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The Study of Properties of Multigrade Asphalt Concrete by Comparison the Aggregate between Steel Furnace Slag and Limestone

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ABSTRACT

Multigrade asphalt concrete is mixture of hot mix asphalt and aggregates. It uses the same aggregate gradation as general asphalt concrete, but uses multigrade asphalt instead of asphalt cement as a binder. The objective of this research is to compare the properties of multigrade asphalt concrete by using steel furnace slag and limestone as aggregates. The compaction of multigrade asphalt concrete was done by the Marshall method and gyratory compactor with different number of gyration.

The results indicated that the steel furnace slag aggregate had higher specific gravity and soundness and lower abrasive resistance than limestone. The design for the steel furnace slag aggregate had higher density, stability, flow and percentage of asphalt cement than limestone in both Marshall and gyratory compactions. When testing the properties of multigrade asphalt concrete, the steel furnace slag aggregate had a higher strength index and resilient modulus and less rutting than limestone. It was concluded that multigrade asphalt concrete using steel furnace slag aggregate are better than limestone in the construction of asphalt concrete pavement.

Key words: multigrade asphalt concrete, steel furnace slag, limestone

INTRODUCTION

Asphalt concrete consists of aggregate and has asphalt cement as a binder. The purpose of aggregate in asphalt concrete is to receive loads from vehicles while that of asphalt cement is to cling the aggregates firmly in order not to move the asphalt concrete when it receives more weight. Thus the performance of asphalt concrete is dependent on the performance of asphalt cement and aggregates.

Currently, most aggregates use limestone. Since limestone consists of calcium carbonate ($CaCO_3$) which easily deteriates, load capacity is lessened, and accidents are caused due to decreased skidding resistance between wheel and pavement.

Steel furnace slag is a product of the steel refining industry. When it is crushed. It can be used as aggregate in subbase, base and pavement. In this research, it was observed that steel furnace slag was used as aggregate in asphalt concrete.

Multigrade asphalt is produced by special refinery processes to provide more structure to the product and enhance the engineering performance. In this research, Multigrade asphalt was used as a binder instead of asphalt cement.

This research is a comparison of the properties of multigrade asphalt concrete when incorporating steel furnace slag or limestone.

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MATERIALS AND METHODS

Materials used in the research

1. Steel furnace slag from Chonburi Steel Mill Services Co., Ltd, Chonburi
2. Limestone from Silamahanakhon mill, Chonburi

Methods used in this research

1. The study of properties of steel furnace slag and limestone. (BMRD, 2000)
2. The study of the properties of multigrade asphalt concrete using steel furnace slag aggregate compared with limestone aggregate by the marshall method. (AASHTO, 1992)
3. The study of the properties of multigrade asphalt concrete using steel furnace slag aggregate compared with limestone aggregate by gyratory compactor at 93, 119, 153 cycles (Asphalt Institute, 1995 and 1996).

RESULTS AND DISCUSSION

The properties of aggregates

The results indicated that steel furnace slag and limestone have passed the specifications of the Department of Highways. It was observed that in coarse aggregates the abrasion of steel furnace slag was 4.3% less than limestone, and the soundness was 0.33% more than limestone. In fine aggregates, the soundness of steel furnace slag was 0.22% more than limestone, and sand equivalent was 4.1% more than limestone.

The multigrade asphalt concrete compaction by marshall method

At 4.0% air void, it was found that multigrade asphalt concrete using steel furnace slag aggregate had the following percentiles of asphalt cement, stability, flow, stability / flow : 1.0%, 26.55%, 8.57% and 16.56% more than using limestone aggregate (Table 1, 2).

The multigrade asphalt concrete compaction by gyratory compactor at 93, 119, 153 cycles

At 4.0% air void, it was found that multigrade asphalt concrete using steel furnace slag aggregate had the following percentiles of asphalt cement, stability, flow, stability / flow : 0.9 – 1.0%, 19.90 – 22.41%, 9.90 – 16.57% and 4.98 – 11.05% more than using limestone aggregate (Table 1, 2).

The properties of multigrade asphalt concrete

Strength index by using both the marshall method and gyratory compactor

Multigrade asphalt concrete using steel furnace slag aggregate had increased strength indices of 3.50%, 5.30%, 3.70%, and 4.20% over limestone aggregate (Table 3).

Resilient Modulus at 15, 25, and 35 degrees celsius by marshall method and gyratory compactor

It was found that multigrade asphalt concrete using steel furnace slag aggregates had higher resilient modulus than using limestone aggregate 13.97 – 17.86%, 12.48 – 19.04%, 6.41 – 14.19% and 7.14 – 18.47% orderly (Table 4 and Figure 1,2).

