INFLUENCE OF VIRGIN AGGREGATE CONTENT AND CURING TIME TO PERFORMANCE OF EMULSION COLD RECYCLED ASPHALT MIXTURE

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ABSTRACT

Cold recycling technologies utilizing emulsion as binder demonstrates a number of high environmental advantages and thus it is widely applied worldwide. There are many factors influencing the performance of emulsion recycled asphalt mixture, such as components, curing, aging etc. This study investigates the influence of proportion of virgin aggregate and curing time on the performance of recycled mixture.

The mixture formulation design at three levels of virgin aggregate addition (0%, 10% and 20%) and one dosage of cement (1.5%) has been conducted. The performance of emulsion recycled asphalt mixture including splitting failure load, splitting failure strength and Freeze-thaw splitting strength has been measured at four curing times (0 day, 7 days, 14 days and 28 days). The effect of proportion of virgin aggregate and curing time on the performance of recycled mixture has been quantified accordingly. The research has manifested that the increment of the proportion of virgin aggregate and the curing time will enhance the performance of the emulsified asphalt cold recycled mixture up to 26%.

KEYWORDS: Asphalt mixture cold recycling; Emulsion; Proportion of virgin aggregate; Curing time; Performance evaluation

1 INTRODUCTION

The recycling technologies for asphalt pavements can be classified into two types according to the manufacturing methods, being hot recycle and cold recycle (Malpass, 2003; Specification for Highway Works, 2004; Kandhal and Foo, 1997; Cornelius and Edwards, 1991). As one of the cold recycle technologies, the emulsion cold recycled asphalt mixture can not only save natural resource and energy, but also extend the environmental limitation for construction project and reduce environmental pollution (Kennedy et al., 1998; Servas et al., 1987; Noureldin and Wood, 1990; Whitcomb et al., 1980). The typical construction process for emulsion cold recycled asphalt pavements includes 3 steps (Sondag et al., 2002; Kandhal et al., 1995; Kingery, 2004; Malpass, 2003):

- Milling and breaking the aged asphalt pavement;
- Mixing Reclaimed Asphalt Pavement (RAP) materials with stabilizer, cement, water, emulsion bitumen and virgin aggregate at certain proportion, and
- Laying and compacting the recycled mixture.

In this paper, the emulsion cold recycled asphalt mixture design was carried out at three different contents of virgin aggregate addition (0%, 10% and 20%) with 1.5% cement as additive. Meanwhile, the performance evaluation was carried out according to the Chinese National Specifications for Highway Asphalt Pavement Recycling (Ministry of Transport of the People's Republic of China, 2008) at different curing times, as 0 day, 7 days, 14 days and 28 days. The effect of proportion of virgin aggregate and curing time on the performance of recycled mixture has been evaluated accordingly.

2 EMULSION COLD RECYCLE ASPHALT MIXTURE DESIGN

2.1 Materials

2.1.1 Reclaimed Asphalt Pavement (RAP)

The RAP materials used in this research originate from a highway maintenance project. The original asphalt mixtures used AC-13 as a wearing course and AC-20 as a base course. The moisture content in the RAP is 0.17%.

2.1.2 Emulsion bitumen

The properties of emulsion bitumen are listed in Table 1.

Table 1: The properties of emulsion bitumen.

Test item	Results	Requirement	Test method
Residue Content, %	64.8	≥57	ASTM D 244
Demulsibility, %	slow	slow	T 66017
Sieve Test, 1.18 mm, %	0.01	≤0.1	ASTM D 244
Saybolt Furol Viscosity, 25°C [Cs]	64	20-100	ASTM D 1665
Particle Charge	+	+	ASTM D 244
Coating Test	＞2/3	＞2/3	ASTM D 244
Penetration, dmm	74	50-200	ASTM D 5

Softening Point, ℃		47.0	≥40	ASTM D 36
Ductility(25℃), cm		＞150	≥40	ASTM D 113
Solubility, Trichloroethylene,% m		>97.5	97.5 min.	ASTM D 2042
Storage Stability, %	1 day	0.6	≤1	T0655-1993
	5 days	2.2	≤5	T0655-1993

2.1.3 Virgin aggregate

The virgin aggregates used in this research are crushed alkaline aggregate and sand, which meet related requirements of Chinese National Technical Specification for Construction of Highway Asphalt Pavements (Ministry of Transport of the People's Republic of China, 2004).

2.1.4 Cement

The cement used in this research is ordinary Portland cement (No. 32.5), which meets the requirements of Chinese National Specifications (National Standard of the People's Republic of China, 1991).

