A review of surface properties enhancement of pavement concrete

Hu Cheng1, Weng Xingzhong1*, Yan Xiangcheng2

1 Department of Airport Building Engineering, Air Force Engineering University, Xi’an 710038, China
2 Troops of 95746, Chengdu 610000, China
* Corresponding author email: 201421010425@chd.edu.cn

Abstract: The surface properties of pavement concrete have great influence on the overall performance of pavement, so it is of great significance to study how to effectively strengthen the surface properties of pavement concrete. The surface properties of pavement concrete are mainly reflected in three aspects: abrasion resistance, frost resistance, and impact resistance. The ways to strengthen the surface properties of pavement concrete are mainly focused on surface fortifier, adding polymer mixture, fiber, and additive, improving the way of maintenance, improving construction technology and optimizing the basic components of concrete. These five ways have its advantages and disadvantages. To enhance the surface properties of concrete economically, effectively and comprehensively, the way that laying fiber mesh into cement mortar layer is put forward.

1. Introduction

The surface properties of pavement concrete are the synthesis of the ability of pavement to resist external action. The surface properties of pavement concrete have a great influence on the overall service performance and safety performance of concrete. Therefore, it is of great significance to study how to effectively enhance the surface properties of pavement concrete. Based on the comprehensive analysis of all aspects, this paper holds that the surface properties of pavement concrete are reflected in in four aspects: abrasion resistance, frost resistance, early cracking resistance, and impact resistance.

2. Abrasion resistance

Insufficient abrasion resistance of pavement would have a great impact on the performance of the runway, and it will also promote the generation of other damages of concrete pavement. Liu[1] believe that there are two main methods to improve the abrasion resistance of concrete, one is to improve the composition of concrete, and the other is to form a protective film on the surface of concrete. Xiong[2] found that in the case of low cement content, reducing the water-cement ratio can enhance the abrasion resistance of concrete to a certain extent. The greater the gas content is, the worse the abrasion resistance of concrete will be. The vibration mixing method is helpful to improve the abrasion resistance of concrete. Weng[3] found that, under the condition of other conditions being unchanged, increasing the concrete sand rate would reduce the abrasion resistance of concrete, and proposed that a lower sand rate should be selected within the reasonable sand rate range. That’s because the increase of sand ratio will lead to the thickening of cement mortar layer, which would lead to greater damage caused by abrasion. Wu[4] found that concrete abrasion resistance was greatly influenced by the fineness modulus. When the...
fineness modulus varying from 2.11 to 3.6 in the process of change, the abrasion resistance showed a trend of decrease after the first growth. When the fineness modulus is 2.64, abrasion resistance is best. Zhang\cite{5} and Yang\cite{6} found that adding polymers can improve the abrasion resistance of concrete to a certain extent, but reduce its compressive strength. It was found that\cite{7} surface fortifier such as silicon cementing agent and epoxy resin could improve the abrasion resistance of concrete to a certain extent. Xiang\cite{8,9} found that SAP internal curing could improve the abrasion resistance of concrete to a certain extent. Sui\cite{10} found that adding polyethylene fiber or steel fiber to the concrete mix could improve its abrasion resistance performance to a certain extent. Zhang\cite{10} found that concrete surface drawing and grooving will reduce the abrasion resistance of concrete. In engineering practice, the balance of skid resistance and abrasion resistance should be considered comprehensively.

3. Frost resistance

In the cold regions, if the pavement concrete has insufficient frost resistance, the pavement surface was prone to freezing-thawing damage, which has a great impact on the safety performance and normal use of the runway. Until the 1990s, the domestic and foreign research mainly focused on freeze-thaw related theory research, involving hydrostatic pressure hypothesis and osmotic pressure hypothesis\cite{11}, the feasibility of air-entraining agent bubble spacing coefficient calculation method, cooling rate and the interval coefficients of bubble\cite{12}, and the relation of concrete space structure of ice crystal pressure causes\cite{13}. After 1990s, the research mainly focused on the improvement of concrete frost resistance. The ways mainly include improving concrete composition, adding inorganic admixtures, fibers, air entrainment agents and emulsions into concrete admixtures, brushing surface fortifier in the surface layer and improving concrete mixing methods. Weng\cite{3} found that the sand ratio can affect the frost resistance of concrete, and when the sand ratio is 30%, the frost resistance is the best. Wu\cite{4} found that the fineness modulus can also affect the frost resistance performance of concrete. When the fineness modulus is 2.64, the frost resistance of concrete is relatively good. Jiang and Liu\cite{1, 14-17} studied the strengthening effect of surface fortifier and found that silane, epoxy resin, epoxy silicon cementing agent, and pure silicon cementing agent could all enhance the frost resistance of concrete to a certain extent. Guo\cite{18} found that within the surface fortifier, the enhancement effect order was that silane > modified polyurea > AH material > epoxy resin. Lv\cite{19} found that adding air entraining agent and reducing water-cement ratio could enhance the frost resistance of concrete, but partially replacing sand with fly ash would have a negative impact on the frost resistance of concrete. Huang\cite{20} found that the addition of epoxy resin emulsion and curing agent could improve the frost resistance of concrete to a certain degree. But at the same time, it would lead to a decline in the flexural strength. Guo\cite{21} and Jia\cite{22} found that appropriate high-frequency vibration can effectively improve the frost resistance of air-entraining concrete. A series of studies by He, et al.\cite{23-25} showed that adding basalt fiber and carbon fiber to concrete can improve its frost resistance to a certain extent, but this puts forward higher requirements on the mixing method of concrete, and the strengthening effect on the surface mortar layer is not obvious.