For rutting, it was found that multigrade asphalt concrete using limestone aggregate had a greater wheel rutting depth a higher rate of rutting than using steel furnace slag aggregate (Figure 3).

CONCLUSION

It was concluded from the results of the research that :

1) The physical property of aggregates indicated that steel furnace slag aggregate had higher strength and soundness than limestone aggregate.

Table 1 Properties of multigrade asphalt concrete using steel furnace slag aggregate.

Properties	Marshall	Gyratory compactor (cycles)			Limit
		93	119	153	
Air Void (%)	4.0	4.0	4.0	4.0	3.0 - 5.0
AC By Weight of Agg.(%)	6.0	6.1	5.9	5.6	-
Density (gm/ml)	2.842	2.841	2.852	2.863	-
Stability (lbs.)	3,670	4,260	4,450	4,640	>1,800
Flow (1/100”)	15.2	20.4	20.7	21.1	8 -16
Stability/Flow (lbs./0.001”)	241.4	208.8	215.0	219.9	> 160
VFB (%)	76.4	77.3	76.8	75.0	-
VMA (%)	17.5	17.6	17.1	16.6	> 14.0

Table 2 Properties of multigrade asphalt concrete using limestone aggregate.

Properties	Marshall	Gyratory compactor (cycles)			Limit
		93	119	153	
Air Void (%)	4.0	4.0	4.0	4.0	3.0 - 5.0
AC by Weight of Agg.(%)	5.0	5.2	4.9	4.6	-
Density (gm/ml)	2.474	2.470	2.480	2.486	-
Stability (lbs.)	2,900	3,480	3,640	3,870	>1,800
Flow (1/100”)	14.0	17.5	18.8	19.2	8 -16
Stability/Flow (lbs./0.001”)	207.1	198.9	193.6	201.6	> 160
VFB (%)	73.1	74.5	73.0	72.0	-
VMA (%)	15.0	15.3	14.7	14.3	> 14.0

Table 3 Strength index of multigrade asphalt concrete.

Method	Aggregate		Different (%)	Limit (%)
	Steel furnace slag (%)	Limestone (%)		
Marshall	87.7	84.2	3.5	> 75.0
Gyratory 93 cycles	89.9	84.6	5.3	> 75.0
Gyratory 119 cycles	86.5	82.8	3.7	> 75.0
Gyratory 153 cycles	85.8	81.6	4.2	> 75.0

Table 4 Resilient Modulus of multigrade asphalt concrete.

Properties	Resilient Modulus (Mpa.)		Different (%)
	Steel furnace slag	Limestone	
Marshall			
at 15°C	10,021.10	8,792.50	13.97
at 25°C	6,035.40	5,124.63	17.77
at 35°C	3,141.23	2,665.20	17.86
Gyratory 93 cycles			
at 15°C	10,577.00	9,403.23	12.48
at 25°C	6,643.07	5,742.67	15.68
at 35°C	3,642.90	3,037.17	19.94
Gyratory 119 cycles			
at 15°C	11,046.90	10,381.80	6.41
at 25°C	7,243.13	6,358.47	13.91
at 35°C	4,108.67	3,598.10	14.19
Gyratory 153 cycles			
at 15°C	11,926.57	11,131.73	7.14
at 25°C	8,296.97	7,432.07	11.64
at 35°C	5,060.70	4,271.87	18.47

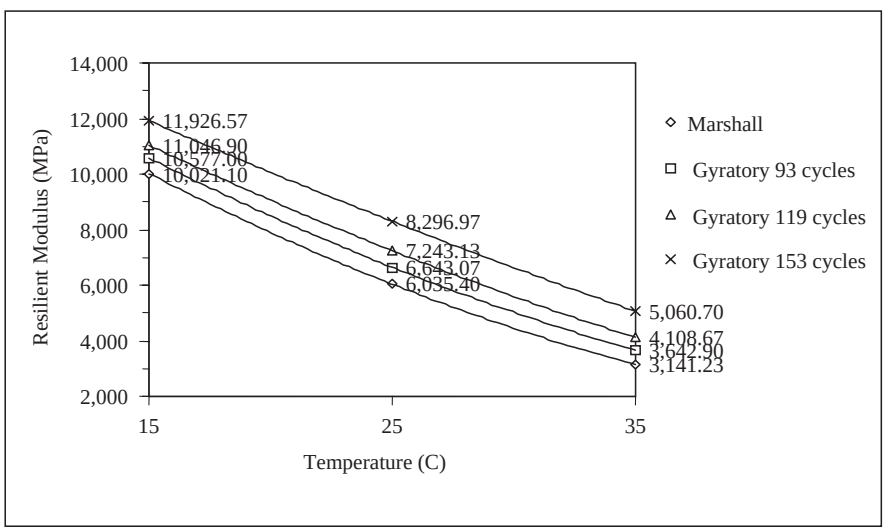

Figure 1 The relationship of resilient modulus of multigrade asphalt concrete using steel furnace slag aggregate.