2.2 Gradation of aggregate

The designed gradation is selected according to the Technical Specifications for Highway Asphalt Pavement Recycling (JTG F41-2008). In order to minimize the influence of gradation to emulsion cold recycled mixtures, the aggregate and RAP are manually sieved and divided into different sieve sizes, which can ensure the gradation of cold recycled mixture to be constant with different proportions of virginal aggregate. The designed gradation is shown in Figure 1.

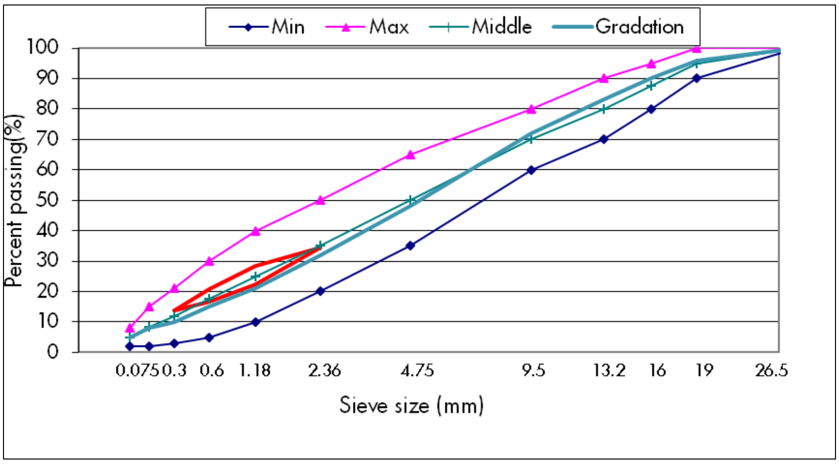

Figure 1: Gradation of aggregates for emulsion cold recycled mixtures.

2.3 Optimum Water Content (OWC)

The strength of emulsion cold recycled asphalt mixture is related to its density. Extra water in cold recycled asphalt mixture occupies space. After water evaporating, some air voids will be left in the mixture and lower its strength. Emulsion cold recycled asphalt mixture has an OWC, at which the dry density of recycled asphalt mixture can be maximized.

The water content at which the compacted specimen has the greatest dry density is defined as OWC. In this research, 4% is selected as emulsion content. The OWC is determined through a compaction test at varying water contents. The test results are illustrated in Figure 2.

From the Figure 2, the maximum dry density is 2.15 g/cm^3 and OWC is 4.5%.

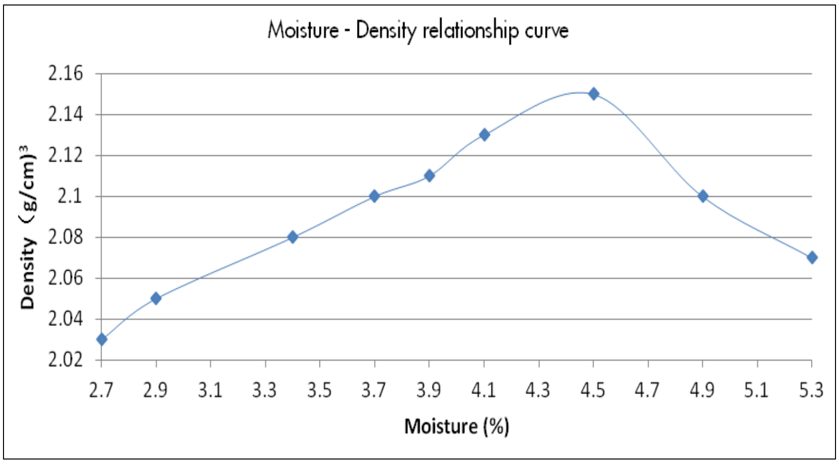

Figure 2: Relationship between density and moisture.

2.4 Optimum Emulsion Content (OEC)

As required in the Chinese Technical Specifications for Highway Asphalt Pavement Recycling, for emulsion cold recycled asphalt mixtures, the designed air voids should be between 9% and 14% (preferably less than 12%), the Indirect Tensile Strength (ITS) should be greater than 0.4 MPa (for base course) or greater than 0.5 MPa (for bottom layer of surface course), and the ITS ratio between conditioned specimens and unconditioned specimens (TSR) should be greater than 75%.

