Asphalt Vision 2030

Building sustainable and low carbon roads

Part 2: Current challenges and opportunities in temperature management of asphalt mixtures

Photo by R. Mihelčič ©

Asphalt Vision 2030: Building sustainable and low carbon roads

The German road network with its around 630,000 kilometres makes a key contribution to economic growth, social prosperity and individual freedom throughout Germany.

In the meantime, another value is gaining priority in road construction: the reduction of greenhouse gases in order to keep our climate stable and our planet habitable. There is a lot of research going on, proven methods re-evaluated, new technologies and procedures and evaluation criteria are developed and established so that our roads can be built and maintained in a more climate-friendly way in the future.

In the series **Asphalt Vision 2030 - Sustainable and low carbon roads**, we have put together facts and information for you how our roads can become more climate-friendly and sustainable.

- **Part 1:** Green concepts in the asphalt industry
- **Part 2:** Current challenges and opportunities in temperature management of asphalt mixtures
- **Part 3:** Temperature management of asphalt mixtures: Methods and technologies
- **Part 4:** Temperature management of asphalt mixtures: Regulations, policies, and evaluation methods for building sustainable and carbon low roads

Wishing you an interesting read and we are looking forward to hear from you!

Publisher
Fliegl Bau- und Kommunaltechnik GmbH
Bürgermeister-Boch-Str. 1
DE-84453 Mühldorf am Inn

Tel +49 86 31-307 381
Mail baukom@fliegl.com
Web www.fliegl-baukom.de

Author and design
Jenny Friedl MSSc

April 2021

Building sustainable and low carbon roads

Current challenges and opportunities in temperature management of asphalt mixtures

Photo: Kelly Lacy @ pexels.com

Increasing traffic volumes and higher loads, up to 20 % of the German roads in need of rehabilitation (BMVI, 2020), more adverse weather conditions due to global warming and the goal of sustainably and effectively reducing greenhouse gas emissions by 55 % until 2030.

Engineers, researchers and manufacturers in the asphalt industry do not see these circumstances as road blocks, but as opportunity to provide asphalt pavements that will satisfy the needs and requirements for high performance road networks well beyond the year 2030.

by Jenny Friedl MSSc

1. Introduction

1.1 Background

The European Union has decided to become the first climate-neutral continent in the world. In order to achieve this goal, greenhouse gas emissions must be reduced by 55% (compared to 1990) by 2030 (German Federal Government, 2019). Currently, up to 51 kg carbon emissions (CO_2) are generated per ton of asphalt mixture. For Germany, that accounts to annually 800.000 tons of CO_2 generated by developing and maintaining roads and highways (EAPA, 2019; Ejven, 2018; Skoglund, 2019). In addition to the effects of road construction on climate change, most countries allocate large portions of their budget into the development and maintenance of roads and highways. Sustainable and low-carbon road construction could therefore contribute both to economic welfare and climate protection.

The reduction of production temperature for asphalt mixtures holds great potential in order to reduce greenhouse gas emissions as 20 kg of the 51 kg of CO_2 are generated by heating the asphalt mixture (Ejven, 2018; Skoglund, 2019).

1.2 Temperature reduction of asphalt mixtures

When production temperature of asphalt mixtures is reduced, not only opportunities are opening up, but also challenges in order to be able to guarantee the load-bearing capacity and service longevity of asphalt roads.

One of the challenges that must and can be solved is temperature segregation in the asphalt mixture.

Opportunities of using temperature reduced asphalt mixtures

- Economic: Reduced energy consumption
- Ecologic: reduced greenhouse gas emissions
- Occupational health: Reduced vapour and aerosol exposure

A high performance road network is the nervous system of our economy and society: It enables participation, economic growth and social prosperity.