4. Impact resistance

Edge and corner of pavement concrete slab are the area of weak force. When the impact load of the aircraft wheel is applied and the track panel of the wrong platform is affected by the impact of the wheel, the edge and corner of pavement slab will be damaged, which would affect the performance of the runway and even endanger the flight safety. So, it is necessary to study the impact resistance of cement concrete pavement structure. The research objects mainly include chopped fiber reinforced concrete, polymer modified concrete and rubber concrete. The research shows that adding fiber into concrete can improve its impact resistance to a certain extent. The fiber includes basalt fiber\cite{26}, polypropylene fiber\cite{27}, carbon fiber\cite{28}, and steel fiber\cite{29}. Polymer modified concrete mainly includes styrene-butadiene emulsion modification and styrene-acrylic emulsion modification, which is mainly used to improve the bond between concrete particles and concrete matrix and fiber, so as to enhance its impact resistance\cite{30, 31}. Rubber concrete includes the mixing of rubber waste powder, rubber particles and rubber fiber. This method can enhance the impact resistance performance to a certain extent, but may cause the reduction
of other strengths. It can be seen from the above introduction that at present, there are few studies on impact test directly on the pavement slab, and even fewer studies on impact resistance of fiber mesh reinforced concrete.

From the above analysis, we can see that the reinforced concrete surface properties mainly focused on the surface of enhancer reinforcement, to add polymer mixture and fiber and additive, to improve the way of maintenance, improvement of construction technology and optimization of concrete basic components. The five aspects above methods each have advantages and disadvantages, so we need to find an economic, effective and can balance the ways of strengthening. Airport cement concrete pavement surface mortar layer is a layer of direct contact with the outside world, and its strength is low. Its resistance to deformation ability is poor. Under external load, the surface layer is prone to cracking, abrasion, peeling and other diseases, which seriously affect the normal use of the runway and safety properties. Therefore, the concrete surface properties can be effectively strengthened by strengthening the mortar layer on the pavement surface.

5. Conclusions
This paper introduces the strengthening methods of pavement concrete surface properties from three aspects: abrasion resistance, frost resistance, and impact resistance. Strengthening methods of surface properties are focused on surface fortifier, adding polymer mixture, fiber, and additive, improving the way of maintenance, improving construction technology and optimizing the basic components of concrete. The five methods all have advantages and disadvantages. To strengthen the surface performance of pavement concrete economically, effectively and comprehensively, the way that laying fiber mesh into cement mortar layer is put forward.

Acknowledgements
This research was supported by the National Nature Science Foundation of China (Grant No. 51708550), Natural Science Basic Research Program of Shaanxi (2020JQ-474), and China Postdoctoral Science Foundation (Grant No.2020M671485). These financial supports are gratefully acknowledged.