The Marshall method is used for emulsion cold recycled asphalt mixture design. Keeping the water content consistently as OWC, five emulsion contents (3.0%, 3.5%, 4.0%, 4.5% and 5.0%) are used to prepare the Marshall specimens. The volumetric properties of the asphalt mixture are shown in Table 2 and the ITS results are shown in Tables 3 to 5. From the test data, the OECs are all 4% for emulsion cold recycled asphalt mixture with 0%, 10% and 20% virgin aggregate addition.

3 PERFORMANCE OF EMULSION COLD RECYCLED ASPHALT MIXTURE

The ITS tests under the freezing and thawing conditions are used to evaluate the influence of virgin aggregate contents to performance of cold recycled asphalt mixture. At the same time, the influence of curing time is also investigated in this research, as 0, 7, 14 and 28 days.

3.1 Performance of emulsion cold recycled asphalt mixture with same curing time

In Figure 3, it is shown that for the same curing time, with increasing of the virgin aggregate content, the ITS of emulsion cold recycled asphalt mixture is increasing with a linear relationship. For the mixture without curing (0 days), compared with the mixture without virgin aggregate, the ITS of the mixture with 10% virgin aggregate is 5.0% higher and the mixture with 20% virgin aggregate is 15.1% higher. After curing for 7 days, the ITS for the mixture with 10% and 20% virgin aggregate are 6.1% and 12.0% higher. After curing 14 days, they are 3.3% and 15.2% higher. After 28 curing days, the ITSs are 7.3% and 18.0% higher.

Table 2: The volumetric properties of asphalt mixture.

New aggregate per cent (%)	Emulsion Content (%)	G_b	G_{mm}	Va (%)
0	3.0	2.169	2.498	13.2
	3.5	2.178	2.487	12.4
	4.0	2.218	2.459	9.8
	4.5	2.238	2.456	8.9
	5.0	2.271	2.470	8.1
10	3.0	2.099	2.520	16.7
	3.5	2.196	2.507	12.4
	4.0	2.210	2.490	11.3
	4.5	2.222	2.457	9.6
	5.0	2.250	2.463	8.7
20	3.0	2.169	2.542	14.7
	3.5	2.195	2.533	13.3
	4.0	2.256	2.524	10.6
	4.5	2.262	2.477	8.7
	5.0	2.281	2.477	7.9

Table 3: Results of ITS test for asphalt mixture without virgin aggregates.

Emulsion Content (%)	$Force_{wet}$ (kN)	$Force_{dry}$ (kN)	IDT_{wet} (MPa)	IDT_{dry} (MPa)	TSR (%)
3.0	5.60	6.83	0.5633	0.6865	82
3.5	6.41	7.62	0.6410	0.7615	84
4.0	8.46	9.37	0.8529	0.9447	90
4.5	7.81	8.87	0.7803	0.8863	88
5.0	7.58	8.48	0.7572	0.8472	89

Table 4: Results of ITS test for asphalt mixture with 10% virgin aggregates.

Emulsion Content (%)	Force $_{wet}$ (Kk)	Force $_{dry}$ (Kk)	IDT $_{wet}$ (MPa)	IDT $_{dry}$ (MPa)	TSR (%)
3.0	2.91	3.58	0.2834	0.3486	81
3.5	6.34	6.87	0.6316	0.6845	92
4.0	8.17	8.39	0.8076	0.8293	97
4.5	6.85	8.10	0.6740	0.7970	85
5.0	6.70	7.69	0.6522	0.7487	87

Table 5: Results of ITS test for asphalt mixture with 20% virgin aggregates.

Emulsion Content (%)	Force $_{wet}$ (kN)	Force $_{dry}$ (kN)	IDT $_{wet}$ (MPa)	IDT $_{dry}$ (MPa)	TSR (%)
3.0	4.51	5.96	0.4535	0.6000	76
3.5	6.73	7.57	0.6736	0.7572	89
4.0	8.03	8.91	0.8020	0.8904	90
4.5	7.61	8.73	0.7575	0.8685	87
5.0	7.63	8.68	0.7471	0.8504	88

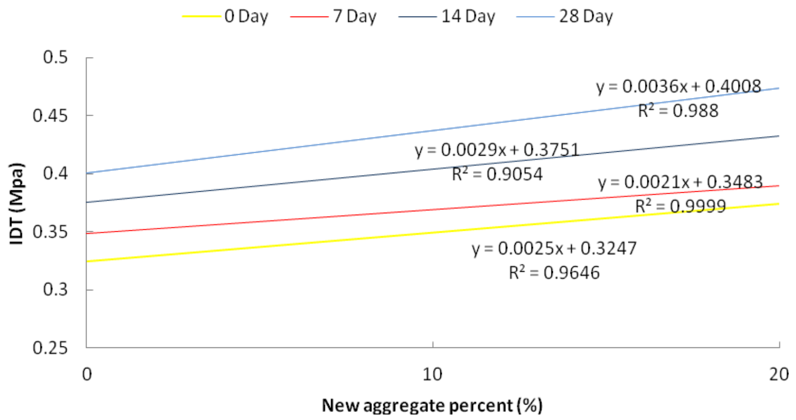

Figure 3: ITS test results with different virgin aggregate content under freezing and thawing condition.

