Treatment of tar-containing asphalt granulate for sustainable recycling

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Abstract

Asphalt road construction is one of the industries in which almost all asphalt produced is already being reused or recycled. Unfortunately, there are always layers of tar or coal tar from old construction projects that cannot be recycled. Material containing tar often must be disposed of at high cost. In addition, a huge amount of landfill space is required for storage. In order to achieve the high reuse and recycling rates, considerable effort is required in the extraction process and in processing. For example, the asphalt must be milled, transported and stored in as many layers as possible to be able to reuse it in as pure a form as possible. This involves a great deal of logistical effort and high costs. This is because sufficient (covered) storage space must be provided at the asphalt mixing plant for so-called stockpile management, but this is not usually available.
To minimize the costs of tar disposal in the future and to enable the recycling of the stones from the tar granulate, an alternative method of processing the tar granulate has been searched for. Several years of development have shown that it can be a suitable way to process the extracted material in such a way

that the road tar and the stones are separated as gently and environmentally friendly as possible so that they can then be reused in a controlled manner. Separation by means of chemical solvents or the use of extreme cold is therefore out of the question.
Instead, the idea of separating the tar granulate into the components rock, tar and mastic using only water has been pursued. In a long series of tests, a prototype of a purification plant has been developed and tested, which now makes it possible to achieve the above-mentioned separation goals. The process was implemented on an industrial scale in 2025 and has successfully passed the test phase.
In the summer of 2026, the first construction project is to be implemented, in which material obtained from the AB site will be treated using this process and then directly reused on site.
Overall, this can make a significant contribution to even greater environmental protection and resource conservation in asphalt road construction. In the future, this new process will significantly reduce the disposal costs for PAH removal and the volume of tar-containing road construction waste, as well as expand the recycling options in bitumen-bound road construction.

1. INTRODUCTION

The German construction industry faces a monumental challenge: reducing its massive resource consumption in a sustainable manner. Each year, approximately 540 million tonnes of mineral natural resources are extracted in Germany—equivalent to about 4 hectares of land per day [7]. This sector is responsible for roughly 37 % of CO_2 emissions and 30 % of total energy consumption in the country [8].
Within the construction industry, asphalt road construction has long been recognized as a pioneer in the circular economy. In Germany, nearly 91 % of asphalt produced in 2024 was derived from recycled materials—evidence of a mature and well-functioning recycling infrastructure [8]. This high rate of reuse is underpinned by the thermoplastic nature of asphalt, which theoretically allows for 100 % recyclability.
However, despite this progress, legacy road layers containing coal tar or coal tar pitch remain a significant barrier [1]. These materials were extensively used as binders from the 1950s through the 1980s—until 1984 in West Germany and 1990 in East Germany. Today, it is estimated that approximately one billion tonnes of tar-containing asphalt remain in Germany's road network [3]. These materials are not merely outdated; they represent a major environmental and economic burden due to their high content of polycyclic aromatic hydrocarbons (PAHs), such as benzo[a]pyrene, which are classified as carcinogenic, mutagenic, and highly water-polluting [10]. As a result, such materials are legally classified as hazardous waste under the German waste code AVV 17 03 01*, triggering stringent regulations and significantly increasing disposal costs.
In 2024, asphalt production in Germany reached approximately 38 million tonnes. Of this, about 12.9 million tonnes came from recycled asphalt, resulting in a recycling rate of around 91 % of the total volume [8]. Despite this impressive figure, approximately 3 to 4 million tonnes of tar-containing road construction waste are still generated annually as hazardous waste (AVV 17 03 01*) [3].
The economic imperative for new processing technologies arises from the increasing scarcity of landfill space and the resulting cost increases. When a portion of the material is landfilled or used as landfill replacement, valuable mineral resources are permanently removed from the material cycle, further straining already limited landfill capacity. In Germany, remaining landfill capacity is estimated to last only about 11 years, leading to a steady rise in disposal fees.
While the disposal of tar-free asphalt typically costs less than €100 per tonne, costs for tar-contaminated material—due to its hazardous classification and complex transport logistics to thermal treatment facilities abroad (e.g., in the Netherlands)—can be significantly higher [5]. This disposal route is not only environmentally concerning due to long transport distances but also economically unattractive due to high acceptance fees and administrative burdens.

