A NEW METHOD FOR HOT RECYCLING OF ASPHALT

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ABSTRACT

Although asphalt recycling started many years ago, recycling is recently becoming more popular due to the savings that can be obtained. The most commonly used hot recycling methods, like 'parallel-drum-dryer-system' and 'system-with-RAP-feeding-to- the-middle-of-aggregate-dryer' have a few practical disadvantages, like the high temperature of the direct heat the RAP is exposed to. That's why a new method was developed to eliminate these disadvantages.

In the New System: RAP is indirectly heated by hot air which streams trough separate channels. Instead of a drum, specially designed units were built. After homogenising the heated RAP and chemical-additives in the New System's primary-mixer, the mixture is transferred to the asphalt-plant-mixer. Due to the presence of this primary-mixer, the plant capacity is increased because there is no need to increase the mixing duration in the asphalt plant-mixer itself to achieve the required homogeneity. RAP will not be segregated due to the presence of pallets used in the heating-drying channel. In this system it is possible to produce asphalt base course mixture that consists of 100% RAP. To achieve this, RAP that is going to be used need to have the right grading by sieving and crushing. RAP goes through the system will be heated to the required process temperature and the mixture is homogenized with the added bitumen and chemical-additives in the primary-mixer.70% recycling can be obtained for Binder course mixtures. RAP also can be used for Surface course mixtures. Tests have shown that the obtained quality of the asphalt produced in this New System meets the requirements.

Keywords: Recycling, recycled asphalt concrete (RAC), reclaimed asphalt pavement (RAP), bitumen, recycling method

1. INTRODUCTION

1.1. Sustainability and the Economic Value of Recycling

Consumption of approximately 1,52 billion tons of virgin aggregate and 80 million tons of bitumen for the production of 1,6 billion tons of asphalt [1] [2] around the world reveals the importance of sustainable environmental approach in terms of environmental effects and natural resource consumption sufficiently. Spreading of asphalt recycling has a potential of creating approximately 1 billion $/year [1] economical value world-wide. This will be possible with applying correct processes to recycle RAP, not to waste it and using efficient and effective techniques. In this way, resulting environmental effects and natural resource consumption for asphalt production processes will minimize.

1.2. Conventional Recycling Methods

Quite a few different methods are being used for asphalt recycling

According to ARRA [4]:

- Hot In-Place Recycling
- Cold In-Place Recycling
- Full Depth Reclamation
- Hot Recycling
  - Integrated in the Asphalt Plant
    - Hot-feeding method to the mixer after RAP is heated and not passed through the sieve for the RAP fed to the asphalt plant dryer from cold silos (Figure 1)
    - Hot-feeding method to the mixer after heating the RAP in a second dryer which is parallel to the Asphalt Plant dryer (Figure 2)
  - Independent from Asphalt Plant
    - Hot recycling method with heating and mixing RAP, additional bitumen and virgin aggregate in a drum mixer (Figure 3)
    - Hot recycling method after heating RAP in a parallel dryer and additional virgin aggregate in another dryer, transferring them to the mixer and adding the additional bitumen (Figure 4).

Since the subject of this paper is Hot Recycling it will only deal with this recycling method.

Before using the RAP, the quality of the RAP has to be determined to be sure that the RAP has the right quality. When the quality of RAP increases, the rate of the recycling can be increased simultaneously. If the RAP does not have the appropriate quality it has to be pre-processed in order to bring the RAP to the right quality level and this will result increased recycling cost. So the Hot Recycling process starts with determining the quality of RAP.

After having tested the RAP to be used (gradation, aggregate type, bitumen content and bitumen properties), the (possible) need for chemical additives to recover the aged bitumen can be determined. Only in this way the optimal use of RAP in the recycling process can be optimised. Next to this it is also important to know the amount/percentage of RAP that is going to be re-used and the type of recycling process that will follow.

Major conventional Hot Recycling processes are shown below.

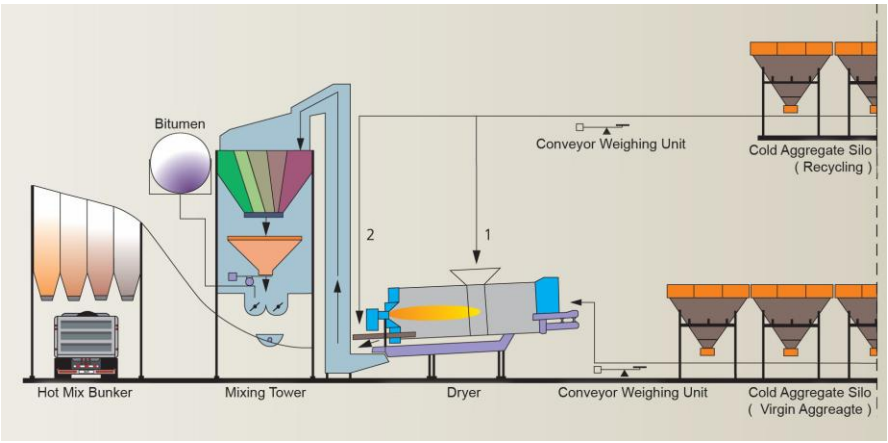

Figure 1: Hot-feeding method to the mixer after RAP is heated and not passed through the sieve for the RAP fed to the asphalt plant dryer or to the dryer exit from cold silos