From Figure 4 it can be concluded that for the same curing time, with the increment of virgin aggregate content, the ITS after the freezing and thawing cycle of emulsion cold recycled asphalt mixtures are also stronger. For the mixture without curing (0 days), compared with the mixture without virgin aggregate, the ITS of the mixture with 10% virgin aggregate is 4.1% greater and the mixture with 20% virgin aggregate is 13.5% greater. After curing 7 days, the ITS increase for the mixture with 10% and 20% virgin aggregate are 6.8% and 8.7%. After curing 14 days, they are 3.0% and 11.0% higher and after 28 days' curing, the ITSs are 6.4% and 15.4% greater.

From Figure 5, it can be seen that the ITS ratios between conditioned (freezing and thawing) specimens and unconditioned specimens (TSR) did not change significantly, and that it still satisfies the specifications.

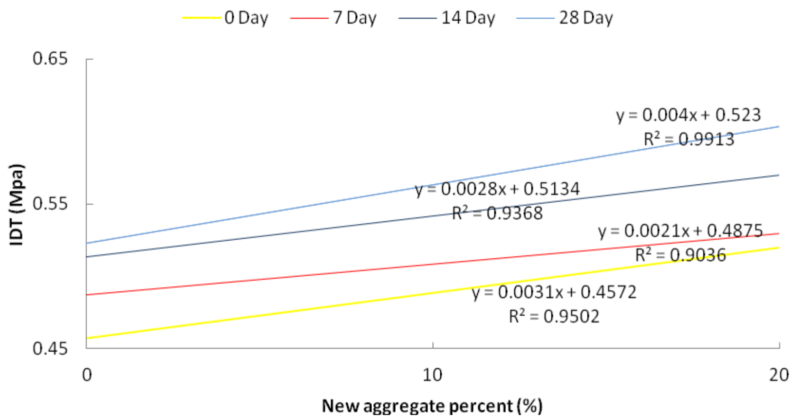

Figure 4: ITS test results with different virgin aggregate content without freezing and thaw condition.

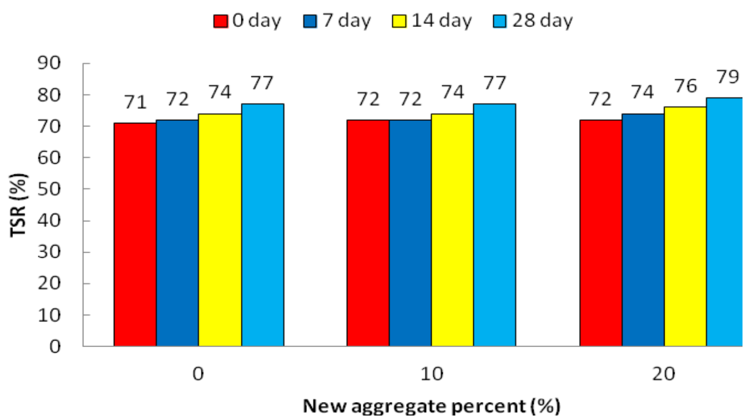

Figure 5: ITS ratio results with different virgin aggregate content.

3.2 <u>Influence of curing time to performance of emulsion cold recycled asphalt mixture</u>

From Figure 6 it can be seen that if the content of virgin aggregate is constant, the ITS of emulsion cold recycled asphalt mixture is linearly increasing with the curing time. For the mixture without virgin aggregate, compared with the specimen without curing, the ITSs are 6.4%, 16.2% and 23.1% greater for curing 7 days, 14 days and 28 days. For the mixture with 10% virgin aggregate, the ITSs are 7.4%, 14.3% and 25.8% greater. For the mixture with 20% virgin aggregate, the increments are 2.5%, 16.3% and 26.3%.