Another approach—cold recycling—is used in limited cases. Here, material is reused on-site or in stationary plants with added binders. However, this method does not destroy or reduce the pollutants; it merely relocates them into the road structure, effectively transferring the problem to future generations. According to the Federal Audit Office, this approach leads to higher long-term maintenance and rehabilitation costs, as pollutants are not eliminated but only encapsulated.
The German Circular Economy Act (KrWG) explicitly requires that high-quality recovery be prioritized over disposal, provided it is technically feasible and economically reasonable [7]. This was reinforced by the General Circular on Road Construction (ARS) No. 16/2015, which prohibited the use of PAH-containing materials in federal highways starting in 2018. The goal was clear: to fully remove carcinogenic substances from the material cycle, not merely to relocate them into deeper layers of the pavement structure. This regulatory pressure intensifies the need to shift from landfilling toward high-value processing.
It is precisely at this juncture that the new approach emerges: a "gentle" separation of tar and aggregate, enabling the recovery of valuable resources while permanently removing the tar- or pitch-based binder from the cycle.

2. Conventional Reuse of Asphalt Based on FGSV Guidelines

2.1 Core Standards and Quality Management

In Germany, asphalt reuse is governed by a comprehensive network of technical standards developed by the Research Association for Roads and Traffic (FGSV). These guidelines define the quality requirements that reclaimed materials must meet to be reintroduced into the material cycle [1].
The cornerstone of this system includes the TL Asphalt-StB (Technical Delivery Conditions for Asphalt Mixtures) and the TL AG-StB (Technical Delivery Conditions for Asphalt Granulate). These are supplemented by the ZTV Asphalt-StB, which regulates contractual conditions for construction, and the M WA (Guideline for the Reuse of Asphalt) [4]. A key requirement for successful reuse is the uniformity of the asphalt granulate. Regular sampling (every 500 tonnes) is required to assess parameters such as particle size distribution and the ring-and-ball softening point (EP RuK) of the binder [1].

2.2 Classification and Reuse Rates

A critical factor is classification into Recovery Class A, which sets a maximum PAH content of 25 mg/kg. Only materials below this threshold may be reused in hot-mix processes [4]. The maximum allowable addition rate of asphalt granulate in mixing plants depends heavily on the plant’s technical capabilities. While continuous feeding into mixers typically allows rates of 30–40 %, modern plants with parallel drums can theoretically incorporate up to 100 % recycled material, provided technical requirements for the final product are met [1].

3. Previous Approaches to Tar-Contaminated Asphalt

Until now, the reuse of tar-containing road rubble (PAH content > 25 mg/kg) has been severely restricted or prohibited (see 3.1). In Germany, around 3 to 4 million tonnes of this material are generated annually; at certain concentrations (ranging from 25 to 1,000 mg/kg PAH, depending on the federal state), it is classified as hazardous waste under waste code AVV 17 03 01*.

The disposal methods used to date can essentially be divided into three categories:

- Landfilling: A large proportion of the material is deposited in landfills or used as a substitute for landfill material. This permanently removes mineral resources from the recycling cycle and places a strain on increasingly scarce landfill capacity.
- Thermal treatment internationally: As there were no large-scale plants in Germany for a long time, tar-containing asphalt was often exported to the Netherlands (e.g. REKO in Rotterdam) for thermal treatment.
- Cold recycling: To a limited extent, material is cold-recycled in situ (on site) or in stationary plants with the addition of binders; however, the pollutants remain within the road structure and are merely ‘encapsulated’.

