstructure affect the unconfined compressive strength and water stability of the pavement base material, and the anti-scouring ability is consistent with its unconfined compressive strength; when the content of persulfate gypsum slag cement is 5%, the unconfined compressive strength of the pavement base material after 7 days of maintenance can meet the standard requirements. Li Xia [23] studied the properties of cement-stabilized phosphogypsum base material and found that the gel product produced by the hydration reaction can fill the inter-particle pores of the pavement base material, resulting in the formation of a high-density structure between the particles, thereby improving the overall quality of the pavement base material. Strength and stability. In addition, Yu Changyun [24] studied the feasibility of phosphogypsum-modified cement-lime stabilized red mud road base material and analyzed the strength formation mechanism of phosphogypsum-modified pavement base material. The hydration products CSH, CASH, NASH gel and ettringite have cementing and filling effects; at the same time, the filling mechanism of ettringite in the pores of the pavement base material was revealed, and it was found that ettringite mainly fills the pore size range of 0.1~1 μm. of pores.

3 CONCLUSION AND RECOMMENDATIONS

The paper sorts out the physical and chemical properties of phosphogypsum. Phosphogypsum is a powdery solid particle whose main chemical components are CaO, SO_3 and P_2O_5 etc. The main mineral in phosphogypsum is gypsum $CaSO_4 \cdot 2H_2O$, which reacts with hydration in the pavement base material to form ettringite, which can improve the early strength of the road base material. In addition, it is introduced that the modified function of phosphogypsum and the synergistic utilization of phosphogypsum cement can improve the overall strength of the road base material. performance, and summarized the hydration reaction mechanism of phosphogypsum-based pavement base material. At present, the research and development of phosphogypsum-based pavement base materials are mostly in the experimental stage, and the impact of P_2O_5, fluoride ions and other harmful elements in phosphogypsum on the environmental performance of pavement base materials has not been studied in depth. Therefore, suggestions for the

future low-carbon research and development of phosphogypsum-based pavement base materials are put forward, which are summarized as follows:

a. Preparing the pavement base material with a high content of phosphogypsum will affect its setting time. Thinking from another perspective, the setting time of the pavement base material can be controlled based on the retarding characteristics of phosphogypsum.

b. Phosphogypsum contains a large amount of gypsum, and the hydration process will generate excess ettringite (hydrated calcium sulfoaluminate), causing volume expansion and cracking of the hardened body of the pavement base. The pavement base material itself has dry shrinkage phenomenon. Therefore, the expansion characteristics of phosphogypsum can be used to compensate for the shrinkage of the pavement base material.

c. When phosphogypsum is mixed alone to prepare pavement base materials, it is difficult to achieve high-volume application of solid waste. If phosphogypsum is used to cooperate with various solid wastes to prepare low-carbon pavement base materials with a high content of solid waste, the effect of "treating waste with waste" can be achieved.

d. Phosphogypsum is an industrial solid waste that contains a large amount of P_2O_5, fluoride ions and other harmful elements. It is necessary to ensure that the environmental performance of the phosphogypsum-based pavement base material is qualified, and to conduct research on the curing mechanism of harmful elements in phosphogypsum.

e. Phosphogypsum contains phosphorus and fluorine elements. Based on chemical coordination theory and charge balance effect, through the silicon-oxygen tetrahedron and the four-coordination isomorphic effect of silicon, phosphorus elements and fluorine ions can be fully utilized to generate new chemical products. Realize the synergistic solidification and stable utilization of phosphorus and fluorine.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Deng Hua, Hou Shuomin, Li Zhongjun. Current status and prospects of comprehensive utilization of phosphogypsum. Inorganic Salt Industry, 2023. DOI: 10.19964/j.issn.1006-4990.2023-0278.

[2] Huang Di, Zong Shirong, Ma Navigation. Research and application progress of phosphogypsum resource utilization technology. Phosphate Fertilizer and Compound Fertilizer, 2023, 38(5): 17-22.

[3] Yan Chao, Peng Qiugui, Zhu Miao. Review of comprehensive utilization and impurity removal methods of phosphogypsum. Phosphate Fertilizer and Compound Fertilizer, 2023, 38(2): 27-33.