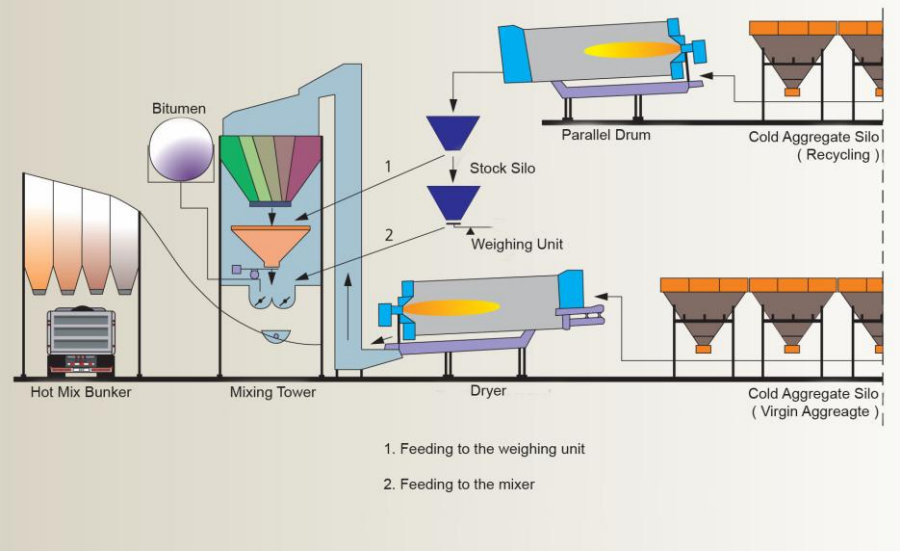

Figure 2: Hot-feeding method to the mixer after heating the RAP in a second dryer which is parallel to the Asphalt Plant dryer

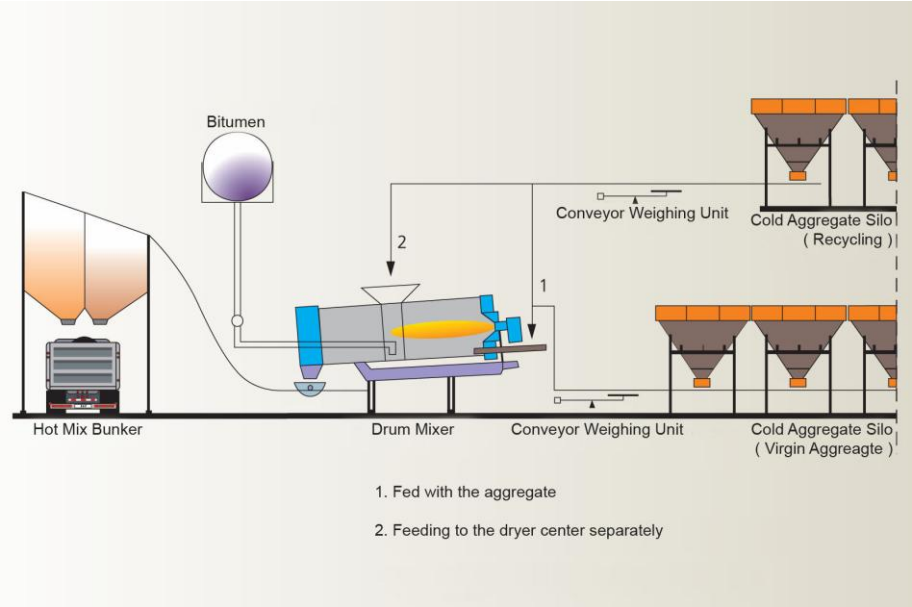

Figure 3: Hot recycling method with heating and mixing RAP, adding bitumen and virgin aggregate in a drum mixer

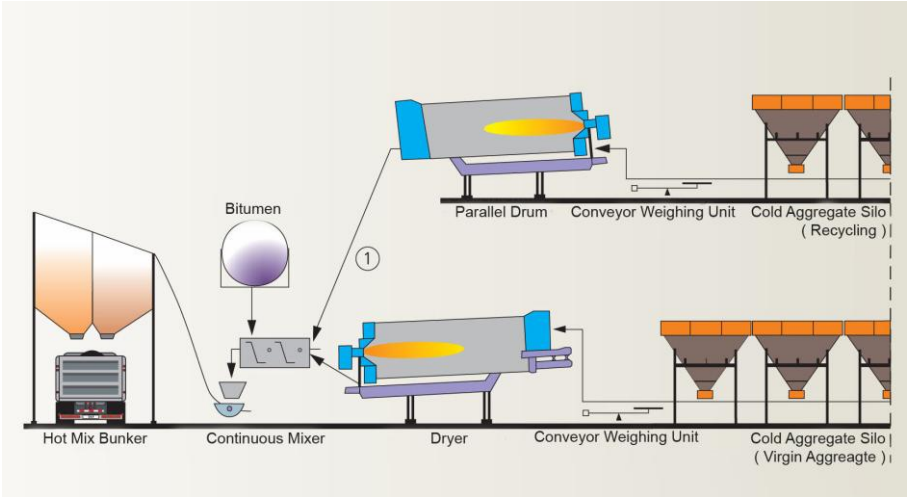

Figure 4: Hot recycling method after heating RAP in a parallel dryer and additional virgin aggregate in another dryer, transferring them to the mixer and adding the additional bitumen