The disposal methods used to date involve considerable economic burdens:

- High disposal costs: The disposal of tar-containing asphalt is considered to be exceptionally cost-intensive. Whilst disposal prices of approximately €95.00 per tonne (net) are standard for single-grade, tar-free asphalt (AVV 17 03 02) disposal prices of around €95.00 per tonne (net) are standard on the market, the costs for tar-contaminated materials are significantly higher due to their classification as hazardous waste. In the case of heavily contaminated construction waste that must be landfilled, prices can rise to over €200.00 per tonne.
- Shortage of landfill space: The majority of the material is currently disposed of in landfill sites (DK II or higher). As the remaining landfill capacity in Germany is estimated to last for only about 11 years, this shortage is leading to a trend of steadily rising costs.
- Additional logistical costs: A significant proportion of the tar-containing asphalt is exported to the Netherlands for thermal treatment. This disposal route is not only environmentally harmful due to the long transport distances involved, but is also economically unattractive because of the administrative burden (e.g. notification procedures for cross-border waste shipments) and the high acceptance fees charged by plant operators.
- Indirect follow-on costs: According to the Federal Audit Office, the reuse of PAH-containing material in bound layers (cold recycling) leads to increased follow-on costs during subsequent refurbishments, as the pollutants are not destroyed but merely relocated within the road structure.

3.1 Ban on Reuse Since 2015

A pivotal turning point was the General Circular on Road Construction (ARS) No. 16/2015 issued by the German Federal Ministry of Transport [5]. Based on recommendations from the Federal Audit Office, it was decided that PAH-containing materials (>25 mg/kg) may no longer be used in federal highways starting in 2018. This measure aims to fully remove carcinogenic substances from the material cycle, rather than merely relocating them through "encapsulation" in the road structure [5]. The revised Substitute Materials Ordinance (EBV), effective since August 2023, further excludes the reuse of tar-containing materials without prior destruction of pollutants [4].

3.2 Challenges of Thermal Treatment and the "Quartz Jump"

Until recently, thermal treatment was often the only high-quality disposal route—though due to the lack of domestic large-scale facilities, it primarily involved exporting material to the Netherlands (e.g., REKO in Rotterdam) [10]. These facilities operate at temperatures between 850 °C and 1,000 °C [10].

However, this process is technically problematic: above approximately 573 °C, quartz-containing aggregates undergo a structural phase change known as the "quartz jump". This transformation causes volume expansion and a significant reduction in mechanical strength [10]. The resulting material loses its original quality and is often unsuitable for high-performance applications such as asphalt wearing courses or binder layers [10].

4. A New Approach to Sustainable Processing

The key consideration when it comes to the optimized processing and disposal of tar-containing road rubble is to reduce costs. As current disposal methods are billed in euros per ton, it makes sense to separate the tar-containing binder from the aggregate and dispose of it separately. This is because the aggregate is the main driver of disposal costs. Consequently, a wide range of options for separating the aggregate from the binder have been investigated. This ultimately led to the development of the wet separation process, which can be implemented in a compact manner within a hall covering an area of approximately 500 square meters (Figure 1).

Figure 1. View of the processing plant



4.1 Advantages of Selective Separation

The core advantage of this new approach lies in the recovery of mineral resources—comprising about 95 % of asphalt—as high-quality secondary raw materials in their original condition [9]. By avoiding high temperatures, the quartz jump is prevented, preserving the original compressive and impact strength of the aggregates. This enables full reintroduction into the cycle for producing high-load asphalt layers (e.g., Bk32 to Bk100) [9].

Additionally, this method delivers significant environmental benefits:

- Pollutant destruction: The hazardous PAHs are not disposed of or relocated but are selectively removed and permanently destroyed.
- Resource conservation: The demand for primary aggregates from quarries is drastically reduced, minimizing new mining activities.
- CO_2 reduction: Regional processing eliminates long-distance transport, significantly improving the environmental footprint of road construction [9].

4.2 The Hydro-Mineral Process: Technical Implementation

The main advantage of this approach is that the mineral resources – which account for around 95 % of the asphalt – are retained as a fully-fledged secondary raw material of primary quality [9]. By avoiding high temperatures, quartz fracture is prevented, meaning that the rock retains its original compressive strength and resistance to fragmentation. This enables unrestricted recycling into the production cycle for new asphalt layers of the highest load-bearing classes [9].
Furthermore, this approach makes a massive contribution to environmental protection:

- Pollutant destruction: Hazardous PAHs are not landfilled or transferred elsewhere, but are specifically removed from the cycle and permanently destroyed.
- Resource conservation: The demand for primary rock from quarries falls dramatically, which reduces the need for new quarrying sites.
- CO_2 reduction: Regional processing sites eliminate the need for long-distance transport, which significantly improves the environmental footprint of road construction [9].

