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Pavement Structures Made of Cobblestones and Slabs in German-Speaking Countries: A Practice-Oriented Technical Overview

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ABSTRACT

Pavement structures made of cobblestones and slabs are widely applied in urban traffic areas, historic city centres, public spaces and low- to medium-loaded road infrastructures in German-speaking countries. Unlike monolithic asphalt or concrete pavements, these systems consist of segmented surface elements with jointed construction, resulting in distinct load transfer mechanisms and deformation behaviour. Their structural performance is therefore governed not only by the paving material itself but predominantly by construction principles, joint configuration, edge restraint effectiveness and drainage conditions. This technical overview synthesises guideline-based knowledge and practical experience on pavement structures made of cobblestones and slabs, covering flexible, rigid and mixed construction methods. Typical paving materials—including natural stone blocks, natural stone slabs and concrete paving elements—are discussed together with key design parameters such as joint widths, minimum slab thicknesses and laying patterns for traffic areas. Furthermore, typical damage mechanisms affecting cobblestone and slab pavements, including settlement phenomena, surface damage, joint deterioration and kerb-related defects, are systematically classified based on established guidelines and field observations. Maintenance, rehabilitation and reconstruction strategies are outlined, with particular emphasis on drainage performance and water-permeable pavement systems. The paper provides a consolidated technical reference intended to support international comparison and informed decision-making in the design, construction and maintenance of cobblestone and slab pavements. The paper is positioned as a technical overview contributing to road materials selection and pavement design practice rather than experimental performance evaluation.

1. Introduction

Cobblestone and slab pavements have been used for centuries in road construction and urban design and continue to play an important role in German-speaking countries. Their application ranges from historic city centres and representative public spaces to pedestrian zones, traffic-calmed streets, bus stops and industrial areas. In addition to architectural and heritage aspects, these pavements are selected for their durability, reparability and adaptability to local functional requirements. Structurally, pavements made of cobblestones and slabs differ fundamentally from asphalt and concrete pavements.

They consist of discrete surface elements separated by joints and supported by bedding and base layers. Load transfer occurs through interlock between paving elements, joint filling material and the supporting layers beneath. Consequently, the performance of these pavements is highly sensitive to construction quality, joint behaviour, edge restraint effectiveness and water management. This overview summarises the structural concepts, material characteristics, typical damage mechanisms and maintenance approaches for cobblestone and slab pavements as applied in German-speaking countries, based on established technical practice and guideline-based knowledge.

2. Types of Pavement Structures Made of Cobblestones and Slabs

Pavement structures made of cobblestones and slabs can be classified according to their structural behaviour and load transfer mechanisms into flexible, rigid and mixed construction systems. This classification is commonly used in practice and provides a framework for selecting suitable pavement types depending on traffic load, subsoil conditions and functional requirements.

2.1. Flexible pavement structures

In flexible pavement structures, cobblestones or slabs are laid on an unbound bedding layer, typically consisting of sand or fine crushed aggregates. Load transfer occurs primarily through interlock between adjacent paving elements and deformation of the bedding and base layers. A typical flexible pavement structure with unbound bedding and base courses is illustrated in Figure 1.

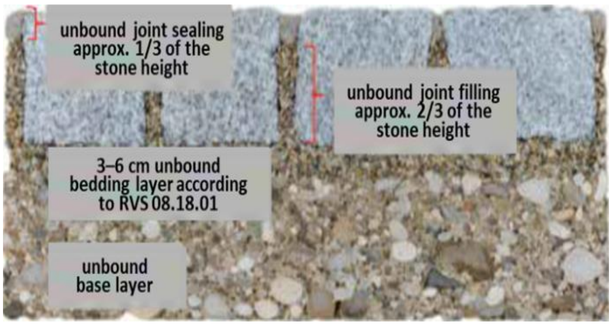

Figure 1. Cross-section of an installed cobblestone pavement (shown here with 8/10 cm granite blocks) constructed using the flexible method
Source: FSV-Seminar, 2016 (edited by author)

Flexible systems are widely applied in pedestrian areas, residential streets and lightly trafficked zones. Due to their deformation capacity, these pavements can accommodate minor settlements without immediate structural failure. However, insufficient joint filling, inadequate compaction of the bedding layer or ineffective edge restraints may lead to progressive deformation and surface unevenness under repeated traffic loading.

