- Final Paper –

Continuous asphalt production without waste – An illusion?

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Authors:
Biedermann, Andreas; Dr., Technology and Knowledge Management
Didier, Jean-Luc; Head of Sales Middle Europe

Main author:
Biedermann, Andreas
Ammann Construction Equipement
Eisenbahnstrasse 25
4901 Langenthal
Switzerland

mobile & fax +41 79 874 84 20
andreas.biedermann@ammann-group.com

Abstract:

Asphalt can be produced either in a continuous or batch-oriented process. Depending on the market demand like size of construction sites, variety in production process and requested performance of the final product, either one of these two processes is applied. While the batch-oriented production process is clearly dominated by twin-shaft paddle mixing, the continuous asphalt production is traditionally done using so called drum mixers. Recent successes in the development of a continuous asphalt production using a twin-shaft paddle mixer instead of a free-fall drum mixer promise a resolution to different drawbacks of the continuous asphalt production as known today.

One main drawback of the traditional continuous asphalt production using drum mixers is the waste of aggregates generated when changing the recipe of the produced asphalt. The same effect happens during each start-up and shutdown of the asphalt production process, for example due to delayed trucks. This waste is due to a segregation of the aggregates which is caused by the varying resilient times of different grain sizes in the drying drum.

Combining the drying drum with a continuous twin-shaft paddle mixer allows the compensation of these segregation effects. Using measurement and control technology, the compensation can be controlled in such a way that the waste of aggregates of asphalt generated can be minimized or even eliminated. Several plant installations of this new technology have been realized and laboratory tests show good results. We will present the achievable successes of this type of asphalt production process, which allows the road construction industry to save aggregates and to go one step further towards the green road.

Continuous asphalt production without waste – An illusion?

1. Asphalt – The unquestioned material for road building

A performing road infrastructure is vital for the economy of a country. Roads build with asphalt are the technology of choice; for example, 90% of all the paved roads in Europe are made of asphalt. Asphalt is a mixture of aggregates, binder and filler. The aggregates used for the production of asphalt origin typically from a local quarry and have to fulfil tight quality requirements regarding grain size, physical and chemical properties. About 5% of weight of the asphalt is bitumen that ensures the cohesion and flexibility of the grain skeleton. Bitumen itself origins from the refining process of crude oil. To alter the characteristics of the asphalt, specific substances are added to the bitumen or the mix directly, e.g. adhesion promoters, polymers or fibres [1].

A typical asphalt road pavement consists of multiple layers: The lower layer consist of unbound but compacted gravel, the upper level is bituminous-bound material. Thanks to this structure, the asphalt pavement can distribute the loads that are caused by the traffic to avoid deformation of the lower formation level. A wide range of types of asphalt exists. This is mainly due to the different requirements depending on traffic load, climate and required additional function as well as the different characteristics of the used raw material. Standard asphalt recipes therefore are usually adapted to the local situation, which results in a big number of different asphalt recipes that need to be produced on an asphalt plant.

Ordinary hot mix asphalt is produced at temperatures between 160°C and 190°C, depending on the type of mixture. Heating, dosing and mixing takes place in stationary or mobile mixing plants that show output rates of several hundreds tons of asphalt per hour. While in developing economies, the asphalt production market is dominated by big road construction sites with high quantities of asphalt of the same recipes, asphalt producers in developed countries face construction sites with smaller quantities and a much higher number of sophisticated asphalt recipes.

Every year, about 1’500 millions tonnes of asphalt are produced worldwide [2]. Since this material mainly consist of natural resources, recycling of the reclaimed asphalt from the old roads is important. Saving the use of new material does also mean avoiding waste during the production process. Therefore, asphalt producers are constantly optimizing the way the valuable raw materials are treated.

In this paper, we therefore present a new production regime in asphalt mixing plants that allow a significant reduction of waste.

2. Batch asphalt production – The dominant approach

Traditionally, there are two types of asphalt production processes: The batch-mix process uses in general a twin-shaft paddle mixer; the continuous production applies a drum mixer.