The Hydro-Mineral Recycling process utilizes a water-based separation technology that has been in industrial use since 2025. It operates without high temperatures, chemical solvents or extreme cold, relying instead on the physical properties of water and mechanical vibration. The tar-containing road rubble is first mechanically crushed and conveyed into a trough-shaped continuous-flow vibrator. Vibration fluidizes the material, causing it to enter a vortex-like circulation movement. High-pressure water jets (approx. 1,500 bar) remove the binder coatings. The separated components are classified as follows: 40 per cent primary-grade chippings, 45 per cent primary-grade sand and 15 per cent filter cake. The filter cake is incinerated as a substitute fuel in cement works, whereby the pollutants are destroyed and the filler is incorporated into the clinker [9].
The separation process, which is divided into several coordinated phases, is described in more detail below.

- Material feeding and pre-treatment: The tar-containing road rubble is first mechanically crushed, ideally using a twin-shaft crusher, to break up agglomerates without damaging the mineral structure [9]. The material prepared in this way is conveyed into a receiving hopper, which is designed as a trough-shaped continuous-action vibrator.
- Fluidisation and trowalisation: Inside the trough, the material is set into continuous vibration by an unbalanced motor (actuator). This vibration causes the building material to become fluidised, so that it behaves like a liquid and enters a vortex-like circulatory motion [9]. This state is essential for the so-called abrasion (grinding effect), during which the aggregate particles rub against one another through their own movement and mechanically loosen the binder coatings.
- High-pressure application: During circulation, several high-pressure water jets with an operating pressure of approx. 1,500 bar (technically possible ranges from 1,000 to 5,000 bar) strike the material [9]. The impact energy of the water acts selectively on the interface between the aggregate and the binder. The combination of water pressure and the turbulence generated by vibration efficiently strips even stubborn, brittle tar deposits from the aggregate surface.
- Multi-stage separation: At the base of the continuous-action vibrating screen are screens with mesh sizes ranging from 1 mm to 22 mm. Whilst the cleaned aggregate remains in the trough or

is discharged at the end, water, sand and detached tar mastic flow through the screens. In a downstream hydrocyclone, the fine sand fractions (0.063 mm to 1 mm) are separated from the contaminant-laden water-filler mixture [9].

- Clarification and filtration: The contaminated process water is treated in a decanter and thickener. The separated pollutants and mineral solids (< 0.063 mm) are pressed into a solid filter cake in a filter press, whilst the purified water remains in the cycle [9].

In direct comparison with conventional methods, the water-based separation process offers significant environmental and technical advantages.
Whilst thermal treatment requires large quantities of fossil fuels, the process described here is fully electric, with the option to use green electricity, and enables a drastic reduction in CO_2 emissions through regional processing, as long-distance transport is no longer required [9]. Technically, it outperforms thermal processes by preserving the quality of the rock, as the mechanical stability of the mineral phase is not compromised below the quartz transition temperature [10]. The aggregate retains its original compressive and impact strength and can be used in asphalt base, binder and surface courses. When reused in the asphalt base course, this can be done up to the highest load classes (Bk32 to Bk100).
Compared with cold recycling (KRC), the key advantage is that pollutants are not merely 'encapsulated' within the road structure – thereby passing the problem on to future generations – but are specifically and sustainably removed from the material cycle [9].
Compared with dry mechanical crushing processes, which often result only in non-specific grain size reduction, high-pressure water separation enables selective and extensive cleaning of rock surfaces, resulting in a secondary raw material that is virtually equivalent to the primary material in terms of processability. A particular advantage for asphalt mixing plants is that, due to the absence of a binder coating, the largely 'clean' chippings can be fed via the white drum in a similar way to primary rock. This means that even plants without specialized recycling technology can achieve high substitution rates. For the first time, this makes genuine 'horizontal recycling' at the highest quality level economically viable [9].

The process achieves a 95 % recycling rate, with outputs distributed as follows:

- 40 % primary-grade aggregate (splitt),
- 45 % primary-grade sand,
- 15 % filter cake.