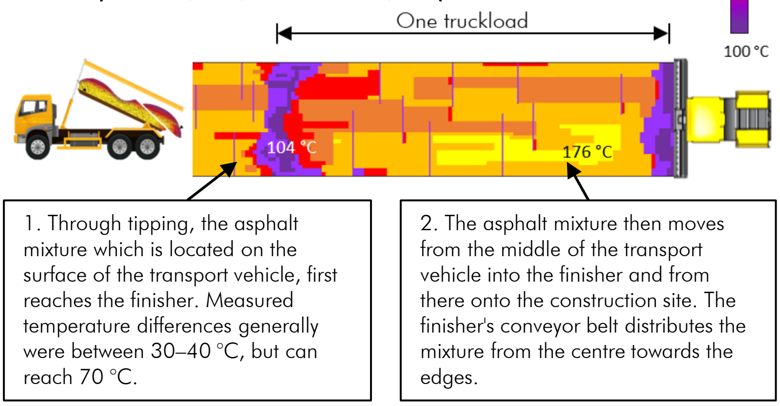

Fig. 1. Temperature profile of a asphalt paving section. A dump truck was used as means of transport. Measured temperature differences were generally bigger than 20 °C. An uneven temperature distribution throughout the asphalt mat was observed (Blab et al., 2015; Böhm & Cickovic, 2014).

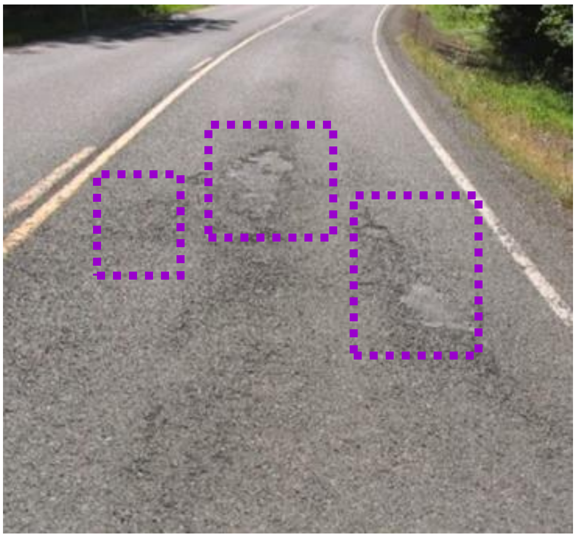

Fig. 2. Consequences of temperature segregation can be road damages such as crumbling, cracks, ruts and potholes (Photo: Sebesta et al., 2013).

2. Challenges

2.1 Temperature segregation

In 1967, Bryant was first to identify segregation as a widespread problem in asphalt pavements. However, it was not until the 1980s that segregation was studied on a larger scale and listed as a problem by road authorities (Willoughby et al., 2001). Probably the most comprehensive and also most impressive definition of segregation is provided by Stroup-Gardiner and Brown: **"Segregation is a lack of homogeneity in the hot- mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es)"** (1998, referred in Willoughby et al., 2001, p. 4).

Temperature segregation occurs when the asphalt mixtures cools down during transport and paving. This can lead to an uneven temperature distribution of the freshly paved asphalt mat (Stroup-Gardiner & Brown, 2000). While material segregation is easy to see, temperature segregation becomes only visible with the help of a thermal imaging camera that displays the different temperatures in different hues. Furthermore, temperature segregation can also occur independently of material segregation in the asphalt mixture (Rahman et al., 2013).

2.2 Temperature segregation and its impact on asphalt compaction

Willoughby et al. (2001) found that temperature differences in the asphalt mixture that are less than 14 °C have no negative impact on compactability.

In contrast, so-called cold spots, i.e. places that are were colder than the rest of the asphalt mixture, exhibited poorer compactability and thus also a higher air void content, which in turn, had a profound effect on pavement life (Rahman et al., 2013; Willoughby et al., 2003). See Figure 1 of a temperature profile above where lower temperatures are illustrated in red and purple and higher temperatures in orange and yellow. Edges and places where the asphalt transport vehicle was changed are also particularly susceptible to temperature segregation. In general, temperature segregation can occur anywhere in the built-in asphalt mat (Gunter, 2012).

Several studies examining the quality of road surfaces have shown that road damages such as crumbling, cracks, ruts and potholes are one of the direct effects of temperature segregation (Chang et al., 2001; Cho et al., 2010; Stroup-Gardiner & Brown, 2000). Typical of road damages caused by temperature segregation is that they deteriorate over time. One of the reasons for this deterioration over times is

