Arūnas Juodžbalis
AB "Kauno tiltai", Lithuania

Vytautas Vilutis
SE "Problematika", Lithuania

Recycling of RA in hot batch mix plant

Earlier pavements were reconstructed, using hot recycling method or leveling layers, which were covered with surface dressing or wearing courses. However with the increase of heavy traffic we were not satisfied with applied before repair methods, because during years top layers became combined from various types of plastic mixes and rutting and waving occurred due to heavy traffic. So it was the demand to replace these layers with more stable and resistant mixes. When replacement of plastic layers started sufficient amounts of reclaimed asphalt concrete (RA) occurred. This pushed us to start recycling the stockpiled wastes. Research made in laboratory showed that all reclaimed asphalt can be recycled in one or another way. Our basic idea was that the recycled mix should comply with new mixture requirements. For hot recycling in the batch plant we defined minimum requirements for reclaimed asphalt. Briefly they are:

RA shall be granulated with max size 1.4D
Recovered binder shall be at least:
Penetration >25 mm^{-1}
Softening point < 65°C

These requirements for recovered old binder were put due to the reason that such bitumen can be still modified to meet minimum requirements of binder. If recovered binder do not meets these minimum requirements it should be recycled in other way. The manufacturing of such mixes forced us to put the requirements on homogeneity of RA in order to have controlled new mix production. These requirements depend on amount of RA used in the new mix.

The trials were done on motorway Vilnius –Kaunas. During reconstruction the base course from the mix 0/32 and binder course from the mix 0/22 were done, using RA in the mix. The amounts placed are:

2001 year – 156500 m^2 (21000tn)
2002 year – 264500 m^2 (35800tn)

Mixture design is made so, that the final mix and its constitutions complies with new mixture requirements. The tests were made with the various RA contents up to 45%. However with the increase of RA amounts the problems occurred:

The temperatures of virgin aggregates need to be very high and due to:

- We had thermal problems on hot sieves
- We had problems with heat stability of binder rejunovators
- The great amount of vapor, which is very difficult to take off
- Air filters were covered with the “greasy” covering

Diminish content is up to 25% problems practically disappeared.

Conclusions:

Reclaimed asphalt in granulated form can be fully recycled in batch mix plant in amount up to 25%.
However for successful use increases the requirement for RA preparation and storage.
Much more of laboratory works is needed for production and laying of good quality mix.
Earlier pavements were reconstructed, using hot recycling method or leveling layers, which were covered with surface dressing or wearing courses. However with the increase of heavy traffic we were not satisfied with applied before repair methods, because during years top layers became combined from various types of plastic mixes and rutting and waving occurred due to heavy traffic. So it was the demand to replace these layers with more stable and resistant mixes. When replacement of plastic layers started, sufficient amounts of reclaimed asphalt concrete (RA) occurred. This pushed us to start recycling the stockpiled wastes. Research made in laboratory showed that all reclaimed asphalt can be recycled in one or another way. Our basic idea was that the recycled mix should comply with new mixture requirements. For the time being we defined requirements for the possible amount of RA to be used in the mix:

20% - in the mixes for wearing courses
30% - in the mixes for base courses.
RA is not allowed to be used for mixes of SMA type.

Requirements for reclaimed asphalt:
Maximum particle size of reclaimed asphalt shall be ≤1.4D, where D equals to upper size of the recycled mix (this is the size of RA granulate before extraction) and the aggregate size after extraction shall be not larger than recycled mix size. For hot recycling in the batch plant we defined minimum requirements for reclaimed asphalt binder (look Table 1).

Table 1. Requirements for recovered bitumen

Indices	Any separate sample, n=1	Mean value of at least 5, n≥5
Penetration, mm-1, not less	25	30
softening point, °C, not more	65	60

These requirements for recovered old binder were put due to the reason that such bitumen can be still modified to meet minimum requirements of binder. If recovered binder do not meets these minimum requirements it should be recycled in other way. The binder shall not contain the tar. The manufacturing of such mixes forced us to put the requirements on homogeneity of RA in order to have controlled new mix production. These requirements depend on amount of RA used in the new mix and are showed in the

Table 2.

Table 2. Homogeneity of the RA

% passing sieve	Maximum standard deviation, n=5	
	Percentage of reclaimed asphalt in the mixture by weight	
	≤10	11-30
<11.2 mm % by weight [1)]	7.0	6.5
Particle <8 mm % by weight [2)]	6.0	5.5
Particle <5 mm % by weight [2)]	6.0	5.5
Particle <2 mm % by weight	5.0	4.5
Particle <0.09 mm % by weight	2.0	1.7
Bitumen quantity, % by weight	0.6	0.5
Bitumen penetration, mm^{-1}	7	5
Bitumen softening point, °C	4.0	3.0

1)is determined for use in mixtures of base courses
2)is determined for use in mixtures of wearing, base and binder courses

Mixture design

If RA comply mentioned requirements the mix design is made. At least 5 samples from different stockpile places are taken and one representative sample is prepared. The moisture content is determined and negotiated amount of possible to use in the mixture content of reclaimed asphalt is determined.