In Europe, most of the asphalt plants are of the batch type (see figure 1): The minerals are added via cold feeders on a conveyor belt and fed into the rotary drum dryer where the aggregates are heated to about 190°C and dried. The rotary dryer is a drum made of steel that is equipped with different types of flights on the interior. In the axis of the drum, a burner with performance of about 15 to 20 MW is heating the aggregates and the air flowing in the drum. From the rotary dryer, the hot aggregates are conveyed via a vertical elevator to the screen that separates the mineral in different grain size fractions. These fractions are stored in hot silos, dosed using scales and mixed in a twin-shaft paddle mixer with hot bitumen and potentially additives. The whole mixing process of a 4 ton batch takes less than a minute. To ensure emission limits, the whole asphalt plant and the rotary dryer in particular is operated with under pressure and the process air is cleaned using a baghouse filter. The reclaimed particles from the process air are fed back into the production process since they improve the material characteristics of the asphalt road.

In the batch mixing plant, the drying and heating are two separate steps of the production. This allows switching the production recipe for each batch. Using a twin-shaft paddle mixer increases the flexibility of the mixing process and ensures an adequate coating of the aggregates with bitumen thanks to the high shear field in the mixer.

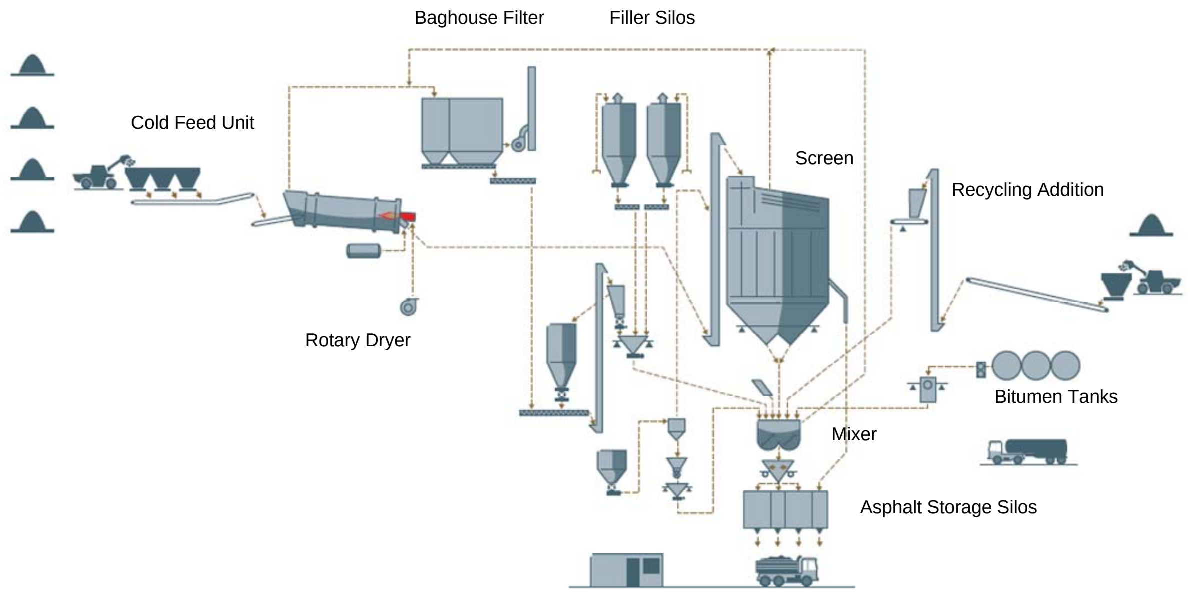

Figure 1: Batch-type asphalt mixing plant

3. Continuous production with drum mixer – The traditional alternative

Predominantly in developing economies and countries that are purely focussing on high volumes of the same asphalt recipe, the continuous production process is popular. Traditionally, continuous hot mix asphalt production is realized using a drum mixer: In contrast to the batch mixing process, the mixing of the aggregates with the bitumen takes place in the rotary dryer directly or indirectly. The mixing itself happens mainly with gravity. No screen is required and hot aggregate storage bins are not available. The asphalt production process is therefore simplified compared to the batch process.

The drum mixer type of asphalt mixing plant is less flexible for changes of recipe, causing long changeover time and waste of material before a steady production state is reached. Due to the free-falling approach for mixing, the coating and kneading effect is less intensive compared with a twin-shaft paddle mixer. Figure 2 shows a typical set-up of a continuous asphalt mixing plant with a drum mixer.