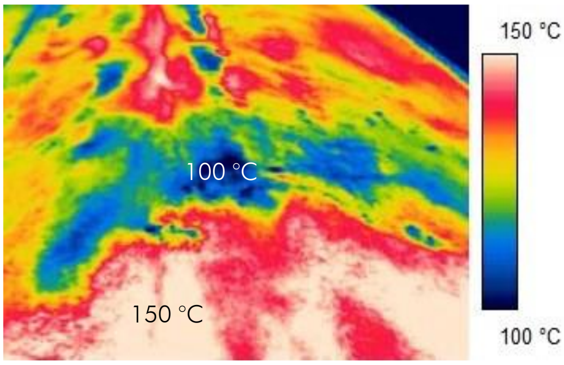

Fig. 3 (le) and 4 (ri): Normal photography and temperature profile taken with a infrared camera (Photo: Rošer, 2020).

that water and salt during the time in which it freezes and thaws, remains in the asphalt cavities and slowly begins to destroy the asphalt. The vehicles that then roll over these areas tear up bit by bit the loose asphalt and accelerate the deterioration process (Gunter, 2012; Willoughby, 2003).

In the three year long field experiments that Willoughby et al. (2001) carried out, every truckload was affected of temperature differences, which significantly and negatively impacted compactability. The typical size of these low temperature areas was 1.2 m x 3 m.

In summary, following conclusions from the above mentioned scientific research can be warranted:

Summary temperature segregation

- Temperature management of asphalt mixture during transport and installation must be improved
- Best would be temperature differences smaller than 14 °C
- Temperature differences are a systematic problem as they occur in every truckload

2.3 Impacts of temperature segregation on raod performance

Numerous studies on newly paved as well as on repaired roads show that temperature segregation

- increases moisture and frost sensitivity,
- increases cracking and rutting,
- increases ravelling and potholes, and
- decreases fatigue life

(Byzyka et al., 2017; Mahoney et al., 2000; Stroup-Gardiner & Brown, 2000; Rahman et al., 2013; Willoughby et al., 2003).

Described in figures, the follow-up costs of temperature segregation can amount to almost half of the original construction costs as damages manifest themselves in only a couple of years after installation. These pavements become quickly a maintenance issue, shortening the lifespan cycle. Stroup-Gardiner and Brown (2000) calculated that the lifespan of these roads can be shortened by up to seven years if the degree of temperature segregation is too high. Se table 1 below.

Table 1. Relationship between surface temperature differnces, level of segregation and additional building costs (after Stroup-Gardiner und Brown, 2000).

Asphalt surface temperature differences	Degree of segregation	Additional costs [%] of the original building costs
<10 °C	–	–
10 – 16	Low segregation	8 – 13 %
17 – 21	Moderate segregation	22 – 30 %
> 21 °C	High segregation	37 – 46 %

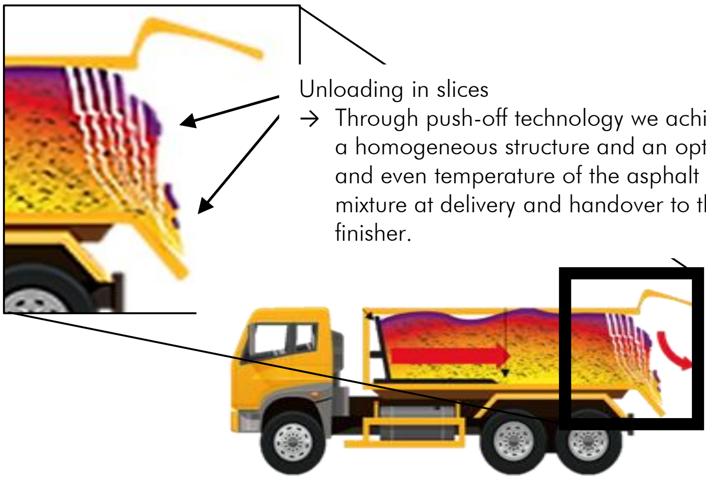

Fig. 5: Transport vehicle with push-off technology for delivering asphalt mixtures (Illustration: EAPA).

