Mechanical properties analysis of emulsified asphalt cold regeneration under layer based on the orthogonal design

Yanhai Yang[1, a], Shuai Dong[1, b], Ye Yang[1, c]

[1]Shenyang, Liaoning, China

[a]yangyanhai168@126.com, [b]575096162@qq.com, [c]yangye138@126.com

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Abstract. To study the mechanical properties of emulsified asphalt cold recycled materials, and recommend reasonable structural parameters. Using orthogonal experiment design method the ABAQUS finite element analysis software to simulate, range method is used to analyze the simulation results. When the emulsified asphalt cold recycled materials thickness is more than 10cm, modulus is greater than 800MPa; The cement stable macadam mixture thickness is more than 40cm, modulus is greater than 1600MPa; The soil base modulus is more than 70MPa, surfacing deflection of asphalt pavement, maximum shear stress and tension stress on the bottom of AC-10 and emulsified asphalt cold regeneration under layer are well. When the structure parameters are under the reasonable condition, emulsified asphalt cold recycled materials used as asphalt pavement under layer completely meet the requirements.

Introduction

More than 90% of provincial trunk highways in our country are the semi-rigid base asphalt pavement, the design life of asphalt pavement is about 12~15 years. By the end of 2014, The national highway mileage is more than 4.4 million kilometers. 10% of pavement are in need of major repair every year, major repairs will produce a lot of waste asphalt of pavement materials every year. Emulsified asphalt cold recycling technology is recycled asphalt pavement material according to a certain proportion of fresh material, emulsified asphalt, cement and water mix at room temperature, and paved a pavement at room temperature, then forms pavement structure layer[1-6]. Emulsified asphalt cold regeneration technology can effectively solve the problem such as the short of the existing asphalt pavement construction period, harmful gases produced in the construction process, and at the same time reducing the maintenance environmental pollution, energy consumption and waste materials to reduce the mountain mining and the asphalt resource demand, and can reduce the traffic and customer inconvenience, it is very suitable for road repair and maintenance[7-10]. Based on previous work experience, emulsified asphalt cold recycling as a layer below the mechanical properties of materials by using orthogonal test method using ABAQUS simulation software for simulation and analysis studies, theoretical foundation for the widespread application of emulsified asphalt cold recycling technology.

Surface Structure model

In view of the emulsified asphalt cold recycled materials as the layer below, research internal stress of pavement structure parameters change and its influence on road table deflection, analysis methods and material parameters are shown in table 1, using L16 (45) orthogonal table analysis[11-13], orthogonal test table are shown in table 2.

Tab.1 Pavement structure and material parameters

Material names	Thickness/cm	The compressive modulus of resilience/MPa	Poisson's ratio
AC-10	3	1200	0.25
Emulsified asphalt cold recycled materials	8/10/12/14	600/800/1000/1200	0.25
Cement stabilized crushed stone	30/40/50/60	1500/1600/1700/1800	0.25
Subgrade		40/70/100/130	0.40

Tab.2 Orthogonal experiment L16（45）

The column	A	B	C	D	E
Experiment	Thickness of emulsified asphalt cold recycling material/cm	Modulus of emulsified asphalt cold regeneration material/Mpa	Thickness of cement stabilized macadam/cm	Modulus of cement stabilized macadam /Mpa	Modulus of soil base /Mpa
1	8	600	30	1500	40
2	8	800	40	1600	70
3	8	1000	50	1700	100
4	8	1200	60	1800	130
5	10	600	40	1700	130
6	10	800	30	1800	100
7	10	1000	60	1500	70
8	10	1200	50	1600	40
9	12	600	50	1800	70
10	12	800	60	1700	40
11	12	1000	30	1600	130
12	12	1200	40	1500	100
13	14	600	60	1600	100
14	14	800	50	1500	130
15	14	1000	40	1800	40
16	14	1200	30	1700	70

Finite element model description. Finite element software ABAQUS is adopted to establish the three-dimensional finite element model[14-15].Take 6m in the x and y direction, take 3m in the z direction.Make origin slots on the wheel center point, x axis parallel to the direction of driving, y axis horizontal vertical driving directions and the z axis vertical surface.Bottom x,y,z three direction of displacement is 0, both sides of the vertical x axis displacement in x direction is 0, both sides of the vertical y axis displacement in y direction is 0, contact conditions between the pavement structure layer upon layer is given priority to with inter layer completely continuous[16]. Use standard tandem-axle loads 100kN, tire pressure is 0.7MPa, wheel radius of pressure is10.65cm, center distance is 31.95cm.