2.2. Rigid pavement structures

Rigid pavement structures made of cobblestones and slabs are characterised by a bound bedding or base layer, commonly consisting of cement-bound material or concrete. In this configuration, the paving elements primarily act as a wearing surface, while load distribution is governed by the stiffness of the bound layer. A schematic example of a rigid construction method is shown in Figure 2.

Figure 2. Cross-section of a rigidly constructed cobblestone pavement with 8/10 cm granite blocks according to RVS 08.18.01
Source: FSV-Seminar, 2016 (edited by author)

Rigid systems exhibit reduced deformation under load and are therefore suitable for higher traffic loads, such as bus lanes, intersections or industrial traffic areas. However, they are more sensitive to thermal and moisture-induced movements. Joint design and detailing are therefore decisive for preventing cracking or debonding of paving elements, as emphasised in practice literature and guidelines.

2.3. Mixed pavement structures

Mixed pavement structures combine elements of flexible and rigid construction. Typical configurations include partially bound bedding layers or transitions between rigid edge zones and flexible central pavement areas. An example of a mixed construction approach is illustrated in Figure 3, showing the combination of different structural principles within one pavement system.

Figure 3. Sett pavement (paving elements) for the “composite” installation method (with cement-mortar joint filling) on an unbound (flexible) upper supporting layer
Source: FSV-Seminar, 2016 (edited by author)

Mixed systems are often selected to balance load-bearing capacity, construction feasibility and maintenance requirements, particularly in urban areas with heterogeneous loading conditions.

3. Paving Materials

3.1. Natural stone blocks

Natural stone cobblestones are commonly produced from igneous or metamorphic rocks such as granite, basalt or gneiss. They exhibit high compressive strength, excellent abrasion resistance and long service life. Due to their durability, natural stone blocks are frequently used in historic pavements and in areas subjected to higher traffic loads (ÖNORM B 3108, 2014).

3.2. Natural stone slabs

Natural stone slabs provide a comparatively smooth surface and are widely used in pedestrian zones and representative public spaces. Their structural performance depends strongly on slab thickness, bedding conditions and joint width. Insufficient slab thickness may result in cracking or breakage under traffic loads, particularly in rigid bedding systems.

3.3. Concrete paving elements

Concrete paving elements are manufactured with standardised geometry and defined material properties. They are widely applied due to economic efficiency, availability and design flexibility. Concrete blocks and slabs can be produced with specific surface textures and colours, allowing adaptation to functional and aesthetic requirements.

4. Joint Widths, Slab Thicknesses and Laying Patterns

Joint width is a key design parameter governing load transfer, deformation behaviour and durability of cobblestone and slab pavements. Recommended joint widths for different paving elements and construction methods are summarised in Table 1. Excessively wide joints reduce interlock efficiency, whereas overly narrow joints may be prone to clogging or damage.

Minimum slab thicknesses required for traffic-bearing applications are provided in Table 2. As shown in Table 2, insufficient slab thickness may lead to cracking or breakage under traffic loading, particularly when combined with rigid bedding conditions.

Laying patterns significantly influence load distribution and structural performance. Interlocking patterns such as herringbone arrangements enhance load transfer and are therefore preferred in trafficked areas, whereas linear patterns are typically limited to pedestrian applications.

Table 1. Joint widths for the rigid and mixed construction methods for cobblestones and slabs according to the Austrian standard

No.	type / description	required joint width
1	slabs type PP1 to PP6 with sawn side surfaces (minimum surface roughness: sandblasted) according to ÖNORM B 3108:2006	8 mm to 20 mm
2	slabs type PP1 and PP2 with split side surfaces according to ÖNORM B 3108:2006	8 mm to 20 mm
3	(missing number in original – continues sequence) slabs according to ÖNORM B 3108:2006	8 mm to 20 mm
4	small stone cube type KPS1 to KPS3 according to ÖNORM B 3108:2006	8 mm to 15 mm
5	mosaic stone cube type MPS1 according to ÖNORM B 3108:2006	8 mm to 15 mm
6	setts and slabs with sawn side surfaces (minimum surface roughness: sandblasted)	8 mm to 15 mm
7	setts and slabs with split side surfaces	8 mm to 20 mm
8	setts and slabs made of artificial stone	8 mm to 15 mm
9	small stone cube and mosaic stone cube	8 mm to 15 mm

Source: Author according to ÖNORM B 2214, 2020

Table 2. Required minimum slab thicknesses depending on slab dimensions (L=slab length, B=slab width) upper table for natural stone slabs, lower table for concrete slabs

slab format up to L/B [cm] natural stone	minimum slab thickness [cm]
24/24	8
32/32	10
36/24	10
48/32	12
48/48	12
72/48	14
slab format up to L/B [cm] concrete slabs	**minimum slab thickness [cm]**
30/30	10
40/40	12
50/50	14
60/40	16
75/50	18
100/100	18

Source: Author according to ÖNORM B 2214, 2020

5. Laying Cobblestones and Slabs

Laying at a right angle in rows (Figure 4) has good load-bearing capacity. The following points are essential for this laying method:

- Laying stones in rows, preferably of the same stone size.
- The stones overlap by 1/2 of the stone's width relative to the next row.