Although 50% recycling rate is mentioned (in theory) for some of the above-mentioned conventional methods, difficulties originated from these methods may prevent effective and efficient recycling [5]. No matter how good the RAP qualities are, it will often not be possible to recycle at this percentage because of the disadvantages of these methods.
These disadvantages are [5]:

1. **High temperature deteriorates quality of bitumen and decrease in quality of Recycled Asphalt Concrete (RAC):** RAP is exposed to direct temperature of 650-750ºC in a parallel dryer or asphalt plant dryer to dry RAP and bring the temperature min. 100-130ºC. As a result, the quality of the bitumen in the RAP deteriorates.
2. **Resulting flue gas emissions exceeds the limits:** Emissions (CO, SO2, NOx,TOC etc.) exceed the permitted legal limits during heating and drying of the RAP in the asphalt plant or parallel dryer by exposing it to the temperature of 650-750°C.
3. **Resulting usage difficulties with the increased stickiness of the RAP:** Due to the bitumen in the RAP, the RAP becomes sticky as the temperature of the RAP increases in the asphalt plant dryer or parallel dryer. The RAP will stick both to the dryer wings and dryer surfaces when it travels through the system and it will clog the system and decrease the efficiency.
4. **Necessity of using more anti-aging agents:** Necessary additives to improve the deteriorated qualities of the RAP due to the aging of the bitumen of RAP are added in the asphalt plant mixer for the entire mixture (including RAP) and this increases the amount of additives usage and the recycling cost.

The New System which is the subject of this paper will eliminate the disadvantages of the conventional recycling methods. The working principle of this system as well as the obtained results will be explained below in detail.

2. HEATING OF THE RAP

The different units that are used in the New System are described in detail in the next paragraphs.

2.1. RAP Feed

The RAP is fed into the system in the same way as it is normally fed into the asphalt plant silos. RAP which had the necessary pre-processing (crushing and sieving) and which is in the storage silos, is fed to conveyor belts by controlling its speed and flaw. Then, RAP is transferred to the vertical elevator's buckets (with conveyor belts) and from buckets it is transferred to the so called "Palletized Triangular Recycling Dryer" (Figures 5 and 10 (for the general overview))

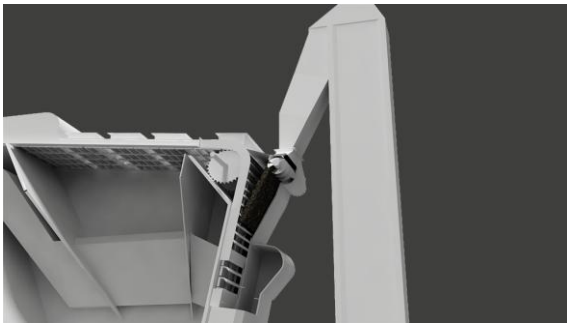

Figure 5: RAP feed into the "Palletized Triangular Recycling Dryer" of the New System

2.2. Heat Generator

The hot air that is used to bring the RAP to the desired process temperature is obtained from a heat generator. The heat generator consists of a combustion space where desired hot air mixture is obtained with the appropriate size of burner. The combustion chamber is built with fire bricks. The released air from the burner which has a temperature of 600-650 ºC is mixed with a controlled amount of cold air through the special structure of the heat generator. After the air temperature is reduced to approximately 400-450ºC (Figure 6), this hot air is fed into the circulation channels of the "Palletised Triangular Recycling Dryer".

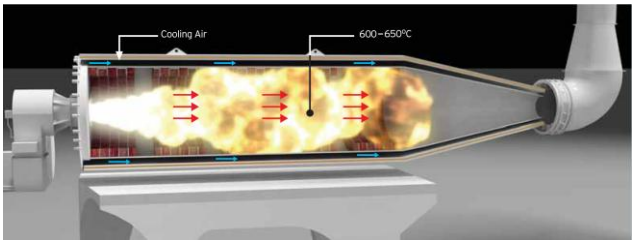

Figure 6: New System Heat Generator

2.3. Palletized Triangular Recycling Dryer

A spiral conveyor, which is at the highest point of the Palletized Triangular Recycling Dryer, is spreading the RAP (coming from the vertical elevator) slowly between the dryer's driving plates. Figure 5

2.3.1. Hot Air Circulation Channels

The temperature, flow rate, speed and pressure of the circulating air in the channels can be controlled automatically. The RAP is brought to the desired process temperature by circulating air which is around 400-450ºC in the channels. When hot air completes its circulation in the channels, the temperature has dropped under 180ºC and when it reaches to filter, its temperature is 90-95ºC. The RAP is indirectly heated through the hot surfaces of the channel and the driving plate surfaces which have been heated with the hot air in the channel (Figure 7). The total amount of heat is controlled to meet the necessary total heat requirement for the RAP.

The heat transfer surface area in the New System's Palletized Triangular Recycling Dryer is 3 times more than the one in the asphalt plant dryer. As the temperature of the hot air used is approximately 200ºC less than the conventional hot recycling methods (where the RAP can be exposed to temperatures of 600-650ºC) the quality of bitumen in the RAP is "protected" and the emissions occur during the process are kept within the permitted limit.