Calculation index. Asphalt pavements under traffic loading, mainly bear the horizontal and vertical loads, so choose the deflection on road table wheel gap center,and maximum shear stress and tensile stress on emulsified asphalt cold regeneration layer as parameter.

Surface Structure model

Emulsified asphalt recycling layer. We study the changing rules of maximum shear stress and tensile stress on the emulsified asphalt cold regeneration by changing the thickness and modulus of emulsified asphalt cold regeneration, thickness and modulus of the cement stable macadam mixture, and modulus of soil base, results are shown in table 3.

Tab.3 Simulation results of emulsified asphalt cold recycled materials mechanical characteristics

In the column	A	B	C	D	E	X	Y
Experiment	Thickness of emulsified asphalt cold recycling material/cm	Modulus of emulsified asphalt cold regeneration material/Mpa	Thickness of cement stabilized macadam /cm	Modulus of cement stabilized macadam /Mpa	Modulus of soil base/Mpa	The maximum shear stress/Mpa	Tensile stress on the bottom /Mpa
1	8	600	30	1500	40	0.0902	0.1575
2	8	800	40	1600	70	0.0939	0.1445
3	8	1000	50	1700	100	0.0966	0.1382
4	8	1200	60	1800	130	0.0974	0.1344
5	10	600	40	1700	130	0.0836	0.1193
6	10	800	30	1800	100	0.0927	0.1420
7	10	1000	60	1500	70	0.0905	0.1295
8	10	1200	50	1600	40	0.0937	0.1509
9	12	600	50	1800	70	0.0796	0.1134

10		12	800	60	1700	40	0.0894	0.1169
11		12	1000	30	1600	130	0.0911	0.1363
12		12	1200	40	1500	100	0.0903	0.1376
13		14	600	60	1600	100	0.0759	0.1024
14		14	800	50	1500	130	0.0798	0.1097
15		14	1000	40	1800	40	0.0854	0.1368
16		14	1200	30	1700	70	0.0901	0.1461
X	I	0.3781	0.3293	0.3641	0.3508	0.3587		
	II	0.3605	0.3558	0.3532	0.3546	0.3541		
	III	0.3504	0.3636	0.3497	0.3597	0.3555		
	IIII	0.3312	0.3715	0.3532	0.3551	0.3519		
	I/K	0.0945	0.0823	0.0910	0.0877	0.0897		
	II/K	0.0901	0.0890	0.0883	0.0887	0.0885		
	III/K	0.0876	0.0909	0.0874	0.0899	0.0889		
	IIII/K	0.0828	0.0929	0.0883	0.0888	0.0880		
	R	0.0117	0.0106	0.0036	0.0022	0.0017		
Y	I	0.5746	0.4926	0.5819	0.5343	0.5621		
	II	0.5417	0.5131	0.5382	0.5341	0.5335		
	III	0.5042	0.5408	0.5122	0.5205	0.5202		
	IIII	0.4950	0.5690	0.4832	0.5266	0.4997		
	I/K	0.1437	0.1232	0.1455	0.1336	0.1405		
	II/K	0.1354	0.1283	0.1346	0.1335	0.1334		
	III/K	0.1261	0.1352	0.1281	0.1301	0.1301		
	IIII/K	0.1238	0.1423	0.1208	0.1317	0.1249		
	R	0.0199	0.0191	0.0247	0.0035	0.0156		

Can be seen from table 3, the maximum shear stress test show that: $R_A > R_B > R_C > R_D > R_E$, the order of its effect is: thickness and modulus of emulsified asphalt cold recycled materials, thickness and modulus of the cement stable macadam, and the modulus of soil base. Drawing the influence to emulsified asphalt cold regeneration layer of maximum shear stress changing trends as shown in figure 1.