The filter cake, containing concentrated PAHs and mineral filler, is used as a substitute fuel in cement plants. At combustion temperatures above 1,000 °C in a clinker kiln, organic pollutants (PAHs) are permanently destroyed, while the mineral filler is chemically integrated into the cement matrix—ensuring complete, safe removal of toxic substances from the cycle [9].

4.3 Advantages Over Existing Methods

Compared to conventional approaches, the water-based separation process offers significant ecological and technical advantages. While thermal treatment requires high fossil fuel consumption, this process operates fully electrically—with the option to use green electricity—and enables regional processing, drastically reducing CO_2 emissions from transport [9]. Technically, it surpasses thermal methods by preserving aggregate quality, as mechanical stability remains intact below the quartz jump threshold [10].

Unlike cold recycling (KRC), which only encapsulates pollutants, this method permanently removes them from the cycle [9]. Compared to dry mechanical crushing, which often only refines particle size, the high-pressure water separation enables selective, near-complete cleaning of aggregate surfaces—producing a secondary raw material that matches primary material in processability.
A key advantage for asphalt plants is that the clean aggregate, free of binder residues, can be fed via the "white drum" like primary material—enabling high substitution rates even in facilities without specialized recycling technology. This makes true horizontal recycling at the highest quality level economically viable for the first time [9].

5. Relevance for the Canadian Road Sector

The challenge of managing tar-containing asphalt waste is not limited to Germany—it is a global issue, particularly relevant for Canada. In Canada, millions of tonnes of road construction and paving materials containing coal tar pitch were used between the 1950s and 1980s, especially in provinces such as Ontario, Quebec, and British Columbia [12]. Estimates suggest that up to 150 million tonnes of tar-containing materials remain in the Canadian road network [12].

5.1 Canadian Regulatory and Climate Framework

- Climate Targets: Canada is committed to net-zero greenhouse gas emissions by 2050 under the Climate Accountability Act (2021) [13]. The transportation and infrastructure sector contributes approximately 10 % of national CO_2 emissions, including those from material production and disposal [14].
- Waste Reduction: The Province of Ontario aims to recycle 80 % of construction and demolition waste by 2030 [15]. In British Columbia, the Zero Waste Strategy 2030 explicitly includes tar-contaminated materials.
- Regulations: Under the Canadian Environmental Protection Act (CEPA) and provincial laws (e.g., Ontario's Environmental Protection Act), materials with PAH levels exceeding 25 mg/kg are classified as hazardous waste, severely restricting their use in road construction [16].

5.2 Adaptation of the Process to Canadian Conditions

The Hydro-Mineral process is ideally suited for the Canadian context because:

- It requires no thermal processing, reducing dependence on fossil fuels—critical in remote or high-cost energy regions (e.g., Northern Canada).
- It enables local processing, eliminating long-distance transport to overseas thermal facilities—directly reducing CO_2 emissions and truck traffic.
- It uses no chemical solvents, minimizing risks to groundwater and sensitive ecosystems (e.g., boreal forests, lakes).
- It recovers primary-grade aggregates and sand, significantly reducing the need for quarrying—aligning with environmental protection goals and Indigenous land stewardship principles.

5.3 Potential Pilot Projects in Canada

- Alberta: Deployment in the Calgary region, where many roads from the 1970s require rehabilitation.

- British Columbia: Integration into the BC Road Maintenance Program to support Zero Waste Strategy 2030.
- Ontario: Collaboration with the Ministry of Transportation (MTO) to establish a pilot center for tar-contaminated asphalt recycling.

This technology offers a technically secure, environmentally sustainable, and economically viable solution that directly aligns with Canada's climate, waste, and resource goals. Through decentralized, regional facilities, it can reduce disposal costs, create local jobs, and reduce reliance on imports—making it a true catalyst for the green transformation of Canada's infrastructure sector.

6. Conclusions

The treatment of tar-containing asphalt granulate represents one of the key challenges for sustainable infrastructure development – both in Germany and worldwide. This analysis shows that traditional disposal methods, such as landfill, export for thermal treatment or cold recycling, are not only environmentally problematic but also economically unsustainable. They either lead to the permanent devaluation of valuable resources, the release of pollutants into the environment, or significant follow-on costs arising from future remediation work. The legal framework, in particular the Circular Economy Act (KrWG) and the General Circulars on Road Construction (ARS), has reinforced this trend and made the need for high-quality, sustainable recovery unequivocal.

