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Research on the Influence of HDP Chemical Modifier on the Performance of Pitchy Concrete Road

Ying Gao*[a], Jianmin Bian[b], Guangyao Li[a]

[a]School of Civil Engineering, Hebei University of Engineering, Handan 056038, China
[b]Transportation Bureau of Handan, Handan 056001, China
gaoying123@sohu.com

Traditional pitch has thermal plasticity in high temperature and rutting can be caused under external load. Aiming at the problem, a mixed pitchy material with high performance of durability is designed in this paper. A comparison test is operated on the stickiness, infrared spectrum, deformation and resistance to corrosion of the material and traditional pitchy material. In research conclusion: in different environment of high temperature, the viscosity of HDP mixed pitch increases rapidly within 20min; it does not change 20min later. The higher environmental temperature is, the lower the viscosity of mixture will be. Before the solidification of HDP mixture, the molecules have the structure of aromatic nucleus and the curve of infrared spectrum is very complex. After the solidification of HDP mixture, some original parts disappear and the curve of infrared spectrum is flat. The product is in three-dimensional network structure that makes HDP have strong strength and the feature of high temperature resistance. Under the load of vehicles, the track of HDP mixed pitch only increases slightly. It has good performance of deformation resistance. At the same time, HDP mixed pitch can prominently enhance the water stability of material. Traditional pitch can be seriously corroded by diesel oil. After being immersed for 120h, 12.1% weight decreases. Marshall residual stability lowers to be below 50%. However, the weight of HDP mixed pitch almost does not change in the 3 periods; Marshall residual stability always maintains to be above 94%. It indicates HDP mixed pitch has good performance of corrosion resistance. The stickiness of tested samples does not lower.

1. Introduction

Pitchy concrete can be got conveniently with low cost. Therefore, it is the main material of urban road, bridge and expressway. With thermal plasticity, pitchy road becomes soft with mobility under the blazing sun. On the crossroad and slope of urban road, rutting can be caused owing to the shearing stress of vehicle load because of emergency brake, acceleration and deceleration. So the flatness of road and safety of driving can be seriously influenced. Adverse consequences caused by rutting: normal traffic can be influenced; ponding or freeze in rutting makes driving difficult or causes traffic accident; deep rutting can cause the increase of road fissures; the strength of road weakens or even the whole road has to be anew paved. This adds to the cost of expressway (Haddock et al., 2005; Hafeez 2013; Wang et al., 2009; Chen et al., 2004; Gu et al., 2016; Fwa and Ong, 2006; Ramsamooj et al., 1998).

Aiming at the inherent defect of pitch, researchers add different intermixtures to pitch for enhancing the strength and performance of pitch. The main intermixtures include SBS, epoxy curing agent, algebraic epoxy pitch, waste plastic, SEAM etc. Above intermixtures can enhance the performance of traditional pitch in certain degree. Because of high cost or difficult construction, there is little improved pitchy concrete applied in actual road construction at present (CapitãO and Picado-Santos, 2006; Maupin and Diefenderfer, 2007; Xiao-Ning and Peng, 2012; Vervaecke and Vanelstraete, 2008; Said et al., 2011; Haritonovs et al., 2010; Ma et al., 2015; Zheng et al., 2017; Diefenderfer and Maupin, 2010; Zheng et al., 2016).

Aiming at the thermal plasticity of traditional pitch in high temperature and the rutting caused by external load of vehicles, a mixed pitch material with good durability is designed in this paper. A comparison test is operated on the stickiness, infrared spectrum, deformation and resistance to corrosion of the material and traditional pitchy material.

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2. Test materials and test specimen preparation

High-Durability Pitch (HDP) is new mixed pitch material. The improved HDP is used in this paper and its main ingredients are A-type epoxy resin and organic acid anhydride curing agent. A-type epoxy resin has no color with viscosity 12500mPa•s and density 1.16g/cm^3; organic acid anhydride curing agent is in faint yellow color with viscosity 43mPa•s and density 0.83 g/cm^3.

In comparison between traditional pitch and the improved HDP used in this paper, the content of pitch in traditional pitch material is 4.7%. The ratio of main annexing agent and hardening agent of improved HDP is 61.5:38.5. It is reserved in 65°C thermal water for 5h. Then the mixture is taken out from water and mix it with traditional pitch in ratio 21:79 in high temperature. It is shaped up finally. Infrared spectrum and field survey are used to analyze the effect of improved HDP on flatness protection and damage resistance of concrete road.