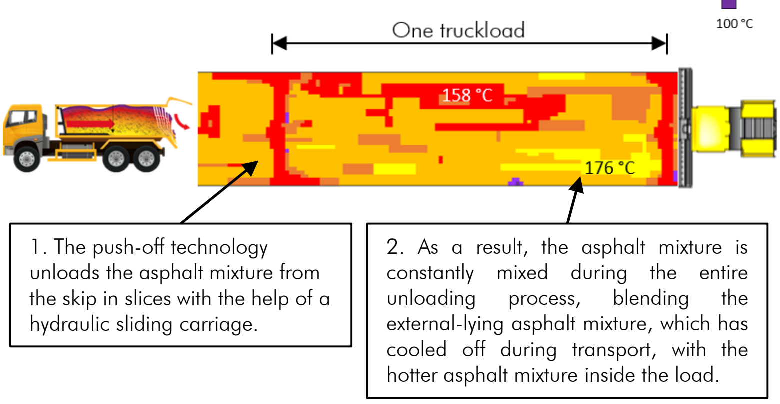

Fig. 6: Temperature profile of a asphalt paving section. A truck with push-off technology was used as means of transport. Measured temperature differences were generally smaller than 20 °C. An even temperature distribution throughout the asphalt mat was observed (Blab et al., 2015; Böhm & Cickovic, 2014).

3. Opportunities

3.1 The push-off technology

One opportunity to limit temperature segregation to a minimum, in addition to the use of thermally insulated skips, is to ensure that colder asphalt is mixed with hotter asphalt during unloading. The push-off technology unloads the asphalt mixture from the skip in slices with the help of a hydraulic sliding carriage. As a result, the asphalt mixture is constantly mixed during the entire unloading process, blending the external-lying asphalt mixture, which has cooled off during transport, with the hotter asphalt mixture inside the load.

3.2 Studies affirming the effectiveness of push-off technology

In order to evaluate the effectiveness of the push-off technology regarding even temperature distribution, several studies were carried out.

Blab et al. (2015) from the University of Technology in Vienna, Austria, compared transport vechicles using dumping technology with transport vehicles using push-off technology as a means to unload the the asphalt mixture. Over a length of approximately 465 m in the Pausingergasse in Vienna, in March and April 2015, the construction site was alternately supplied with dumper respectively push-off transport vehicles. Transportation time was a little bit over 60 minutes. The asphalt surface was photographed directly behind the screed using a thermal imaging camera (Type Testo 880-3). In addition, the asphalt temperature was recorded every five meters at six different measuring points by means of a penetration thermometer in the middle of the layer and drill cores ∅ 100 mm were removed for density testing.

Blab et al. (2015) concluded that the significantly lower temperature differences (~10 °C) in the laid asphalt mat are due to the constant blending process during unloading. Overall, the surface temperatures in the asphalt mat were ten degree Celsius higher and more homogeneously distributed when deliverd by transport vehicles with push-off technology than when delivered by transport vehicles with dumper technology (see Fig. 6).

A similar comparative study between dump and push-off technology was carried out by the Swedish Construction Development Fund (SBUFa + b, 2018) between March and December 2018. Instead of being conducted downtown, it was conducted on four different country road sections (a. E18 Rösa-Norrtälje, b. V243 Gyttorp-Älvhyttan, c. V51 Svennevad-Kvarntorp, d. V35 Björkåkla-Hackefors) in South Sweden. The calculated PDI-value (for more information, please see page 6) clearly showed that the asphalt mixture is distributed more homogeneously laid if push-off

technology
was used than the dump technology (SBUFb, 2018).

Böhm and Cickovic (2014) and the Austrian provincial road authority, the Direktion Straßenbau und Verkehr der oberösterreichischen Landesregierung (2015), also confirm the effectiveness of using push-off technology regarding a more homogeneous temperature distribution in the laid asphalt mat than when dump technique is used.

Push-off technology thus makes an important contribution that the target value of temperature differences (<14 °C), as specified by Stroup-Gardiner and Brown (2000) can be achieved.

Summary push-off technology

- Push-off technology effectively minimizes the risks of temperature and material segregation, and as a result, prevents road damages
- Push-off technology can therefore regarded as an important factor in building sustainable roads
- Since the push-off technology delivers asphalt mixtures with low temperature differences, it creates the opportunity to reduce the asphalt production temperature to protect our climate

4. Final remark

Increasing traffic volumes and higher loads, up to 20 % of the German roads in need of rehabilitation (BMVI, 2020), more adverse weather conditions due to global warming allied with the goal of reducing carbon emissions effectively, are challenges that engineers, manufacturers and researchers in the asphalt industry face.