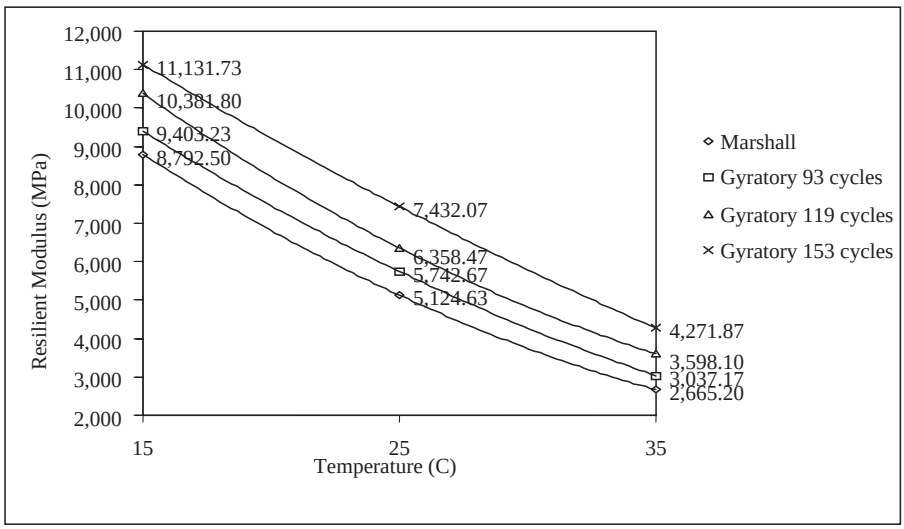

Figure 2 The relationship of resilient modulus of multigrade asphalt concrete using limestone aggregate.

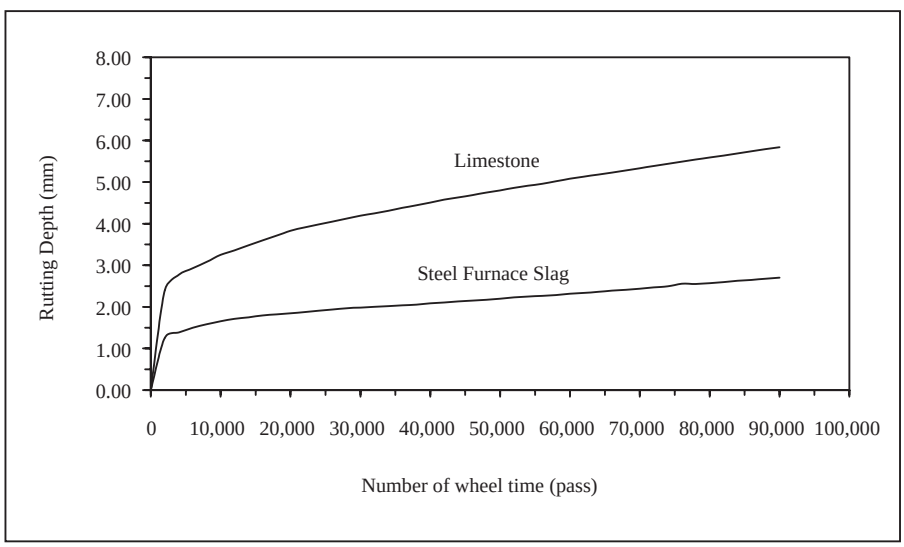

Figure 3 The relationship between the number of wheel times and wheel rutting depth of multigrade asphalt concrete.

2) The compaction of multigrade asphalt concrete by the marshall method and by gyratory compactor when considering 4% air void, using steel furnace slag aggregate had higher percentages of asphalt cement, stability, flow, stability / flow than using limestone aggregates i.e. 0.9 – 1.0%, 19.90 – 26.55%, 8.57 – 16.57% and 4.98 – 16.56%.

3) When testing the properties of multigrade asphalt concrete, steel furnace slag aggregate had a 3.5 – 5.3% greater strength index than using limestone aggregates. Also steel furnace slag aggregate had higher resilient modulus than

using limestone aggregates i.e. 13.97 – 17.86%, 12.48 – 19.94%, 6.41 – 14.19% and 7.14 – 18.47%.

4) The wheel rutting depth multigrade asphalt using limestone aggregate was greater than using steel furnace slag aggregate, and there was a higher rate of rutting.

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