3. Test result and analysis

HDP mixture and traditional pitch can form thermoset substance in high temperature after they are mixed and stirred. Figure 1 shows viscosity curve between HDP and traditional pitch with different temperature 170°C, 180°C and 190°C. On the whole, in 20min that HDP is mixed with traditional pitch in the three temperatures, viscosity increases rapidly. 20min later, it almost does not change. The higher environmental temperature is, the lower viscosity of their mixture will be. The largest viscosity of the mixture is 430mPa•s in 170°C; the largest viscosity of the mixture is 210mPa•s in 180°C; the largest viscosity of the mixture becomes 40mPa•s in 190°C.

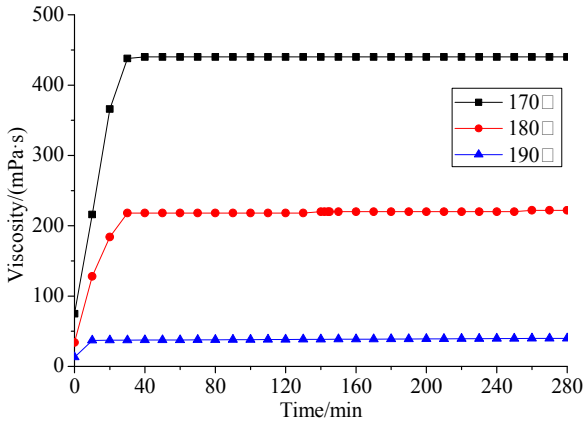


Figure 1: Viscosity curve between HDP and traditional pitch in different temperature

Figure 2 shows infrared spectrum before and after HDP solidification. In the figure, the infrared spectrum curve before solidification is very complex because the molecules have aromatic nucleus structure. After solidification of HDP, original parts in the mixture disappear and the infrared spectrum curve becomes flat. In the analysis of figure 2, HDP reaction principle and epoxy solidification reaction principle are same. The products of reaction are in three-dimensional network structure that makes HDP have strong strength and the feature of high temperature resistance.

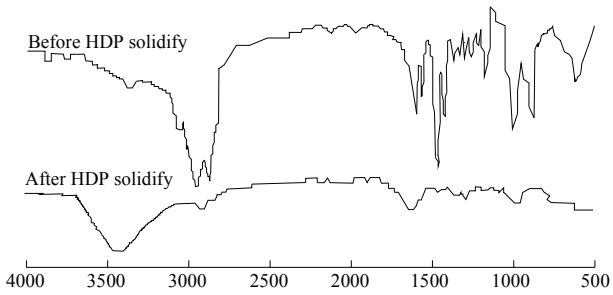
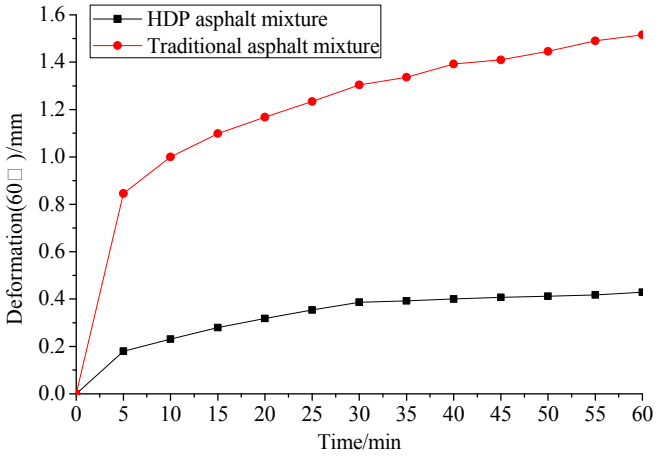
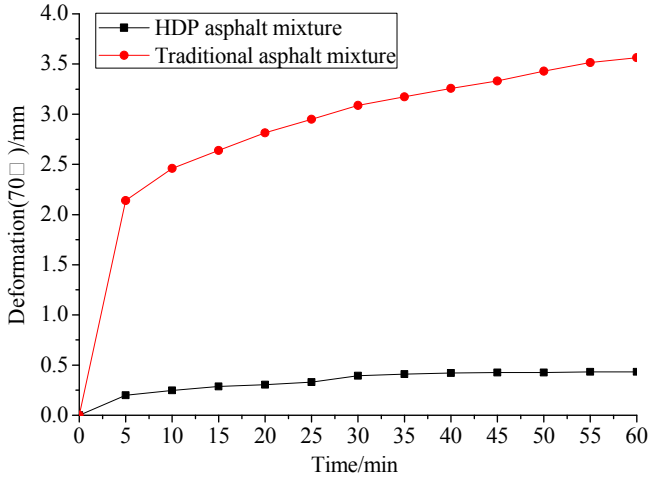