In this paper we showed that there are already effective technologies in place that successfully can help us master the challenges. Push-off technology demonstrates how it can improve temperature management by providing asphalt mixtures with small temperature differences. Beside having a positive impact on asphalt pavement quality, leading to a longer service life of roads, push-off technology can be regarded as an opportunity to reduce and prevent carbon emissions effectively as it enables us to use **temperature reduced asphalt mixtures.** This in turn

- reduces energy consumption (economic benefit), and
- reduces vapour and aerosol exposure (occupational health benefit).

Push-off technology contributes to asphalt pavements that will satisfy our needs and requirements well beyond the year 2030.

References

Blab, R., Kluger-Eisl, W., Hofko, B., Hospodka, M., Dimitrov, M., & Riedmayer, T. (2015). *Asphalttemperatur von Mischanlage bis Einbau. Baubegleitende Temperaturmessungen und asphalttechnologische Untersuchungen*. Projekt D23006154003/15406. Wien: Technische Universität Wien.

Böhm, S., & Cickovic, M. (2014). *Temperaturverlauf im Asphalteinbauprozess. Temperaturmessung von Asphalt vom Mischwerk bis zum Einbau.* Projekt UB2014-0128. Darmstadt: Technische Universität Darmstad.

Byzyka, J., Rahman, M., & Chamberlain, D. A. (2017). Thermal segregation of asphalt material in road repair. *Journal of Traffic and Transportation Engineering*, 4(4), 360-371.

Fig. 7: Transport vehicle with push-off technology at A8, Karlsruhe, Germany (Photo: Fliegl).

BMVI (2020)]. *Verkehrsinvestitionsbericht für das Berichtsjahr 2018.* Berlin: Bundesministerium für Verkehr und digitale Infrastruktur. https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehrsinvestitionsbericht-2018.pdf?__blob=publicationFile.

Chang, C. M., Baladi, G. Y., & Wolff, T. F. (2001). Using pavement distress data to assess impact of construction on pavement performance. *Transportation research record, 1761*(1), 15-25.

Cho, Y. K., Kim, Y. R., & Bode, T. (2010). *Infrared Thermography-Driven Flaw Detection and Evaluation of Hot Mix Asphalt Pavements.* Report 309. Nebraska Department of Roads. https://digitalcommons.unl.edu/matcreports/10/

Cong, L., Shi, J., Wang, T., Yang, F., & Zhu, T. (2019). A method to evaluate the segregation of compacted asphalt pavement by processing the images of paved asphalt mixture. *Construction and Building Materials, 224*, 622-629.

Direktion Straßenbau und Verkehr (2015). *Wissenschaftliche Untersuchungen im Asphaltstraßenbau*. Linz: Amt der Oberösterreichischen Landesregierung.

EAPA (2019). *The asphalt industry's contributions to climate neutrality and preservation of Europe's natural environment*. Brussels: European Asphalt Association. https://eapa.org/wp-content/uploads/2019/12/EAPA-manifesto.pdf.

EAPA (2020). *Asphalt in figures 2019*. Brussels: European Asphalt Association. https://www.eapa.org/asphalt-in-figures-2019.

Ejven, L. (2018). Emissionen reduzieren. *Asphalt & Bitumen, 4(05), 34-37.*

German Federal Government (2019). Klimaschutzprogramm 2030. Berlin: Die Bundesregierung. https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimaschutzprogramm-2030-1673578.

Gunter, C. B. (2012). *Field evaluation of temperature differentials in HMA Mixtures.* Report No. FHWA-SC-12-02. South Carolina Department of Transportation, Office of Materials and Research.

Mahoney, J. P., Muench, S. T., Pierce, L. M., Read, S. A., Jakob, H., & Moore, R. (2000). Construction-Related Temperature Differentials in Asphalt Concrete Pavement: Identification and Assessment. *Transportation Research Record, 1712*(1), 93–100.

Rahman, M. M., Grenfell, J. R. A., Arulanandam, S. J., Ianakiev, A. (2013). Influence of thermal segregation on asphalt pavement compaction. *Transportation Research Record: Journal of the Transportation Research Board, 2347*, 71-78.

Rošer, R. (2020). Temperaturna segregacija pri vgradnji asfaltnih zmesi. Master thesis. University of Ljubljana: Ljubljana.

SBUFa (2018). *Utvärdering av push-off flak för asphalt*. Raport ID:13544. Stockholm: Svenska Byggbranschens Utvecklingsfond.