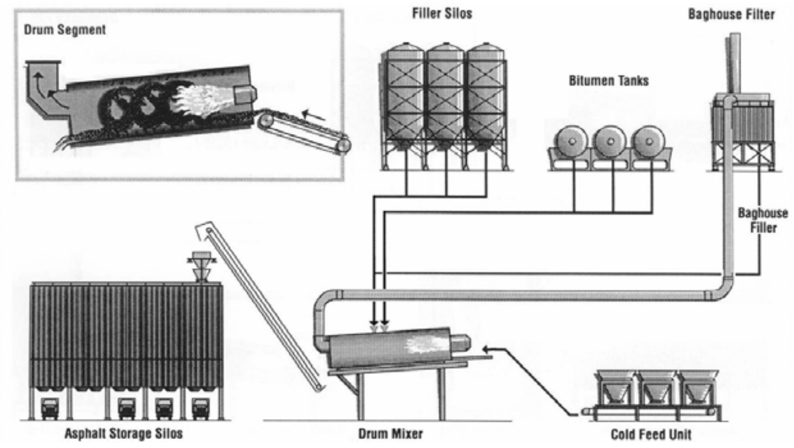

Figure 2: Continuous asphalt plant using a drum mixer; [3]

4. ContiMix - Continuous production with separate mixer –The new alternative

Latest development in the asphalt production process has led to a revival and optimization of a well-known basic principle: The continuous asphalt production with a twin-shaft paddle mixer. The combination of the basic principle with global asphalt production experience and modern control technology has resulted in a production principle which is the response to the demand for continuous mix preparation at high quality levels, without compromising the intense mixing of a twinshaft paddle mixer.

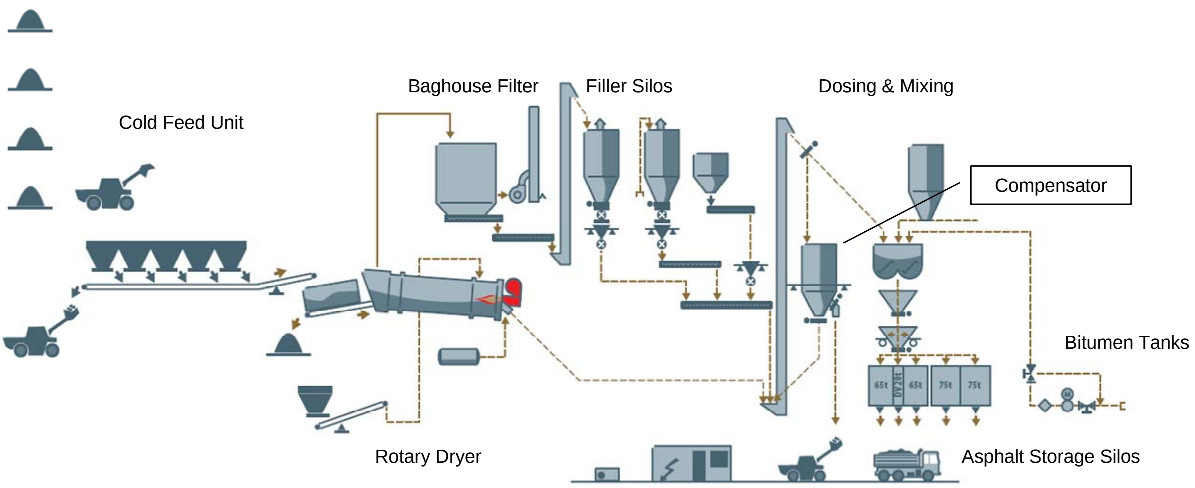

Figure 3: Flow chart of a ContiMix equipped with compensator

The core part of the ContiMix concept is the hybrid mixer which combines the advantages of a batch mixer with those of a continuous mixer (see figure 4): It generates the important high shear field for mixing and coating of the aggregates, it allows the high throughput ratios of a continuous production process and ensures the required flexibility on the mixing cycle and mixing time. It can be operated in batch or continuous mode, thereby enabling a high degree of production flexibility to be achieved. The special alignment of the agitator arms to the mixer shafts ensures a high quality batch in both cases.