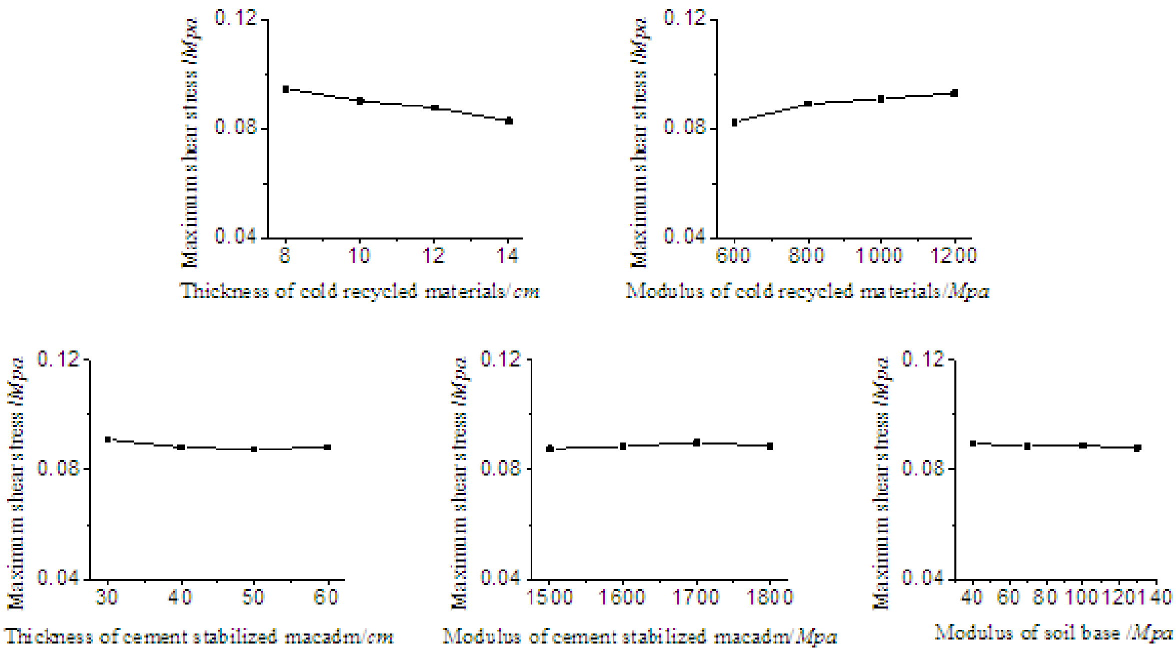

Fig.1 Test factors affect maximum shear stress

Can be seen from figure 1, the maximum shear stress in emulsified asphalt cold regeneration layer is smaller, thickness and modulus of emulsified asphalt cold recycled materials, thickness and modulus of the cement stable macadam mixture, and the modulus of soil base impress little on the maximum shear stress in the emulsified asphalt cold regeneration layer.

Can be seen from table 3, tensile stress on the bottom of emulsified asphalt cold regeneration layer test: $R_C > R_A > R_B > R_E > R_D$, the order of its effect is: the thickness of cement stabilized macadam, thickness and modulus of emulsified asphalt cold recycled materials, modulus of soil base and modulus of cement stabilized macadam. Drawing the influence to emulsified asphalt cold regeneration layer of tensile stress on the bottom changing trends as shown in figure 2.