SBUFb (2018). *Utvärdering av push-off flak för asphalt – del 2.* Raport ID:13709. Stockholm: Svenska Byggbranschens Utvecklingsfond.

Sebesta, S., Scullion, T., & Saarenketo, T. (2013). *Using infrared and high-speed ground-penetrating radar for uniformity measurements on new HMA layers.* Transportation Research Board. Washington, DC: The National Academies Press. https://doi.org/10.17226/22769.

Skoglund, J. (2019). The asphalt industry can reach their climate targets!. *Våre Veger, 01*, 60-62.

Statens vegvesen (2017). *Varmefotografering som grunnlag for beregning av bonus og/eller trekk. Vedlegg till konkurransegrunlaget "Konktrakter: Asfaltarbeider i Region øst 2019".* Oslo: Statens vegvesen Region øst.

Stroup-Gardiner, M., & Brown, E. R. (2000). *Segregation in Hot-Mix Asphalt Pavements*. National Cooperative Highway Research Program Report 441. Washington, DC: National Academy Press.

Willoughby, K. A., Uhlmeyer, J. S., Mahoney, J. P. Anderson, K. W., & Pierce, L. M. (2003). Construction-related variability in pavement mat density due to temperature differentials. *Transportation Research Record, 1849*(1), 166-173.

Further information on transport vehicles with push-off technology can be found on the EAPA homepage under the link https://eapa.org/plant-to-paver-asphalt-delivery/ .

Outlook: Scandinavian competition rules

Various municipalities in Sweden and Norway have introduced a bonus and deduction system to motivate road construction contractors to deliver asphalt with good homogeneity.

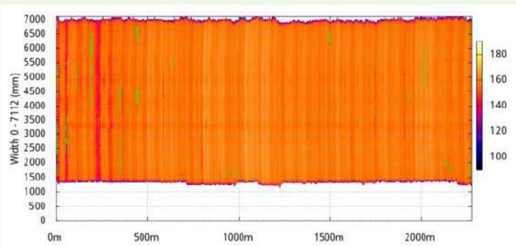

Fig. 8: Surface temperature profile with infrared camera (SBUFb, 2018).

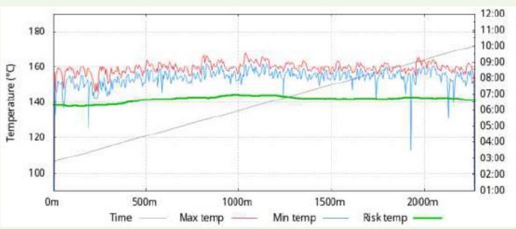

Fig. 9: Temperature histogram with risk areas (SBUFb, 2018).

Based on the temperature profiles, risk areas are calculated that have less than 90% of the floating average value of the surface asphalt layer. A value, called PDI, is derived from these risk areas and the bonus or deduction is calculated from this PDI value with the help of a table or with specified equations (se also SBUFb, 2018; Statens vegvesen, 2019).

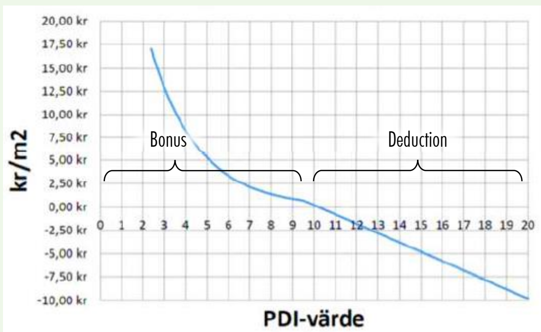

Fig. 10: PDI-Imbursement table of Stockholm's road authority (SBUFb, 2018).

Welcome! We look forward to discussing with you asphalt optimization by using push-off technology. Fliegl takes part in the following conferences in the next months:

General refurbishment of the 15/33 runway at Salzburg Airport 2019. More than 120.000 tons of asphalt, approx. 8.000 tons daily, were in record time installed. Trucks with the by Fliegl developed push-off technology were in use and guaranteed a smooth and fast handover to the asphalt paver. You'll find more information about the project at the homepage of Salzburg Airport under the link: https://www.salzburg-airport.com/unternehmen-airport/news-presse/news/news-detail/artikel/der-flughafen-hat-eine-neue-piste