References
[1] Liu P.C. Study on surface Strengthening and durability of airport Cement concrete pavement[D]. Xi'an; Air Force Engineering University, 2015.
[2] Xiong J.P, Shen A.Y, Song T, et al. Study on the abrasion resistance of pavement cement concrete[J]. Concrete, 2011, (02): 134-138.
[3] Weng X.Z, Zhang G.X, Han, Han Zhao, et al. Effect of sand ratio on performance of pavement concrete[J]. Journal of Xi'an University of architecture and technology (Natural Science edition), 2013, (02): 239-244.
[5] Zhang B. Study on pavement of polymer Modified cement concrete[J]. Shanxi Science & Technology of Communications, 2020, 03: 39-43.
[6] Yang T. Study on the Performance of Polymer Mechanism Sand Modified Cement Concrete Highway[J]. Fly ash comprehensive utilization, 2019, (06): 46-50.
[8] Xiang Shang, Effect of SAP Internal Curing[J]. Jiangxi Building Materials, 2019, 244(5): 158-159.
[9] Sui Y.Q, Chen J.B. Study of Mechanics Performance and Wear-ability of Steel Fiber Concrete in Road[J]. Northeastern Highway, 2001, (03): 19-21.
[10] Zhang T, Ceng G.P, Li X.Q, et al. Effect of surface construction technology on abrasion resistance of concrete [J]. China Concrete and Cement Products, 2012, 000(005): 67-70.
[11] POWERS T C. A Working Hypothesis for Further Studies of Frost Resistance of Concrete [J]. Journal of the Aci, 1945, 16(4): 245-72.
[12] T.C. Powers, R.A. Helmuth. Theory of Volume Changes in Hardened Portland Cement Paste During Freezing[J]. Proceedings of the Highway Research Board.1955,32:285 ~ 297 [J].
[13] MICHEL P, MARTIN L. Critical Air Void Spacing Factors for Concretes Submitted to Slow Freeze-Thaw Cycles [J]. ACI Journal Proceedings, 78(4).
[14] Su L.H, Lv Y, Yi J.G, et al. Research on frost resistance of airport pavement concrete enhanced by surface material[J]. Concrete, 2019, 353(03): 35-39+44.
[15] Jiang L. Study on pavement characteristics of cement concrete suitable for new aircraft [D]. Xi’an; Air Force Engineering University, 2015.
[16] Xie Y.C, Weng X.Z, Liu PC, et al. Study on frost resistance durability of surface-strengthened concrete [J]. Journal of Railway Science and Engineering, 2017, 09): 80-87.
[17] Zhu Mj, Weng X.Z, Gao R, et al. Study on Performance of Reinforced Concrete Material for Airport Pavement [J]. Journal of Shandong Agricultural University (Natural Science Edition), 2018, v.49(02): 118-25.
[18] GUO T, WENG X. Evaluation of the freeze-thaw durability of surface-treated airport pavement concrete under adverse conditions[J]. Construction and Building Materials, 2019, 206(MAY 10): 519-530.
[19] Lv J.W. Study on Factors Influencing Frost Resistance of Airport Cement Pavement[J]. Engineering and Technology Research, 2020, 5(12): 29-31.
[20] Huang Z.Q, Zhang, E.Q, Lv CX, et al. Experimental study on polymer modified concrete frost durability[J]. Concrete, 2016, No.318(04): 55-8+61.
[21] Dun X, Zhang Hen, Cheng A.D, et al. Research of high-frequency vibration on frost resistance of airport pavement air-entained concrete[J]. Concrete, 2013, 07): 159-162.
[22] Jia P, Du G.C, Reng Y.Y, et al. Strength and Frost-Resistance Properties of the Vibration-Mixed Concrete[J]. Journal of Northeastern University (Natural Science), 2019, 40(12): 1784-1789.
[23] He J.Y, Tian CY. Study on durability of basalt fiber hydraulic high performance Concrete[J]. CHINA CONCRETE AND CEMENT PRODUCTS, 2013, 5:46-48.
[24] Zhao B.B. Experimental on frost resistance of basalt-Polypropylene hybrid fiber reinforced concrete [J]. Journal of Liaoning Technical University (Natural Science) , 2015, 34: 1402-1407.
[25] Nie H.B, Gu S.C, Gao P.K, et al. Experimental Study on the Frost Resistance of Carbon Fiber Reinforced Concrete in Cold Areas [J]. CHINA CONCRETE AND CEMENT PRODUCTS, 2020, 05: 46-50.
[26] Sun S.H. Study on Mechanical Properties and Durability of Basalt Fiber Reinforced Concrete [D]; Liao Ning: Shenyang Ligong University, 2020.
[27] Ma S.B, Xu W.B, Xu Y.W, et al. Study on impact resistance of polypropylene fiber high performance concrete[J]. Concrete, 2018, 342(04): 26-29.
[28] Chen Q.F, Li S.S, Yu L.Z, et al. Study on the impact resistance of carbon fiber concrete[J]. JOURNAL OF HENAN UNIVERSITY OF ENGINEERING, 2019, 31(04): 28-31.
[29] Pan H.M. Ma Y.Z. Impact Resistance of Steel Fiber Reinforced Concrete and Its Mechanism of Crack Resistance and Toughening[J]. Journal of Building Materials. 2017, 020(006): 956-961.
[30] Li M. Experimental Study on the Pavement Performance of Styrene-butadiene Modified Steel Fiber Reinforced Concrete[D]. Heilongjiang: Northeast Forestry University, 2017.
[31] Wang Z.H, Chen X, Wang J.L. Study on road performance of new polymer modified cement concrete[J]. New Building Materials, 2016, 43(010): 56-59.