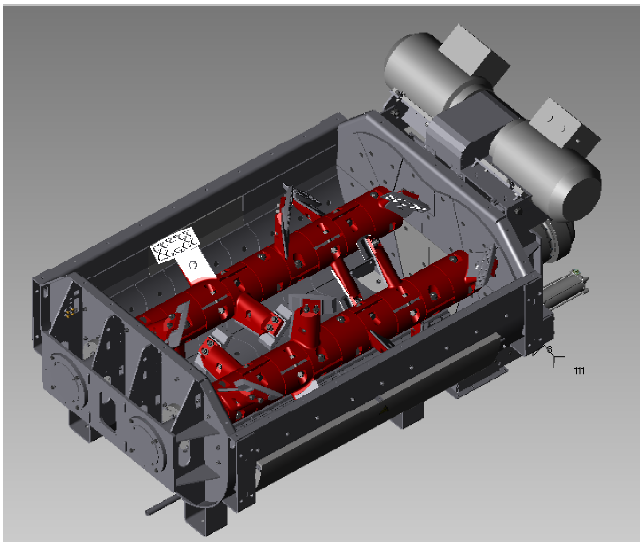

Figure 4: Hybrid twin-shaft paddle mixer: Continuous and batch-production possible

The concept shows several advantages, for example the clear separation of material heating and mixing processes which reduces emissions. In addition this plant concept overcomes a major drawback of drum mixer plants because it allows the simple, precise and flexible addition of all the ingredients needed in modern mix production like fibres or additives straight into the mixer. In particular the addition of heat-sensitive bitumen to the recipe outside of the drier is possible. The production of warm mix asphalt using foam bitumen or other technologies is possible and so-called “cold mixes” that also use foam bitumen can be mixed without heating the aggregates.
Plants incorporating this ContiMix concept (see for example figure 5) are characterised by all the benefits of a simple and cost-effective production. Since the continuous asphalt production is often

used for high volume road construction site, the ContiMix concept is available in stationary and mobile version but they all show a max height of only about 20m if using a horizontal skip. Hydraulic lifting gear for installation without a crane is also available.

Figure 5: ContiMix asphalt plant

5. Waste - Basic problem of continuous asphalt production

Heating and drying of the aggregates takes place in a rotary dryer. At the end of the drying process, dry aggregates at typical temperatures of 190°C exit the drum. The rotary dryer is heated by an open flame fuelled with natural gas, light, heavy or recycling oil, or powder fuels like brown coal dust. During the drying and heating process, different heat transfer modes take place:

- Heat transfer from the hot air to the aggregates (convection)
- Heat transfer from the hot walls of the dryer to the aggregates (conduction)
- Heat transfer mainly due to heat from the flame (radiation)

While radiation and conduction are predominant in the combustion zone next to the flame, convection is the important effect in the area where aggregates form a tight curtain for optimal heat transfer.

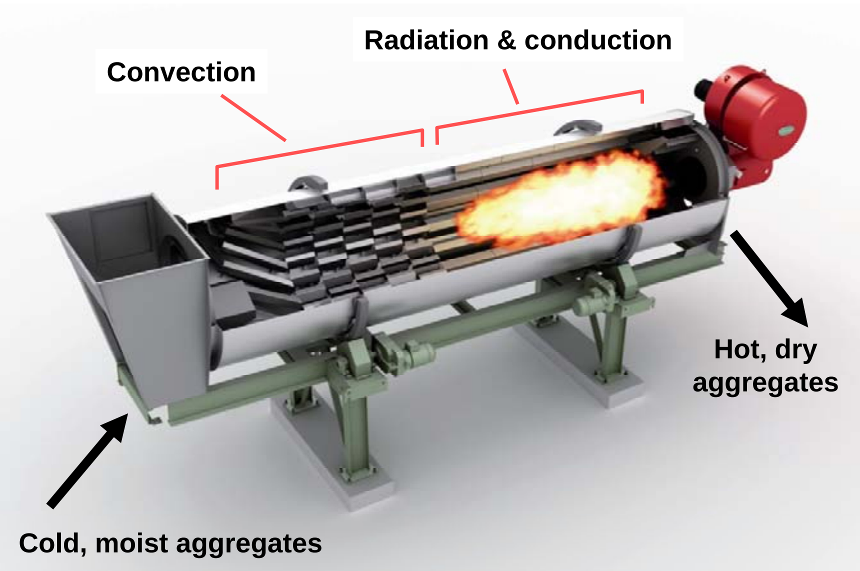

Figure 6: Rotary dryer: Convection and radiation zone

In addition to the heat transfer, a mass transfer of moisture resulting in drying of the aggregates takes place. To ensure appropriate drying, a constant air flow through the drum is required. The aggregates are moved in the drum, lifted up and fall down through the hot drying and heating air. In

the convection zone, the curtain of aggregates is rather tight; the combustion room in the radiation zone is free of stones to ensure an optimal combustion.
Drying and heating of virgin aggregates usually takes place in counter flow dryer, meaning that the grains enter the drum at the air flow outlet. Reclaimed asphalt is traditionally heated in co-current flow heater. According to Krokida [4] the main effect influencing the residence time of aggregates can be described as follows:

- Cascade motion is the result of the lifting and free-falling of the material within the drum. Since the drum has a certain slope, the free-falling of the aggregates results in a motion of the aggregates in axial direction.
- Kiln action describes the motion of the grains when they slide on the metal surface, within the buckets or flights. Kiln action usually takes place in the lower sections of the dryer and if influenced by the shape of the buckets, the flow behaviour of the aggregates as well as by the rotation speeds of the drum.
- Bouncing occurs when a grain falls down from the flights on the underlying surface of other grains of metal. Depending on the surface, the particle is either absorbed or reflected leading to bouncing.

In rotary dryers for asphalt production, a fourth physical effect plays an important role: Since a constant air flow through the dryer is present, the free-falling particles are shifted in the direction of the air flow. Because the drag effect of the air flow on the particles depends on the surface of the grain (see figure 7), the air flow in the drum causes particles to move with different average speed through the dryer, depending mainly on their size which is characterized by the maximum diameter.

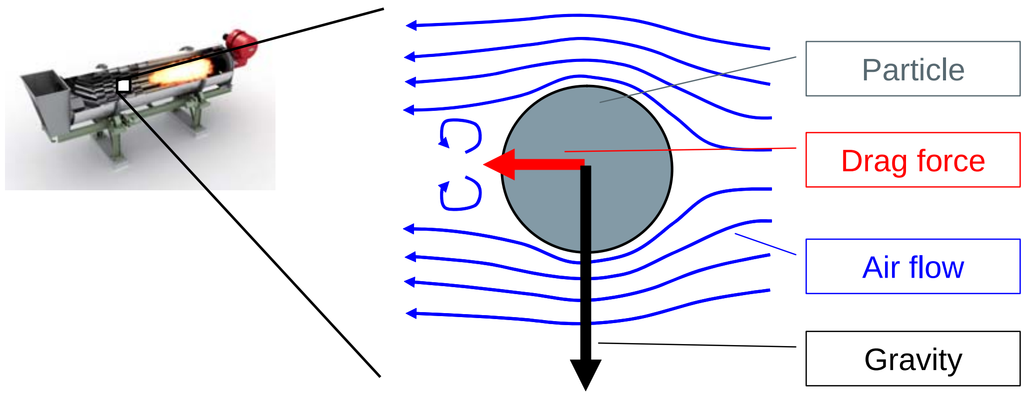

Figure 7: Forces on particles due to air flow

The sum of all the physical processes taking place in the dryer lead to different retention times of the aggregates depending on grain size, density, and shape. Density of the aggregates does not vary during production and also the shapes of the grains are rather similar. In contrary, the maximum diameter of the individual grains varies between 0.063mm and about 22mm. To illustrate this: A mineral grain of 22mm diameter is about 40’000’000 times heavier than a grain of 0.063mm diameter, while its surface is only about 120’000 times larger than that of a small grain. This difference in the “surface to mass ratio” results in a strong influence of the air flow on the retention time of the smaller particles. As a consequence, smaller particle stay longer in the counter-flow dryer than larger ones and move faster through a parallel flow dryer than the larger grains.
The difference in retention time of particles in the dryer depending on their size causes waste each time the asphalt recipe is changed or the asphalt plant is shut down. The reason is the tight quality criteria for asphalt regarding the grain size distribution. If the grain size distribution of the minerals does not meet these criteria, the lifetime of the asphalt pavement will be shortened due to layer deformation and crack propagation. While the first tonnes of hot and dry virgin aggregates cannot be used for asphalt production due to a lack of small particles, the last tonnes have to be thrown away due to an excess of small particles (see figure 8).