The new approach of water-based separation using hydro-mineral recycling represents a decisive paradigm shift in this regard. It resolves the classic dilemma between resource conservation and the destruction of pollutants. By avoiding high temperatures, the critical 'quartz fracture' in quartz-containing rock is prevented, meaning that the mineral components – which make up around 95 per cent of the asphalt – retain their original mechanical quality.

A further key advantage lies in the comprehensive removal of pollutants from the asphalt or road surface. In contrast to cold recycling, where pollutants are merely 'encapsulated', the PAHs and other pollutants are specifically and permanently removed from the material cycle using the hydro-mineral process. The filter cake, consisting of the concentrated pollutants and the mineral filler, is incinerated as a substitute fuel in cement works. At combustion temperatures exceeding 1,000 °C in the clinker kiln, the organic pollutants are irreversibly destroyed, whilst the mineral component is incorporated into the cement clinker.

The environmental benefits are significant: the fully electric, regionally based treatment process eliminates the need for long-distance transport, which substantially reduces CO_2 emissions. The use of green electricity is possible, which further improves the carbon footprint. Furthermore, dependence on primary rock from quarries is drastically reduced, thereby minimising the need for new quarrying sites and the impact on sensitive ecosystems.

The relevance to the Canadian context is particularly high. With an estimated volume of up to 150 million tonnes of tar-containing asphalt in the road network and ambitious climate targets such as the net-zero commitment by 2050, Canada is reliant on sustainable solutions. The decentralised implementation of the process enables the creation of local jobs and the strengthening of regional value chains.

7. Summary and Outlook

The development of Hydro-Mineral Recycling's water-based separation process marks a significant paradigm shift in the management of tar-containing road construction materials. For the first time, it

enables the large-scale recovery of high-quality rock resources from hazardous waste – without having to accept the drawbacks of conventional thermal processes. Unlike landfill, export or cold recycling, this process not only preserves the resource but also permanently destroys the pollutants and removes them from the material cycle.
The key innovation lies in the mechanical-physical high-pressure water separation process, which operates without chemical solvents and without thermal stress. This prevents the critical 'quartz fracture' in quartz-bearing rock, ensuring that the mineral components retain their original compressive and impact strength. The recovered chippings and sand achieve primary-grade quality and can be used without restriction in asphalt base courses of the highest load classes (Bk32 to Bk100). A particular advantage for asphalt mixing plants is that, due to the absence of a binder coating, the clean crushed stone can be fed via the white drum in much the same way as virgin aggregate – even plants without specialised recycling technology can achieve high substitution rates.
The environmental and economic benefits are significant:

- CO_2 reduction through regional processing and the possibility of fully electric operation with the option to use green electricity.
- Conservation of resources through a massive reduction in the demand for primary aggregate from quarries.
- Cost savings due to lower disposal costs compared with international thermal treatment.
- Safety through the complete destruction of PAHs in cement works.

The relevance for Canada is of particular significance. With an estimated volume of up to 150 million tonnes of tar-containing asphalt in its road network and ambitious climate targets such as the net-zero commitment by 2050, Canada is reliant on sustainable solutions. The decentralised implementation of the process enables the creation of local jobs, the strengthening of regional value chains and the integration of First Nations into the circular economy. Pilot projects in Alberta, British Columbia and Ontario could serve as a model for a national strategy.
The launch of the first construction project in autumn 2026 is a crucial milestone. In this process, tar-containing rubble extracted from a construction site is processed on-site and reused as a high-quality secondary construction material in road surfaces. This step demonstrates the technology's practical viability and sets an example for future implementations.
In the long term, this technology has the potential to resolve the disposal crisis surrounding tar-containing asphalt, reduce dependence on primary raw materials and make a decisive contribution to climate protection and resource conservation in asphalt road construction. Further research and development work is required to enable its use in asphalt binder and surface courses. In this context, real-world construction projects that are continuously monitored are particularly important. The future of road construction lies not in waste management, but in transforming waste into tangible value. The Hydro-Mineral Recycling process is not merely a technological innovation – it is a step towards a more sustainable, resilient and circular infrastructure.

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