Figure 2: Infrared spectrum before and after HDP solidification

Figure 3 shows the deformation of traditional pitch and HDP mixed pitch in high temperature 60°Cand 70°C.In the figure, under the load of vehicles, the depth of rutting of HDP only increases slightly. In 60°C, the largest deformation is 0.43mm; in 70°C, the largest deformation is 0.435mm. The difference of deformation of HDP in the two temperatures is little. In 60°C, the largest deformation of traditional pitch mixture is 1.514mm; in 70°C, the largest deformation of traditional pitch mixture is 3.538mm. They are 3.52 times and 8.13 times as that of HDP, respectively. In addition, their deformation can increase largely in short time. It indicates HDP mixed pitch has good performance of deformation resistance.



(a) 60°C



(b) 70°C

Figure 3: Rutting depth of traditional pitch and HDP mixed pitch

Three-point bending test is operated to compare the bending-resistance strength and strain of traditional pitch and that of HDP mixed pitch. In the figure, the bending-resistance strength of HDP mixed pitch is 2 times as that of traditional pitch. When temperature declines from 15°C to be -10°C, the bending-resistance strength of HDP mixed pitch declines for 15.4% but that of traditional pitch declines for 33.3%. In -10°C and 0°C, the strain of them is same. In 15°C, the strain of HDP mixed pitch is much smaller than that of traditional pitch. Above analysis proves that HDP in traditional pitch can effectively increase the strength of pitch and decrease its deformation.

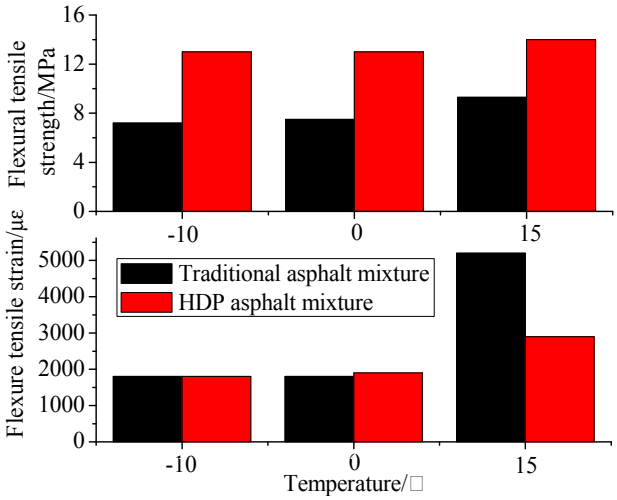
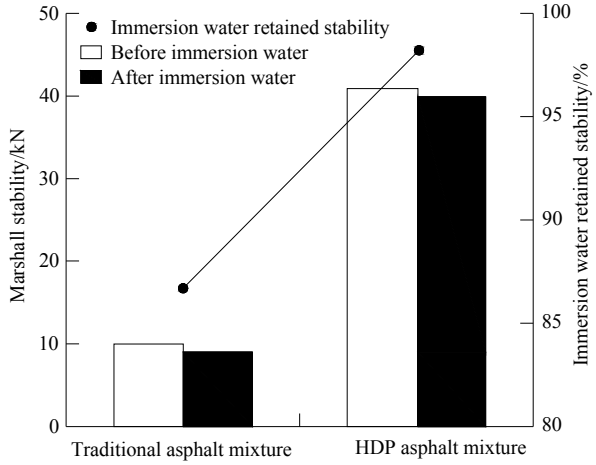
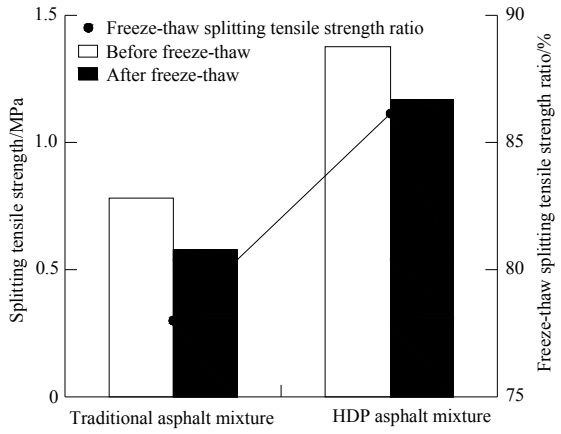