When amount of RA in the mixture is determined, the rejunovators for binder are designed. Depending on recovered from RA binder's properties the ways of restoring binders properties can be different. Anyway the mixture of old binder and the new one shall meet standard requirements for specific type of the mix. Normally we use or fluxing of old binder including adhesion promoters or using softer additional binder.

Then final grading, including new virgin aggregates is designed and final mixture design is done, taking into account the amount of old binder. Mixtures are designed by Marshal method. Typical binder courses requirements are in the

Table **3**

Table 3. Requirements underwear pavement layers asphalt concrete mixes

Mixture grade	0/22S-A	0/22-A	0/16S-A	0/16-A	0/11-A
1. Mineral materials	S grade aggregate, S grade crushed sand, natural sand, filler	aggregate, crushed sand, natural sand, filler	S grade aggregate, S grade crushed sand, natural sand, filler	aggregate, crushed sand, natural sand, filler	aggregate, crushed sand, natural sand, filler
0.09 mm, % by weight	3-9	3-9	3-9	3-9	3-9
>2 mm, % by weight	65-80	65-80	60-75	60-75	50-70
>8 mm, % by weight	-	-	-	-	≥20
>11.2 mm % by weight	-	-	≥20	≥20	≤10
>16 mm, % by weight	≥20	≥20	≤10	≤10	-
>22.4 mm, % by weight	≤10	≤10	-	-	-
Crushed and natural sand ratio	≥1:1	≥1:1 [1)]	≥1:1	≥1:1 [1)]	-
2. Binder					
Type and grade of binder	B 50/70 (B70/100) [2)]	B 50/70 (B70/100) [2)]	B 50/70 (B70/100) [2)]	B 50/70 (B70/100) [2)]	B 50/70 (B70/100) [2)]
Binders quantity [3)], % by weight	3.8-5.5	3.8-5.5	4.0-6.0	4.0-6.0	4.5-6.5
3. Mix					
Residual void content according to Marshal, % by volume:					
a) SV, I,II pavement type and III pavement type with extraordinary loading	5.0-7.0	5.0-7.0	4.0-7.0	4.0-7.0	
b) III, IV, V and VI pavement type		4.0-7.0		3.0-7.0	3.0-7.0
Stability according to Marshal, kN: [4)]					
a) SV, I,II pavement type and III pavement type with extraordinary loading:	≥ 8.0				
b) III, IV pavement type	≥ 7.0				
c) V, VI pavement type	≥ 6.0				
Marshal flow, mm:	2.0-4.0				
Marshal quotient, kN/mm: [4)]					
a) SV, I,II pavement type and III pavement type with extraordinary loading	≥ 2.2				
b) III, IV pavement type **:**	≥ 2.0				
c) V, VI pavement type	≥ 1.7				
4. Layers					
Layer thickness, cm	5.0-10.0	5.0-10.0	4.0-8.5	4.0-8.5	
mixture quantity, kg/m^2	120-250	120-250	95-210	95-210	-
Degree of compaction, %	≥97	≥97	≥97	≥97	≥96, when thickness ≥3 cm

[1)] valid for SV, I,II pavement type and III pavement type with extraordinary loading.
[2)] only in certain cases.
[3)] binding materials quantity specified over 100% of mineral materials.
[4)] valid only for mix design.

Production

The production of mix is done in the batch plant. The general view is in the Picture 1. Additionally to standard set the 10 m^3 feeding bin for RA is mounted. This bin with transportation belt and belt scales is feeding controlled amount of RA straight to the mixer; the cycle is in the same time as virgin aggregates are loaded.
Additionally the devaporing equipment is mounted, to take off the vapor from the mixer.
There are two possibilities to add the renjunovators and adhesion promoters:
Mix additives in the binder tank
Feed additives straight in the mixer with additional dozing equipment

Picture 2 AB "Kauno tiltai" asphalt plant.

As the temperature of RA shall be raised by taking off the heat from virgin aggregates, the temperature of aggregates is raised, depending on the percentage of RA used. The temperature is determined according the chart 1.
Additional temperature correction shall be made depending on moisture content of RA. The temperature correction is made as shown in the Table 4.
As the feeding to the mixer of damp RA is done by belt scale, for controlled dozing of RA the moisture content was tested more frequently. As the homogeneity of RA is always questionable the binder content and grading of RA after extraction was tested also more frequently to compare with conventional mix production.

Laying

The transportation and laying of mixture is the same as with conventional mixture and no any problems arise during laying and compaction.