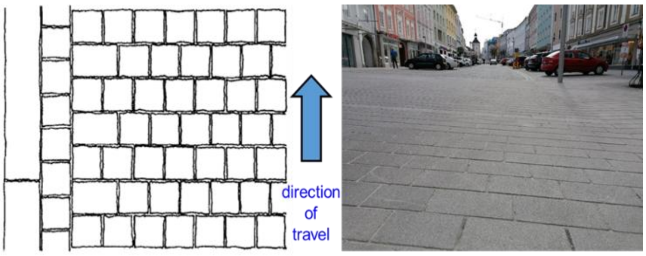

Figure 4. Example of laying slabs in rows at a right angle
Source: RVS 08.18.01, 2009 (edited by author)

Figure 5 shows that “diagonal laying in rows” provides good load-bearing capacity. The following points are essential for this laying pattern:

- Laying stones in rows, preferably of the same stone size.
- The rows are laid at a 45° angle to the road axis, i.e., the direction of travel.
- At the edge, a stone with five corners, a so-called "Bishop's Mitre" (marked in red in Figure 5 – Germ. *Bischofsmütze*) or a stone with three corners, a so-called "three-corner piece" (Germ. *Zwickel*), with dimensions of 15/15 cm, is placed.

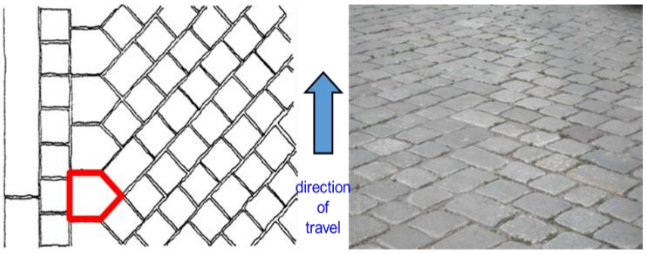

Figure 5. Example of diagonal laying in rows
Source: Litzka and Nowotny, 2006 (edited by author)

The main characteristics of paving in rows with slabs of different widths (Figure 6) are:

- Laying in rows with elements of the same width in one row.
- The laying must be carried out in a straight line relative to a reference line.
- The overlap of the slabs relative to the slabs in the adjacent row is 1/3 to 1/2 of the slab length.
- Laying at a right angle in rows has good load-bearing capacity.

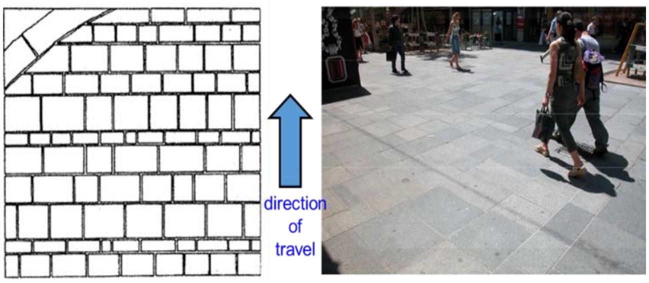

Figure 6. Paving in rows with slabs of different widths
Source: Litzka and Nowotny, 2006 (edited by author)

Diagonal laying of slabs with cross joints (Figure 7) requires uniform slabs with precise dimensions that are laid in rows without overlapping, thereby creating cross joints. Laying slabs with cross joints in a diagonal direction has a higher static load-bearing capacity than laying slabs with cross joints that run parallel to the reference line. Generally speaking, laying cobblestones in a diagonal direction relative to the reference line increases the static load-bearing capacity of the paved surface. Laying slabs "with cross joints" that run parallel to the reference line (direction of travel) is unsuitable and therefore prohibited for trafficked areas used by motor vehicles.