Figure 7: Hot air Channels of the New System (shown in yellow/red)

2.3.2. RAP driving plates

Due to special structure of the RAP driving plates, the RAP which is stored between these plates is circulated by rotating with a controllable speed without sticking to driving plates or the channel's surfaces and without segregation. The form of the driving plates and their arrangement in the channels has been designed in such a way that the RAP between them does not stick to the channels and driving plate surfaces. The RAP is heated in an indirect way by the hot circulating air. The speed of the driving plates can be controlled and in this way the RAP has the desired temperature at the end of its circulation.

2.4. Hot RAP Bunker

The RAP that has been heated in the RAP channel goes to hot RAP storage bin when it has reached its desired temperature (120-130°C) at the end of circulation line. When it is stored in the bin, it will maintain warm. The resulting gas and dust together with hot air that circulated in the recycling dryer are left to the atmosphere after passing thorough asphalt plant filter system. Figure 8

Figure 8: Hot RAP Bunker of the New System

3. RAP PRIMARY MIXER

In the New System, the hot RAP can be used in two different ways. It can be used in combination with virgin material, but it can also be used as 100% recycled material.

3.1. RAP recycling in the asphalt plant in combination with virgin material

This procedure can be used for the production of asphalt that is going to be used for Surface and Binder courses. In this case the New System works in parallel with the asphalt plant. The RAP to be added to the new mixture can be pre-mixed with additives and/or bitumen before it is send to the mixing unit of the asphalt plant. The recycling rate used will depend on the quality of the RAP and/or the requirements of the new mixture. Figure 9

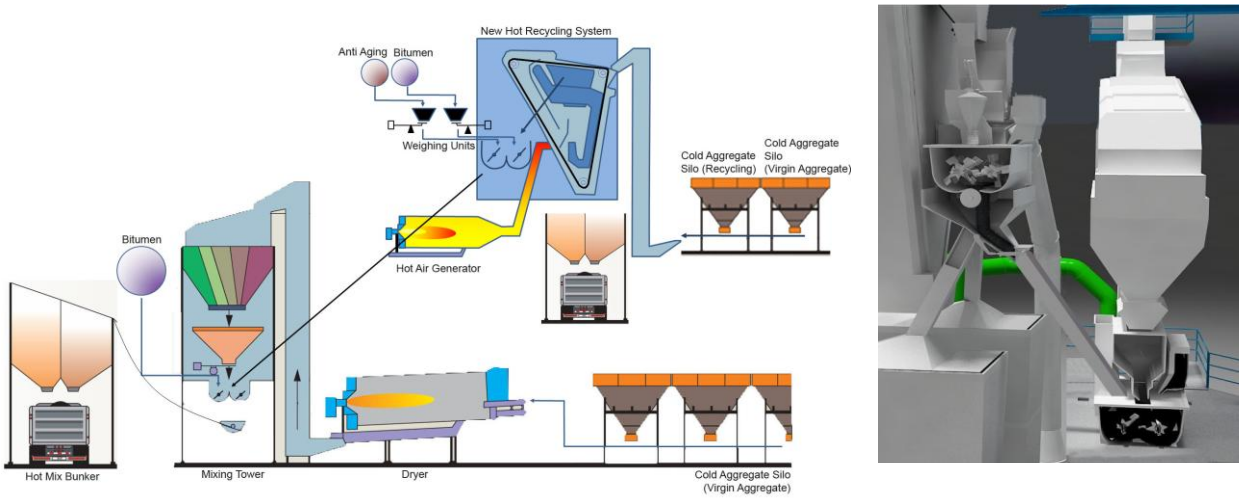

Figure 9: Hot recycling of RAP to be used for Binder and Surface courses with the New System

3.2. RAP production independent of the asphalt-plant; 100% recycling

This procedure can be used for the production of asphalt mixtures for base course layers. In this case the New System works independently from the asphalt plant and the asphalt mixture production is now based on 100% recycling (Figure 10). At the same time the asphalt production in the asphalt plant itself can continue.