Figure 4: The bending-resistance strength and strain of traditional pitch and HDP mixed pitch



(a) Water immersion experiment



(b) Splitting experiment

Figure 5: Water immersion and splitting experiment of traditional pitch and HDP mixed pitch

Figure 5 shows water immersion and splitting experiment of traditional pitch and HDP mixed pitch and their strength in the two experiments. In the figure, after water immersion and splitting experiment, the stability and bending-resistance strength of both traditional pitch and HDP mixed pitch decline in certain degree. The stability of HDP mixed pitch after and before water immersion is more than 40kN; but the stability of traditional pitch is only about 9kN. The former is 4 times as the latter. Residual stability ratio rises from 87% of traditional pitch to be 98% of HDP mixed pitch; before and after splitting experiment, the bending-resistance strength of traditional pitch is about 0.7MPa but the bending-resistance strength of HDP mixed pitch is about 1.3MPa that is two times as that of traditional pitch. Ratio of bending-resistance strength rises from 78% of traditional pitch to be 86% of HDP mixed pitch. Above analysis indicates HDP mixed pitch can prominently enhance the water stability of materials.

The strength of urban roads declines owing to the corrosion of gasoline and diesel oil leaked from vehicles. Their lifetime is shortened. Table 1 shows the quality and Marshall residual stability of traditional pitch and HDP mixed pitch immersed in diesel oil for 24h, 48h and 120h. In the table, traditional pitch is seriously corroded by diesel oil. After it is immersed for 120h, its weight decreases for about 12.1% and Marshall residual stability lowers to be below 50%. In the three periods, the weight of HDP mixed pitch has little change and its Marshall residual stability maintains to be above 94%. It indicates HDP mixed pitch has good performance of corrosion resistance. Viscidity of the tested samples does not decline.

Table 1: Marshall residual stability and specimen quality before and after oil immersion test

Mixture type	Immersion oil time/h	Quality			Marshall stability		
		Before immersion oil/g	After immersion oil/g	Quality change/g	Before immersion oil/kN	After immersion oil/kN	Retained stability/%
Traditional	24	1225.7	1179.2	-46.5		7.33	58.8
asphalt	48	1225.3	1158.8	-66.5	12.46	6.69	53.7
mixture	120	1225.1	1110.4	-114.7		4.75	38.1
HDP	24	1225.6	1227.3	1.7		44.28	97.6
asphalt	48	1226.2	1226.5	0.3	45.38	46.73	103.0
mixture	120	1226.5	1226.6	0.1		42.84	94.4

4. Conclusions

A mixed pitchy material with high performance of durability is designed in this paper aiming at the problem that traditional pitch has thermal plasticity in high temperature and rutting can be caused under external load. A comparison test is operated on the stickiness, infrared spectrum, deformation and resistance to corrosion of the material and traditional pitchy material. Research conclusions are listed below:

(1) In different high temperatures, the viscosity of HDP mixed pitch rises rapidly in 20min and almost does not change 20min later. The higher environmental temperature is, the lower viscosity of the mixture will be.

(2) The molecules of HDP mixed pitch have aromatic nucleus structure before solidification and the curve of infrared spectrum is very complex. After solidification, the original parts of the mixture disappear and infrared spectrum is flat. The products after reaction has three-dimensional network structure that makes HDP have strong strength and the feature of high temperature resistance.

(3) Under the load of vehicles, slight increase of rutting is caused to HDP mixed pitch which has good deformation resistance performance. At the same time, HDP mixed pitch can prominently improve the water stability of materials.

(4) Traditional pitch can be seriously corroded by diesel oil. After immersion for 120h, 12.1% weight decreases and Marshall residual stability lowers to be below 50%. In the three periods, the weight of HDP mixed pitch has little change and its Marshall residual stability maintains to be above 94%. It indicates HDP mixed pitch has good performance of corrosion resistance. Viscidity of the tested samples does not decline.

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