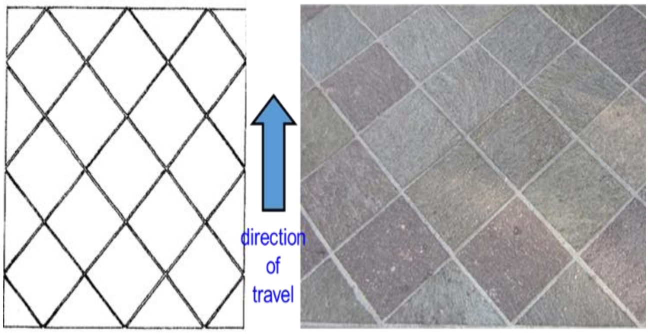

Figure 7. Diagonal paving with cross joints
Source: RVS 08.18.01, 2009 (edited by author)

Figure 8 shows "Roman paving", while Figure 9 shows "Polygonal paving".

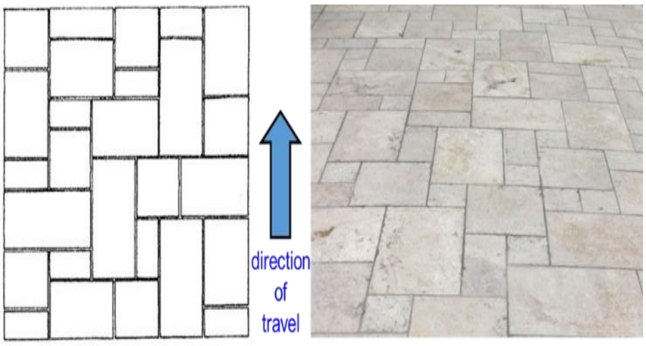

Figure 8. Roman paving
Source: RVS 08.18.01, 2009; Pinimg, 2021 (edited by author)

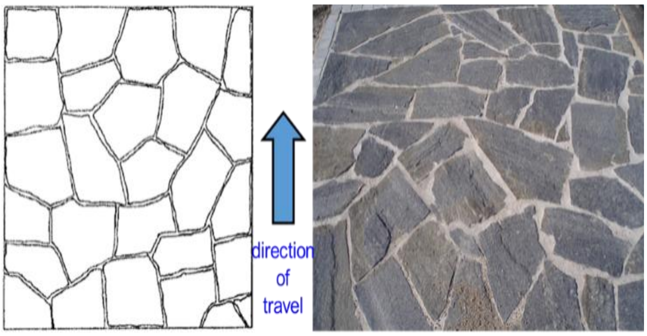

Figure 9. Polygonal paving
Source: RVS 08.18.01, 2009; Granier-Diffusion, 2021 (edited by author)

6. Damage to Pavement Structures Made of Cobblestones and Slabs

Laying at a right angle in rows (Figure 4) has good load-bearing capacity. The following points are essential for this laying method:

6.1. Damage to Kerbs

Damage to kerbs that delimit or structurally support pavement surfaces made of cobblestones or slabs can be categorised (Hoffmann, 2013) (Figure 10):

1. Insufficient joint-filling material: Causes may include settlement and mechanical loading, erosion due to weather exposure, chemical influences (such as de-icing agents), and freeze–thaw effects.
2. Irregular or poorly executed patch repairs on the footpath: Causes may include inadequately processed joints, settlement due to insufficient compaction of the surrounding material, or poorly compacted trench backfill in areas adjacent to the kerb.
3. Kerb displacement and detachment of thin asphalt layers: Causes may include kerb settlement, mechanical impacts (e.g. from heavy or off-road vehicles), or localised edge pressure.
4. Kerb settlement accompanied by cracking in the drainage channel zone: Causes may include insufficient compaction of the base layers, cobblestones or slabs not bearing properly, and erosion caused by surface runoff.
5. Manhole settlement accompanied by surrounding cracking: Causes may include poor installation of the manhole, drainage pipes that do not fit correctly, joint widening, or erosion of the bedding layer.

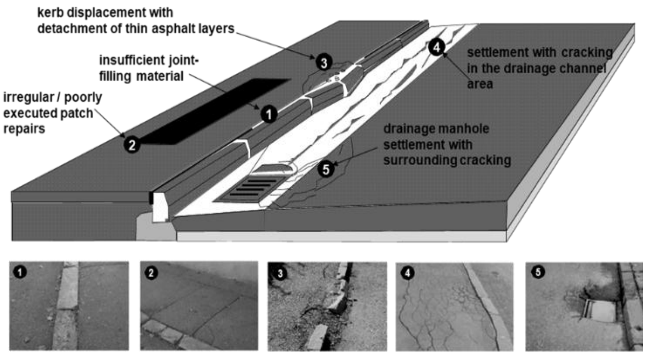

Figure 10. Types of kerb damage affecting pavement structures made of cobblestones and slabs
Source: Hoffmann, 2013 (edited by author)

Practical examples of these types of kerb damage are shown in Figures 11 to 16.