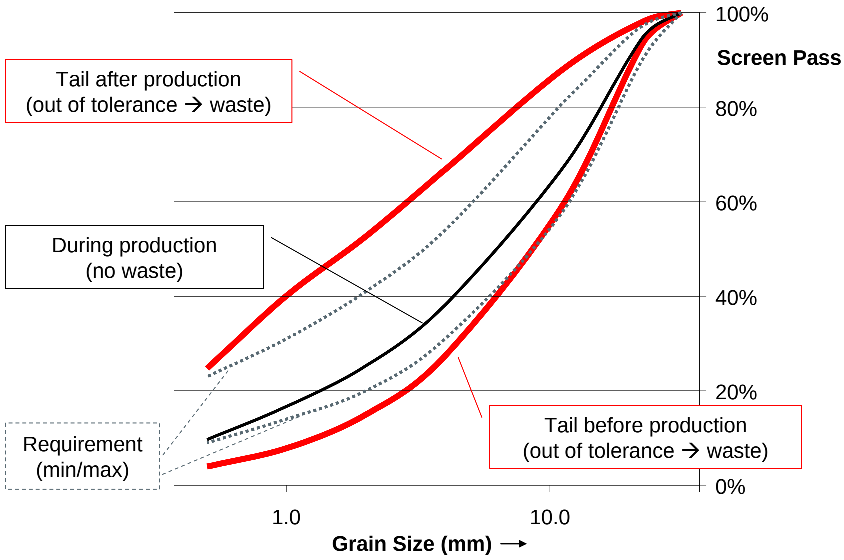

Figure 8: Grain size distribution before, during and after production (e.g. AC 22)

Traditionally, this effect is mitigated by starting the feeding of the smaller grain sizes prior to the coarse aggregates. This measure has only minor effects on reducing the waste, but has a negative impact either on the overall plant performance or the quality of the first and the last tonnes of asphalt. Assuming five starts or recipe changes on a continuous asphalt plant per day and an average waste of 4 tons each, 20 tons of hot and dry aggregates have to be thrown away a day. This equals approximately 140 litres of heating oil used for heating up the waste aggregates every day. In addition, these aggregates of the start and end tails cannot be used to produce high-quality asphalt anymore, since their grain size distribution does not meet the quality requirements. Figure 9 shows the typical waste piles that accumulate next to drum mix plants. This waste cannot be used for the production of high quality asphalt anymore, since its composition is indefinable.

Figure 9: Wasted asphalt and aggregates next to a drum mix plant)

6. ZeroWaste ContiMix – Solving a drawback of continuous asphalt production

Introducing the continuous asphalt production using a continuous twin-shaft paddle mixer allows overcoming this major drawback of the normal continuous drum mix plants. Thanks to separating the drying and heating process from the mixing process, it is possible to minimize waste in the continuous asphalt production by altering the production process slightly:

- By installing a special, isolated hot mineral buffer silo (see figure 13) between dryer and continuous mixer, segregated aggregates can be diverted into this buffer prior entering the mixer.

This buffer silo, superimposed on load cells, is connected via a dosing outlet back to the hot elevator. This unique feature signifies a radical improvement in the continuous asphalt production process.

– The first aggregates of a production lot that exit the drum show an excess of coarse aggregates. This start tail is now first stored this buffer silo (see figure 13). Since more and more small particles flow out of the drum, the mass flow into the dedicated storage silo (compensator) increases constantly.
– A constant mass flow into the compensator indicates that the drying process has reached a steady state and that the grain size of the aggregates leaving the drum equals to the one entering the drum. The silo is mounted on load cells to exactly know the amount of aggregates in the silo. As soon as the control system detects a constant mass flow, the hot aggregates are directed in the twin-shaft paddle mixer to start the hot mix asphalt production. Already the first tonne of produced asphalt meets the quality criteria and no bitumen or hot mineral that enters the mixer is spoiled.
– At the end of the production, the end tailing of aggregates is stored in the dedicated silo, as well. Since the end tailing shows an excess of fine grains, the overall grain size distribution of the aggregates stored in the compensator meets the quality criteria of high-quality asphalt, again (see figure 10).
– After the last mineral has left the mixer, the mixer flap is closed to operate the mixer in batch-mode. Therefore, the aggregates from the silo are fed into the mixer, bitumen is added and asphalt is produced like on ordinary batch mixing plants. Thanks to the fact that all the mineral that is fed into the drum is also used to produce asphalt, no excess mineral is heated up at all.