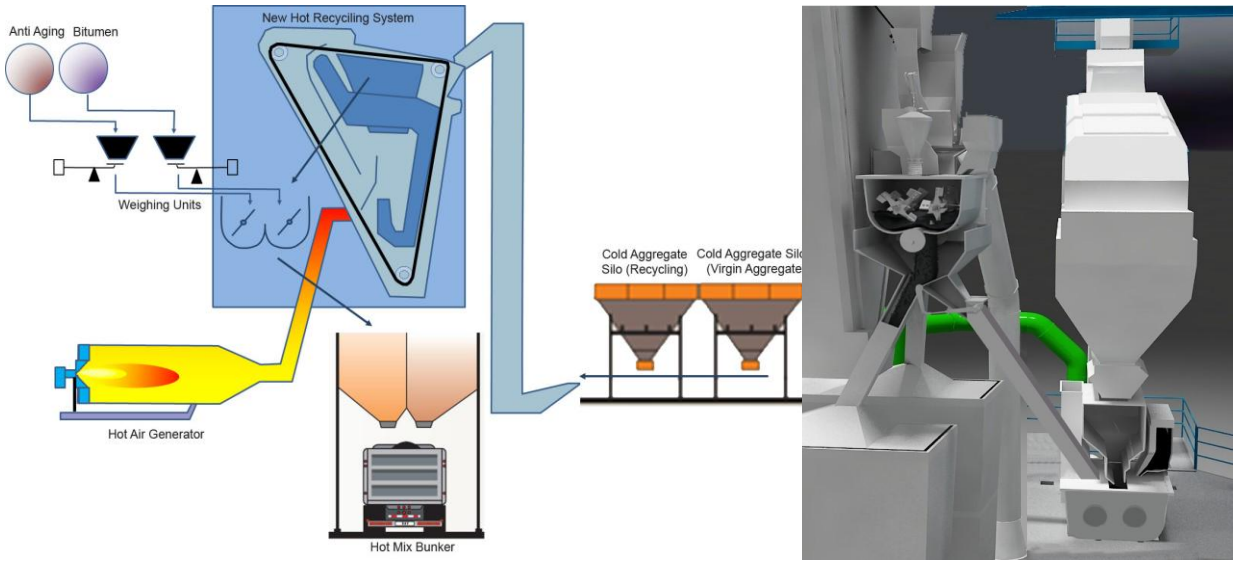

Figure 10: Hot recycling of RAP to be used as base course material with the New System

4. MIXING PROCESS

4.1. Weighing Unit Prior to Mixing

The RAP which is in the storage bin (with a temperature of 120-130°C) is transferred to primary mixer by controlling the weight for pre-mixing.

4.2. Chemical Additives

During the pre-mixing process of RAP, additives can be added to get the target composition. During the pre-mixing process, different types of additives and/or bitumen can be added according to the needs. The additives can be added with a dosing pump or by using load cells and weight control. Because of this pre-mixing process there is no need for an extension of mixing duration in the asphalt plant mixer and it does not reduce the asphalt production capacity.

4.3. Control of the new additional bitumen

In the case of producing 100% recycled material the targeted amount of additional bitumen is added to pre-mixing process in the primary mixer by a bitumen weighing unit.

4.4. Mixing Duration

4.4.2. For the asphalt production with partial recycling, the bitumen and virgin aggregate are mixed in the asphalt plant mixer with the RAP and other additives that were pre-mixed in the New System primary-mixer. Due to the pre-mixing in the New System, the mixing duration in the asphalt plant does not extend and the capacity of the plant is used efficiently.

4.4.3. In case of 100% recycling the asphalt production in the asphalt plant itself can continue. In this way, the overall production capacity of the facility increases.

4.5. Virgin Aggregate Addition

To be able to achieve the target grading of the asphalt mixture, there might be a need to add virgin material to the RAP. This procedure does not differ from conventional asphalt plants that are fit for recycling.

4.6. Capacity of the New System

The New System can be designed for different asphalt production capacities. As in a conventional asphalt plant the production depends on external conditions, terms of use and the qualities of RAP to be used.

5. TRIAL PRODUCTIONS WITH THE NEW SYSTEM

Trial production results are shown below to show how the problems with conventional methods have been eliminated through the New System.

The concept of the New System has been developed in 6 years. It started in 2005 and the first version was completed in 2007. The second version was finalised in 2011. Under real working conditions and by using 40 ton RAP material, 120 ton RAC was produced by the New System integrated to an existing asphalt plant.

In order to obtain valid statistical data through sufficient number of RAC production trials, the New System's conformity to required standards, performance under working conditions, strength, safety, compatibility to required user and working conditions as well as environmental impacts has been tested and validated.

The methodology of production, testing and experimentation used during production trials has been according to "EN 13108-8 Bituminous mixtures material specification Part 8 Reclaimed Asphalt" and other related standards for aggregate and asphalt concrete. Since specified standards require that ranges between the measured results of softening point, bitumen content and particle fraction for samples taken from each RAP material cannot exceed T_{perm} max values given below; RAP materials which can meet these criteria are used during the trial productions [2]. The moisture content of the RAP material used for the trial productions was maximum 3 % .Table 1

Depending on the quality of RAP to be used, the production input target compositions which will include additional bitumen and virgin aggregate to be added, have been prepared for RAC trial productions.

RAP is the most important input to be used in hot recycling trial productions. The number of samples to represent each party of RAP is according to "EN 932 - Test for general properties of aggregates - Part2 Part1". Sample properties are described with the example shown below. Table 2

Table 1: Overall tolerances T_{perm} of relevant characteristics as a function of asphalt mixture type

Range Tperm	Softening Point $T_{R\&B}$	Bitumen Content	Particle Fraction		
			<0,063 mm	Between 0,063 and 2mm	≥ 2 mm
	EN 1427	EN 12697-1	EN 12697-2		
	^0C	*[M.-%]*	*[M.-%]*	*[M.-%]*	*[M.-%]*
SURFACE and BINDER COURSES	8,0	1	6,0	16,0	16,0
BITUMEN BASE	8,0	1,2	10,0	16,0	18,0

Table 2: The characteristics of RAP which is suitable for addition to Bitumen Base and Binder mixtures