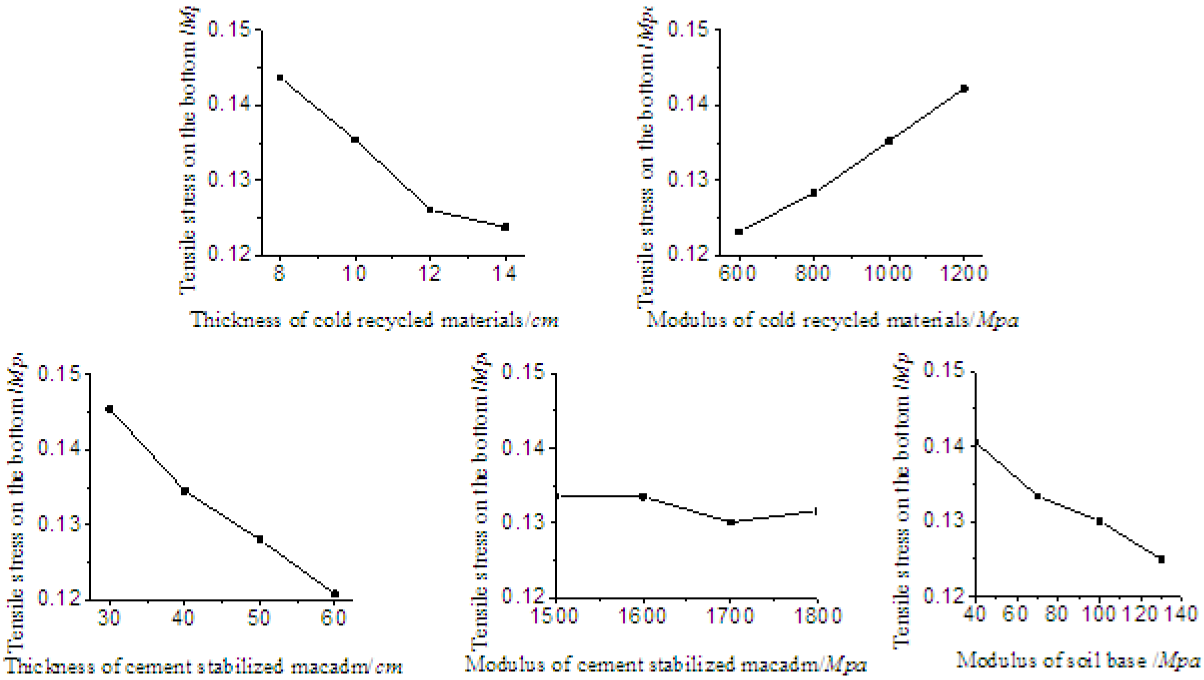

Fig.2 Test factors affect emulsified asphalt material layer bottom bending tensile stress

Can be seen from figure 2, as the thickness of the emulsified asphalt cold recycled materials, thickness of the cement stable macadam, and the modulus of soil base increase, the tensile stress on the bottom of emulsified asphalt cold regeneration decreases. It also increases when the modulus of emulsified asphalt cold recycled materials increases. But it changes a little, its scope is within 0.03, the influence of modulus of cement stabilized macadam is smaller.

Conclusions

The maximum shear stress of emulsified asphalt cold regeneration layer is smaller, the thickness and modulus of emulsified asphalt cold recycled materials, thickness and modulus of the cement stable macadam, and modulus of soil impressed a little on the maximum shear stress in the emulsified asphalt cold regeneration layer. The tensile stress on the bottom of emulsified asphalt cold regeneration layer decreases as the thickness of the emulsified asphalt cold recycled materials, the thickness of the cement stable macadam, and the modulus of soil base increase, it also increases as the modulus of emulsified asphalt cold regeneration material increase. But small change is within 0.03MPa, the influence of modulus of cement stabilized macadam is smaller.

The thickness of the emulsified asphalt cold recycled materials is more than 10cm, modulus is greater than 800Mpa; the thickness of the cement stable macadam mixture is more than 40cm, modulus is greater than 1600Mpa; when soil base modulus is greater than 70Mpa, the effect of surfacing deflection, the tensile stress on the bottom and the maximum shear stress on the AC-10 surface and on the emulsified asphalt cold regeneration layer are good.

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