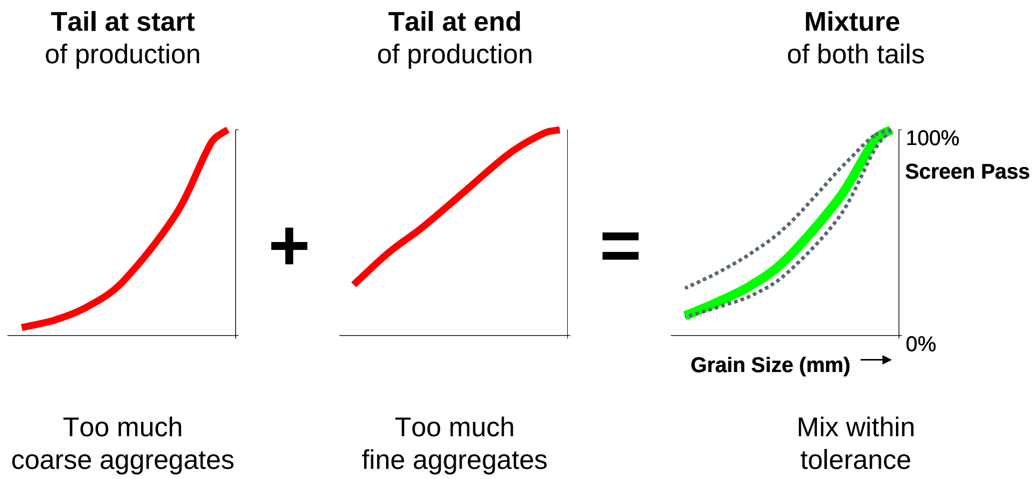

Figure 10: Start tail and end tail results in high-quality asphalt

To master this patented compensation and mixing, the whole process is automated on the as1 plant control system. The automation of the whole compensation process ensures towards the operator and the plant management that all the relevant process steps are carried out in a reproducible way. This special compensation process is only possible because of the clear separation of each process step (drying, mixing) in the whole chain of continuous asphalt production. Figure 11 displays a typical flow scheme of a ContiMix equipped with the ZeroWaste compensation system.

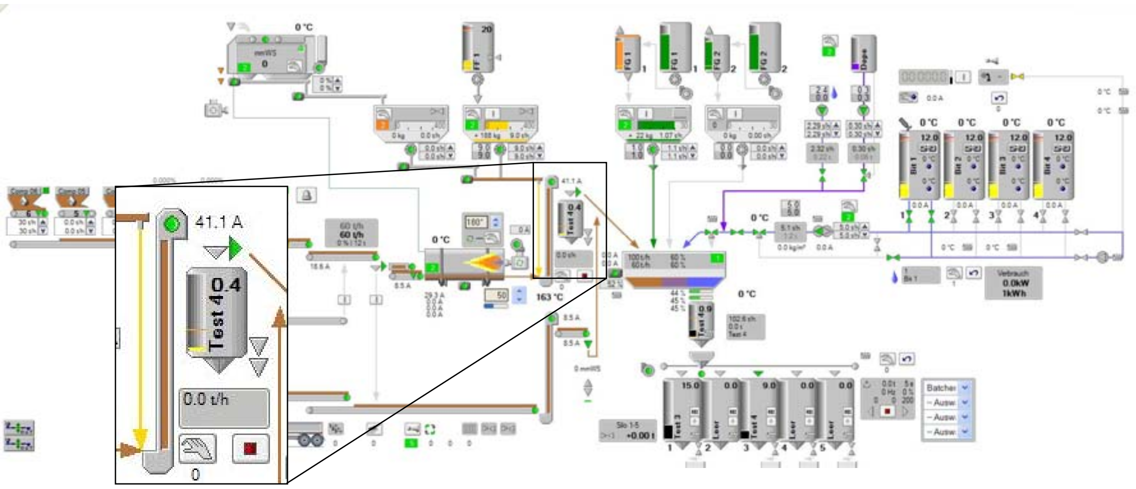

Figure 11: as1 control system screen of a ContiMix including automatic compensation

7. Zero-Waste ContiMix - Example Eurovia

Figure 12: Completely cladded ContiMix plant using compensator technology

The Zero-Waste concept is intensively used in the new ContiMix plant of SMC (Centre de traitement de Mâchefers de Blainville-sur-Orne) in the French Normandie. The French road construction sector is well-known for its high quality requirements for asphalt. The company SMC is a subsidiary of the global Eurovia construction group. Since more than 15 years, about 100’000 tons per year are produced for the communities of Bayeux and Falaise as well as the region Pays d’Auge. Due to the sensitive environment of the neighbourhood of the plant, the whole installation has been packed in a housing allowing very low noise and odour emissions (see figure 12).
Using the compensator technology prevents waste of about 4 tons of asphalt each time the recipe is changed. Assuming five such changes a day, a total waste saving of about 3’000 tons of asphalt per year can be realized. This equals to about 21’000 litre of heating oil.