Sample	Softening Point	Bitumen Content	Particle fraction		
			<0,063 mm	Between 0,063 and 2mm	≥ 2 mm
	EN 1427	EN 12697-1	EN 12697-2		
	^{0}C	[M.-%]	[M.-%]	[M.-%]	[M.-%]
1	67,6	4,1	6,9	32,1	61
2	65,0	4,3	10,2	28,9	60,9
3	63,8	4,4	8,8	20,4	70,8
4	67,0	3,9	7,2	21,9	70,9
5	65,4	4,7	10,8	26,7	62,5
Mean Value	**65,8**	**4,2**	**8,8**	**26,0**	**65,2**
Max.	**67,6**	**4,7**	**10,8**	**32,1**	**70,9**
Min.	**63,8**	**3,9**	**6,9**	**20,4**	**60,9**
Range	**3,8**	**0,8**	**3,9**	**11,7**	**10,0**

Recycling rate curve has been prepared by using the formula given below for Bitumen Base, Binder and Surface courses to evaluate the permitted ranges separately for each RAP qualities specified in Table 2 and depending on these recycling in which rate can be decided [2]. Measurement results are marked on curves and according to these results that intersect at the peak point of the curve, for Binder course 50% of RAP and for Bitumen Base 70% of RAP material usage has been determined. Figures 6 and 7

For Bitumen Base course: $Z_{poss} = \frac{0{,}5 \times T_{perm}}{\alpha_{\max}} 100$; For Surface and Binder courses: $Z_{poss} = \frac{0{,}33 \times T_{perm}}{\alpha_{\max}} 100$

Where;

Zposs: Maximum possible reclaimed asphalt addition amount in M.-%

$\alpha_{\max}$: Maximum permissible range of corresponding characteristic

T_{perm}: Permissible overall tolerance of the characteristic in accordance with ZTV Asphalt-StB 07

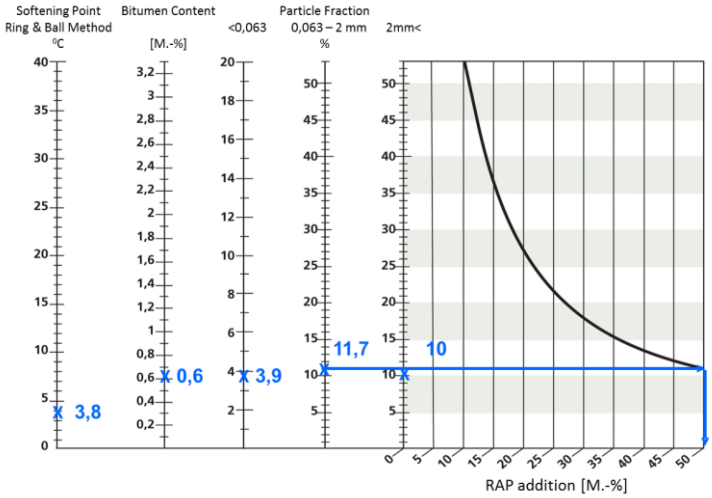

Figure 11: For determining the maximum possible RAP addition amount for binder course mixture with reference to the homogeneity of the RAP characteristics

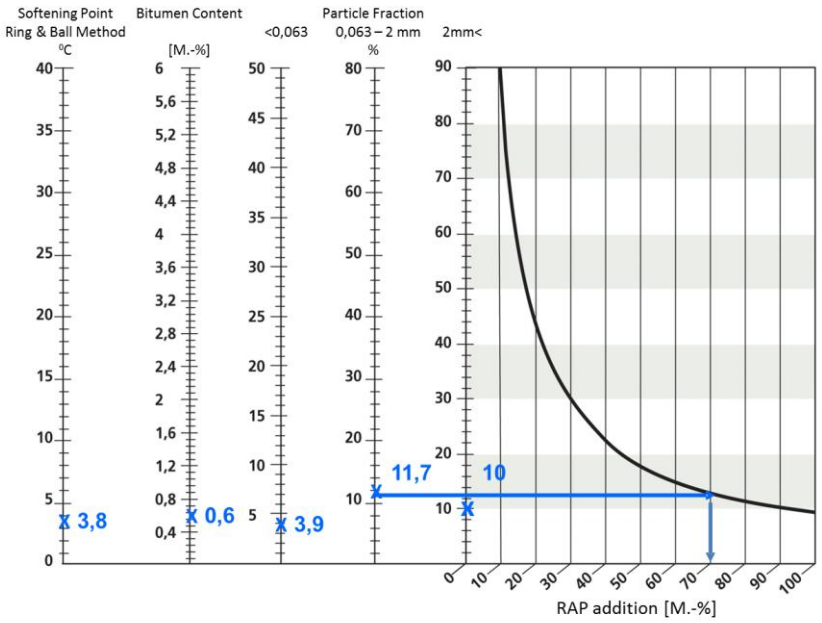

Figure 12: For determining the maximum possible RAP addition amount for bitumen base mixture with reference to the homogeneity of the RAP characteristics

Therefore, during RAC trial productions, RAP usage rates in the new mixture according to RAP qualities in this particular sample have been determined as 50% for Binder course and 70% for Bitumen Base course. Frankly, different rates may be determined according to the obtained measurement results and their ranges for the samples taken from a different RAP batch.

After making sure that determined results are within the permitted limits, the input target composition will be prepared via ANSI/ASTM D 5581-96 (2001), ANSI/ASTM D 6927-05e1, ANSI/ASTM D 6926-04 Marshall Methodology for the particular RAP batch. Input target composition components for trial productions are determined as mentioned below in Table 3.