In Figure 7 it is shown that for the same virgin aggregate contents, the ITSs for specimens after freezing and thawing cycle are also linearly increased with curing time. For the mixture without virgin aggregate, compared with the specimen without curing, the conditioned ITSs are 4.8%, 12.2% and 13.9% greater for curing 7 days, 14 days and 28 days. For the mixture with 10% virgin aggregate, the ITS increments are 7.5%, 11.1% and 16.4% and for the mixture with 20% virgin aggregate, the increments are 0.3%, 9.7% and 15.7% respectively. From Figure 8 it can be seen that for the same virgin aggregate content, the ITS ratios between conditioned (freezing and thawing) specimen and unconditioned specimen are slightly increasing with curing time, while they satisfy the specification requirements.

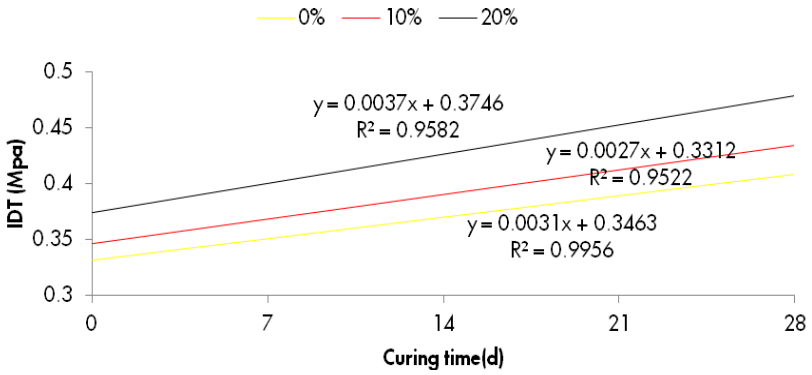

Figure 6: ITS test results with different curing time without freezing and thaw condition.

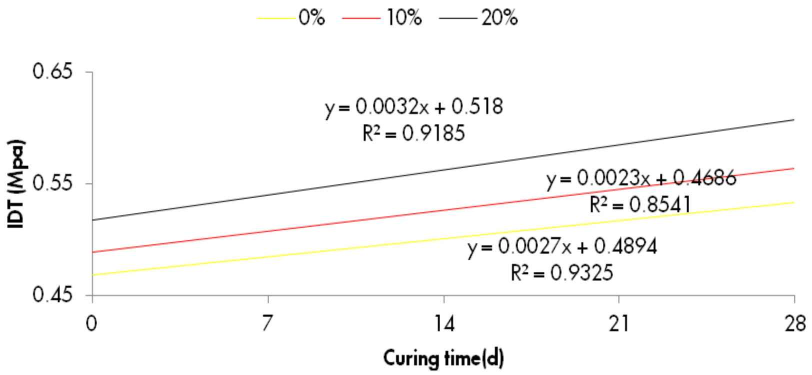

Figure 7: ITS test results with different curing time without freezing and thaw condition.

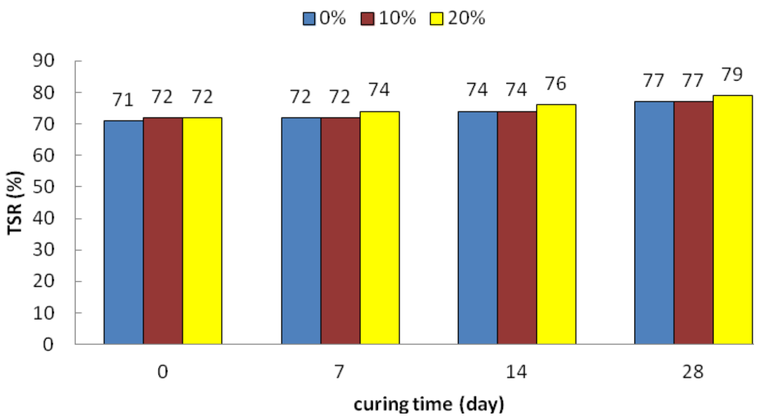

Figure 8: ITS ratio results with different curing time.

4 CONCLUSIONS

From this research, it can be concluded that:

1. The ITS of emulsion cold recycled asphalt mixture increases with the increment of virgin aggregate contents. The ITS ratio (TSR) for freezing and thawing is increasing slightly.
2. The ITS of emulsion cold recycled asphalt mixture increases with curing time. The TSR is slightly increased.
3. Compared with mixtures without virgin aggregate, the mixtures with virgin aggregate have a higher ITS after the freezing and thawing cycle. This means that the freezing and thawing cycle has a greater influence on the RAP than on the virgin aggregate.
4. The increment of unconditioned ITS with curing time is less than for the conditioned ITS, which means that curing time has a higher impact to the mixture's ITS after freezing and thawing cycle.

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