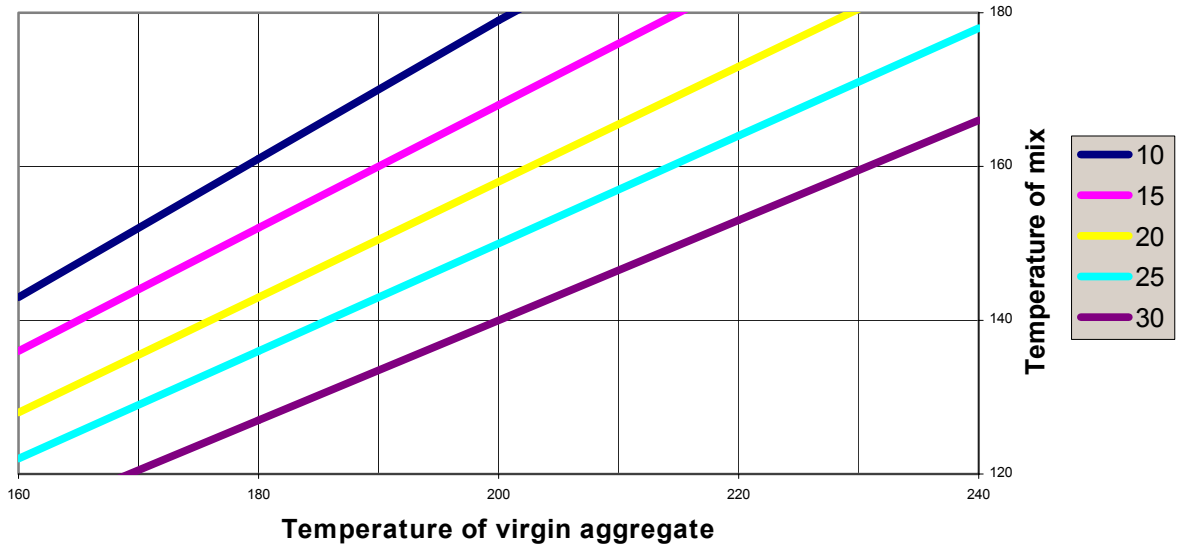

Chart 1. Chart for determining the temperature of virgin aggregates

Table 4. Temperature correction depending on moisture content

Quantity of RA in the mix % by weight	Moisture of reclaimed asphalt, % by weight					
	1	2	3	4	5	6
	Temperature correction °C					
10	4	8	12	16	20	24
15	6	12	18	24	30	36
20	8	16	24	32	40	48
25	10	20	30	40	50	60
30	12	24	-	-	-	-

Experience

The trials were done on motorway Vilnius -Kaunas. During reconstruction the base course from the mix 0/32 and binder course from the mix 0/22 were done, using RA in the mix. The amounts placed by AB "Kauno tiltai" are shown in
Table **5**:

Table 5. Production of RAC by AB "Kauno tiltai"

	0/32 C			0/22 A			Total		
	km	m2	tn	km	m2	tn	km	m2	tn
2001	10	37000	7500	10	119500	13500	10	156500	21000
2002	16.9	62500	12800	16.9	202000	23000	16.9	264500	35800
Total	26.9	99500	20300	**26.9**	321500	36500	26.9	421000	56800

Mixture design is made so, that the final mix and its constitutions comply with new mixture requirements. The RA homogeneity was slightly changing during production, but generally test results showed sufficient quality production. The test results are shown in **Table 6** and **Table 7**.

Table 6. Grading and binder content deviation of mixture

Mix 0/22- A 2001 y.

	0.09	0.25	0,71	2	5	8	11.2	16	22,4	Binder deviation
Average	6.35	10.96	19-13	26.97	35.13	44.27	56.33	71.46	96.45	-0.05
Maximum	7,34	12,66	22,42	29.74	40,75	52.44	63.79	78.19	100	0.26
minimum	5.67	9.96	17.62	23.4	30.95	39.76	49.3	65.33	93.3	-0.34

2002 y.

Average	6.45	13,21	21.88	29.06	38.36	47.6	57.14	74.78	97.16	0,09
Maximum	7,60	14.7	23.31	33	45,59	56.67	64.11	78.98	98.9	0.59
minimum	5.23	11.27	19.65	25.96	34.6	43.55	52.8	69.37	95-3	-0,23

Table 7. Physical mechanical properties

0/22-A 2001 y,

	Marshal stability, kN	Flow, mm	Void content, %	Average density	Max. density
Average	12.66	3.7	4.2	2.476	2.583
Maximum	15.4	4	4.9	2.493	2.612
minimum	10,7	3,3	3.4	2.444	2.558

0/22-A 2002 y.

Average	13	3.7	4.7	2.478	2.6
Maximum	14,1	4	5.3	2.49	2.618
minimum	11,2	3.3	4.1	2.463	2.584

Very close results the deviations are for mix 0/32.

The tests were made with the various RA contents up to 45%. However with the increase of RA amounts the problems occurred:

The temperatures of virgin aggregates need to be very high and due to:

- We had thermal problems on hot sieves
- We had problems with heat stability of binder rejunovators
- The great amount of vapor, which is very difficult to take off
- Air filters were covered with the "greasy" covering Diminish content is up to 25% problems practically disappeared.

Conclusions:

Reclaimed asphalt in granulated form can be fully recycled in batch mix plant in amount up to 25%.

However for successful use increases the requirement for RA preparation and storage.

Much more of laboratory works is needed for production and laying of good quality mix.