Table 3: Input target composition components table for Binder course trial productions

RAP INPUT TARGET COMPOSITION COMPONENTS	RAP			ADDITION			TOTAL	
	Kg	%		Kg	%		Kg	%
AGGREGATE	1.199,6	100%	50,4%	1.180,4	100%	49,6%	2.380,0	100%
BITUMEN	50,4	4,2%	42,0%	69,6	5,9%	58,0%	120,0	4,8%
TOTAL	1.250,0		50,0%	1.250,0		50,0%	2.500,0	

Table 4: Input target composition components table for Bitumen Base course trial productions

BITUMEN BASE INPUT TARGET COMPOSITION COMPONENTS	RAP			ADDITION			TOTAL	
	Kg	%		Kg	%		Kg	%
AGGREGATE	1.679,5	100%	70,0%	720,5	100%	30,0%	2.400,0	100%
BITUMEN	70,5	4,2%	70,5%	29,5	4,1%	29,5%	100,0	4,0%
TOTAL	1.750,0		70,0%	750,0		30,0%	2.500,0	

Within the New System, paving grade bitumen for the trial productions has been used with %50 RAP by using partial recycling for Binder course and 70% RAP used for Bitumen Base course by using the 100% recycling system. As mentioned in "EN 13108-1 Bituminous mixtures – material specifications Part 1 Asphalt Concrete - Attachment A", penetration and softening point of the bitumen in the RAP and included in the new mixture has to be checked for the conformity of determined recycling rate. Input target composition conformity which is prepared with the mixture rates determined with given formula in the standard is controlled as it is explained in the example below. Recycling of

bitumen in RAP is accomplished according to "EN 12697-3 Bituminous mixtures - Test methods for hot mix asphalt - Part 3".

Penetration calculation of the bitumen in RAC:

$$a \lg pen1 + b \lg pen2 = (a+b) \lg pen_{mix}$$

pen $_{mix}$: calculated penetration of the binder in the mixture containing reclaimed asphalt;
pen1: penetration of the binder recovered from the reclaimed asphalt;
pen2: penetration of the added binder;
a and b: portions by mass of the binder from the reclaimed asphalt (a) and from the added binder (b) in the mixture; $a + b = 1$.

Softening-point calculation of the bitumen in RAC:

$$T_{R\&B}\ mix = a \times T_{R\&B}\ 1 + b \times T_{R\&B}\ 2$$

$T_{R\&B}$ mix : calculated softening point of the binder in the mixture containing reclaimed asphalt;
$T_{R\&B}$ 1 : softening point of the binder recovered from the reclaimed asphalt;
$T_{R\&B}$ 2 : softening point of the added binder;
a and b : portions by mass of binder from the reclaimed asphalt (a) and from the added binder (b) in the mixture ; $a + b = 1$.

Conformity of bitumen penetration and softening point where Binder and Surface courses include 50 % RAP and Bitumen Base course includes 70% RAP has been determined with the formula mentioned above. According to the calculation results, RAC production has become possible within the indicated mixture rates given in the tables 3 and 4.

Table 5: Penetration and softening point control of the bitumen of a mixture when 50% RAP is used for binder course

EXPERIMENT		Bitumen in RAP	Bitumen that will be added to mixture	Rates in RAC		LOG Mixture Rate	Total percentage of bitumen in the mixture	ACCAPTANCE RANGE		Result
				RAP%	Bitumen%					
			B 50/70	0,42	0,58					
PENETRATION	**EN 1426**	22,0	60,0	9,2	34,8	1,5951	**39**	**50,0**	**70,0**	**REFUSAL**
SOFTENING POINT	**EN 1427**	66,4	47,0	27,9	27,3	-	**55**	**46,0**	**54,0**	**REFUSAL**
With 6% Anti-aging additive										
PENETRATION	**EN 1426**	50,0	60,0	21,0	34,8	1,7449	**56**	**50,0**	**70,0**	**OK**
SOFTENING POINT	**EN 1427**	53,0	47,0	22,3	27,3	-	**50**	**46,0**	**54,0**	**OK**

Table 6: Penetration and softening point control of the bitumen of a mixture when 70% RAP is used for base course

EXPERIMENT		Bitumen in RAP	Bitumen that will be added to mixture	Rates in RAC		LOG Mixture Ratio	Total percentage of bitumen in the mixture	ACCAPTANCE RANGE		Result
				RAP%	Bitumen%					
			B 50/70	0,705	0,295					
PENETRATION	**EN 1426**	22,0	60,0	9,2	34,8	1,4710	**30**	**50,0**	**70,0**	**REFUSAL**
SOFTENING POINT	**EN 1427**	66,4	47,0	27,9	27,3	-	**61**	**46,0**	**54,0**	**REFUSAL**
With 5% Anti-aging additive										
PENETRATION	**EN 1426**	48,0	60,0	20,2	34,8	1,7098	**51**	**50,0**	**70,0**	**OK**
SOFTENING POINT	**EN 1427**	55,0	47,0	23,1	27,3	-	**53**	**46,0**	**54,0**	**OK**

RAC production to be used as Binder course with 50% RAP in the New System by following the partial recycling;

RAP has been taken into the circulation in the system, heated up to 120-130 ºC and kept subject to pre-mixing in the New System's mixer in 1.250 kg batches with 6 % anti-aging. Then it has been added to 1.180,4 kg of dry mixture in the asphalt plant mixer. By homogenizing with 5,9 % bitumen added to dry mixture in the asphalt plant mixer, RAC production has been carried out.