[4] Zhou Miaoqin, Tao Snow, Liao fast. Research progress on phosphogypsum production and emission and resource utilization. Yunnan Chemical Industry, 2022, 49(12): 4-8.

[5] Wu Hao, Han Chaonan, Tang Yu. Research progress on resource utilization of phosphogypsum in my country. Modern Chemicals, 2023, 43(3): 18-21.

[6] Pan Keliang, Li Na, Hu Jingping. Research progress on the extraction and recovery of rare earth elements in phosphogypsum. Journal of Huazhong University of Science and Technology (Natural Science Edition), 2023, 51(10): 77-83.

[7] Yi Hui. A review of research on modified phosphogypsum as cement retarder. Sichuan Building Materials, 2016, 42(3): 23-24.

[8] Zhou Jiliang. Research on the technology of using phosphogypsum to produce medium element fertilizer. Liaoning Chemical Industry, 2023, 52(5): 746-749.

[9] Yang Hua, Qi Jiamin, Li Bin. Research progress on phosphogypsum soil improvement. Phosphate Fertilizer and Compound Fertilizer, 2023, 38(5): 40-44.

[10] Ma Xiaoling, Tan Hongbin, Hou male. Research status and development trends of phosphogypsum production of sulfuric acid co-production of cement. New Building Materials, 2021, 48(3): 71-76.

[11] Shen Weiguo, Zheng Xiaoping, Li Hongzhen. A review of the classification of pavement base materials and their service status. Journal of Wuhan University of Technology, 2021, 43(9): 1-5.

[12] Li Pengpeng, Ren Qiangqiang, Lu Qinggang. A review of low-carbon cement raw material/fuel substitution technologies for dual carbon. Clean Coal Technology, 2022, 28(8): 35-42.

[13] Kai Jun, Xie Weimin, Dong Xiongbo. Research progress on comprehensive utilization of phosphogypsum materials. Materials Herald, 2023, 37(16): 167-178.

[14] Li Ming, Liang Huan, follow Jiefei. Progress and prospects of phosphogypsum resource utilization in my country. Phosphate Fertilizer and Compound Fertilizer, 2020, 35(7): 30-36.

[15] Shen Weiguo, Jiang Ship, Zhang Korea. Research on the performance of phosphogypsum modified lime pavement base material. Highway, 2008(1): 141-145.

[16] Wu Kaiquan, Lu Yong, Zhang military. Discussion on modified fly ash gravel base with waste phosphogypsum. Road Construction Machinery and Construction Mechanization, 2007(11): 56-58.

[17] Shen Weiguo, Zhou Mingkai, Cha Enter. Research on the mix proportion design method of phosphogypsum modified fly ash pavement base material. Comprehensive Utilization of Fly Ash, 2004(3): 13-15.

[18] Liu Chao, Zhao Deqiang, Ma Qian. Research and application of cement-phosphogypsum stabilized gravel pavement base material. Bulletin of Silicates, 2023, 42(6): 2121-2130.

[19] Du Tingting, Li Zhiqing, Zhou Yingxin. Research on cement phosphogypsum stabilizing materials used in pavement base. Highway, 2018, 63(2): 189-195.
[20] Zhou Mingkai, Zhang Xiaoqiao, Chen Xiao. Study on the properties of cement phosphogypsum stabilized gravel pavement base material. Highway, 2016, 61(4): 186-190.
[21] Wu Shangfeng, Cao Penghui. Application and economic benefit analysis of cement phosphogypsum stabilized gravel materials in highways. Low Carbon World, 2021, 11(11): 114-116.
[22] Xu Fang, Li Heng, Sun Tao. Microstructure and mechanical properties of perthionate gypsum slag cement pavement base material. Journal of Building Materials, 2022, 25(3): 228-234.
[23] Li Xia. Research on the properties and application of cement-stabilized phosphogypsum base material. Chengdu: Chongqing Jiaotong University, 2023.
[24] Yu Changyun. Feasibility study on phosphogypsum modified cement-lime stabilized red mud road base material. Nanjing: Southeast University, 2022.