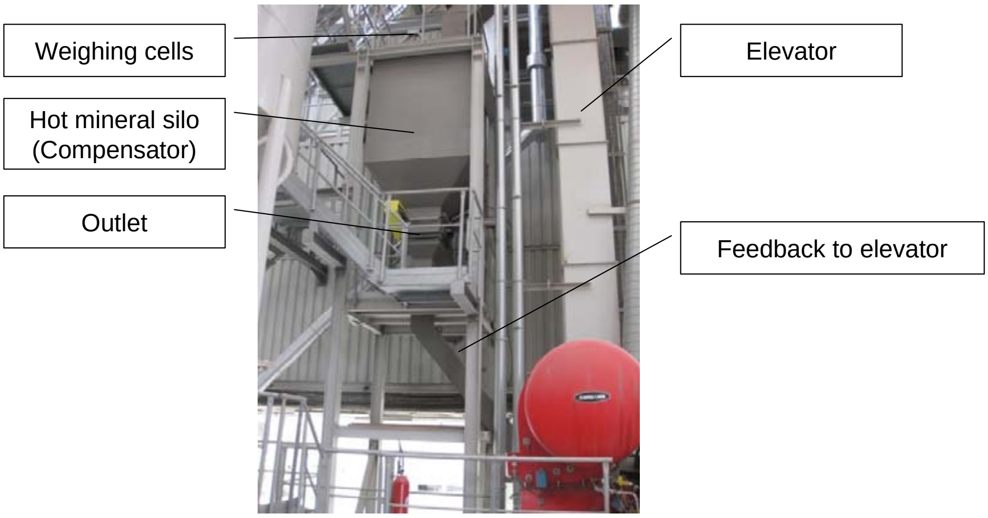

Figure 13: Compensator: Dedicated hot aggregate silo to eliminate waste

8. Summary and Conclusion

Asphalt can be produced either in a continuous or batch-oriented process. Comparing the two asphalt production concepts, illustrates clearly the areas of application of the different approaches. While the continuous Drum Mixer concept shows lower investment costs and typically higher production capacities per plant, the batch concept is clearly to be favoured in case of frequent changes in recipes, but with higher investment cost. One main drawback of the traditional continuous asphalt production using drum mixers is the waste of aggregates generated when changing the recipe of the produced asphalt. The same effect happens during each start-up and shutdown of the asphalt production process. Recent successes in the development of a continuous asphalt production using a twin-shaft paddle mixer instead of a free-fall drum mixer promise a resolution to this and other drawbacks of the continuous asphalt production as known today.

	Batch Plant	Drum Mixer	ContiMix
Investment & Flexibility			
Investment Costs	+	++	++
Production capacity	+	++	++
Time for recipe change	++		+
Flexibility and Quality			
Possible asphalt recipes	++		++
Intensity of mixing	++	-	++
Environment			
Prevention of waste	++	-	++*
Emission values	++	+	++

*: ContiMix ZeroWaste concept

Figure 14: Comparison of different asphalt production concepts

Market demands for Asphalt mixes and types are constantly increasing. The necessity of intense mixing forces is more and more underlined, simultaneously emission reduction and recycling gain importance. The present ContiMix concept allows a clear focus on each demand and gives a state of the art answer. The ContiMix can now be considered as a plant concept combining the advantages of both worlds. Several plant installations of this new technology have been realized and laboratory tests show excellent results. Continuous asphalt mix production at lower investment cost with ZeroWaste is available.

9. References

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[2] European Asphalt Pavement Association EAPA (2007) : Asphalt in figures ; http://www.eapa.org/asphalt.php

[3] European Asphalt Pavement Association EAPA (2007) : Environmental Guidelines on Best Available Techniques (BAT) for the Production of Asphalt Paving Mixes

[4] Magdalini Krokida, Dimitris Marinos-Kouris, and Arun S. Mujumdar (2006): Rotary Drying in Handbook of Industrial Drying – Third Edition – Arun S. Mujumdar ; Taylor & Francis; p 155ff