RAC production to be used as Bitumen Base course with 70% RAP in the New System by following the 100% recycling;

RAP has been taken into the circulation in the system, heated up to 120-130°C and subjected to pre-mixing in the New System's mixer in 1.750 kg batches. Asphalt plant mixer hasn't been used. To obtain targeted particle fraction for Bitumen Base course, 29,5 % of additional virgin aggregate which the gradation determined with input target composition from New System's cold silos loaded to New System by adding to 70,5 % of RAP. Mixture of RAP and additional virgin aggregate have been homogenized by circulating in New System and reached to process temperature. RAC production has been carried out by adding and homogenizing 4,1% of bitumen and 5% of anti-aging during mixing in New System's primary mixer. Figure 4

6. RESULTS OF THE NEW SYSTEM

6.1. RAC Production Results

RAC samples that will be used as Binder and Bitumen Base courses and have been produced as mentioned above were prepared according to "EN 13108-20 Bituminous mixtures - Material specifications - Part 20 Appendix C" and kept subject to laboratory verification.

Table 7: Measurement Results to determine the qualities of RAC produced for Binder and Bitumen Base courses

DESIGN CRITERIA			BINDER		BITUMEN BASE	
RAP Usage Rate		%	50		70	
Bitumen added to mixture in the Asphalt Plant		%	5,7		-	
Bitumen added to mixture in the New System		%	-		3,6	
			Min.	Max.	Min.	Max.
Amount of Bitumen	EN 12697-1	%	4,6	5,1	3,9	4,2
Stability	EN 12697-34	kN	1.140	1.210	1.090	1.140
Flow Value	EN 12697-34	mm	2,6	3,9	2,1	3,8
Voids filled with bitumen	EN 12697-8	%	57	66	63	72
Voids	EN 12697-8	%	4,4	5,3	5,0	6,4
Voids between aggregates	EN 12697-8	%	13,6	14,4	12,2	14,5

Tests specified in "EN 13108-20 Bituminous Mixtures – Material Specifications – Part 20: Type Testing" standard and other related standards have been applied to these samples and obtained results have been categorized as shown below. Table 7

Trial production results mentioned above show that hot recycling can be achieved successfully with the specified process of the New System.

6.2. Flue Gas Emission Measurement Results

As described above, RAC which is obtained with trial productions performed to ensure sufficient statistical confidence has been checked against the compliance of related product standards and resulting environmental effects. [5] Resulting flue gas emissions with this new recycling process have been measured by using current international methods. Table 8

During trial productions in which natural gas has been used as fuel, hot recycling has been carried out by using both ways in both asphalt plant mixer and New System primary mixer. Permitted emission limits for industrial facilities determined with law and regulations vary from country to country [5]. For this reason, measured results have been given in the table directly without comparing with limits. Table 8

Table 8: Emission Measurement Results

			Asphalt Production in normal conditions		Hot Recycling Asphalt Production with the New System	
			Ave.	Max.	Ave.	Max.
Dust Concentration	ISO 9096 EN 13284	mg/Nm³	2,08	2,51	3,12	3,77
CO Concentration	ISO 12039	mg/Nm³	158,75	178,75	349,25	393,25
CO_2 Concentration			1,04	0,85		
SO_2 Concentration	ISO 7935	mg/Nm³	< 2,86*	< 2,86*	< 2,86*	< 2,86*
NOx Concentration	US EPA CTM 022	PPM	1,33	2,0	1,29	2,3
Total Organic Carbon Concentration	EN 12619	mg/Nm³	16	24	38	48

7. CONCLUSIONS

Based on the experience gained with the New System the following conclusions can be drawn:

- The disadvantages of the conventional recycling methods have been eliminated with the New System and higher recycling rates have been achieved. The possible recycling rates only depend on the RAP quality to be recycled.
- With the process of the New System, RAP is not subjected to direct flame contact and it is heated indirectly with hot air. In this way the RAP can easily reach the required process temperature and also emissions caused by gas and vapour released from the process have been minimized.
- With the New System, hot recycling of asphalt could be achieved efficiently and effectively. The recycling qualities of RAP should be protected during removal, transportation and storage. As RAP quality increases, recycling rate will increase as well. At the same time, required pre-treatment costs to bring RAP's deteriorated qualities to an appropriate level will be minimized.
- The amount of consumed energy during hot recycling process for Bitumen Base course was decreased by 20% with the New System.
- With the patented structure of the New System, RAP which is brought to the process temperature has been circulated between driving plates without sticking, segregating and decreasing in efficiency.
- The New System presents two different recycling methods according to user needs. Particularly for Bitumen Base course mixtures during RAC production, hot recycling could be obtained with the New System independent of an asphalt plant. Total amount of production equals to both the capacity of the asphalt plant and the New System. It can be obtained simultaneously.
- During the production of Binder and Surface course mixtures, loss of asphalt plant production capacity could be prevented during the RAC production. Because there is no need to increase mixing duration of the mixture together with RAP in the asphalt plant mixer through the pre-mixing carried out in the New System's primary mixer.

8. REFERENCES

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