Figure 11. Insufficient joint-filling material at the kerb and cracking in the asphalt footpath
Source: Hrapović, 2025

Figure 12. Irregular and poorly executed patch repairs on the footpath

Source: Hrapović, 2025

Figure 13. Example of kerb displacement and detachment of thin asphalt layers
Source: Hrapović, 2025

Figure 14. Example of kerb displacement and detachment of thin asphalt layers
Source: Hrapović, 2025

Figure 15. Example of kerb displacement

Source: Hrapović, 2025

Figure 16. Settlement with cracking in the drainage channel area
Source: Hrapović, 2025

6.2. Surface Damage to Pavement Structures Made of Cobblestones and Slabs

Surface damage to cobblestone and slab pavement structures can be categorised according to Hoffmann (2013) (Figure 17):

1. Open joints and tilting of cobblestone elements: Causes may include erosion of the joint mortar or the bedding layer beneath the cobblestones, excessively wide joints between individual elements, or missing or loosened edging of the cobbled surface.
2. Chipping or breakage of cobblestone elements: Causes may include incorrect structural design (e.g. slabs that are too large in combination with insufficient thickness), unsuitable materials for the paving elements, excessive traffic loading, and freeze–thaw effects.
3. Complete loosening and loss of stones or slabs: Causes may include full separation of cracked slabs from the bedding layer and loss of loosened slabs under traffic loading when timely maintenance is not carried out.
4. Asphalt patches as provisional repairs on the paved surface: Causes may include short-term repair measures carried out by road maintenance services using asphalt patches.

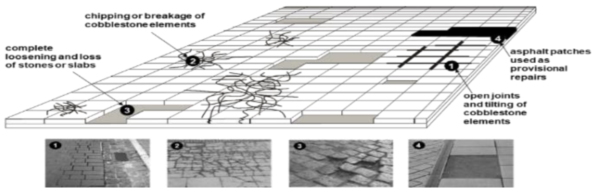

Figure 17. Types of surface damage in pavement structures made of cobblestones and slabs *Source: Hoffmann, 2013 (edited by author)*

6.3. Types of Settlement in Pavement Structures Made of Cobblestones and Slabs

Settlement of cobblestone and slab pavement structures can be categorised according to Hoffmann (2013) (Figure 18):

1. Dish-shaped depressions with local unevenness: Causes may include erosion of the joint mortar or the bedding layer beneath the cobblestones, insufficient bearing capacity of the subgrade, or inadequate drainage.
2. Rutting: Causes may include traffic channelisation, a high proportion of heavy vehicles, increased loading on uphill sections, curves and intersections, or settlement within the bedding layer.
3. Temporary (provisional) resurfacing by filling ruts: Provisional filling of deeper rut depressions in the longitudinal direction using, for example, hot or cold asphalt mixtures at locations where more pronounced surface settlement has occurred.
4. Irregular corrugations and local unevenness: Causes may include insufficient compaction of the subgrade and supporting layers, heaving of the pavement structure due to frost action, or the lateral displacement of lower supporting layers from loaded wheel paths into unloaded areas.

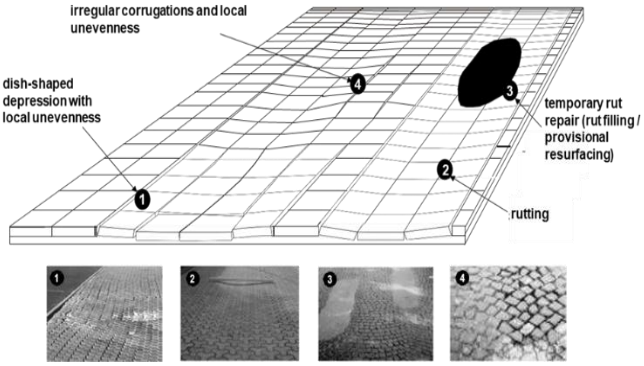

Figure 18. Types of settlement in pavement structures made of cobblestones and slabs
Source: Hoffmann, 2013 (edited by author)

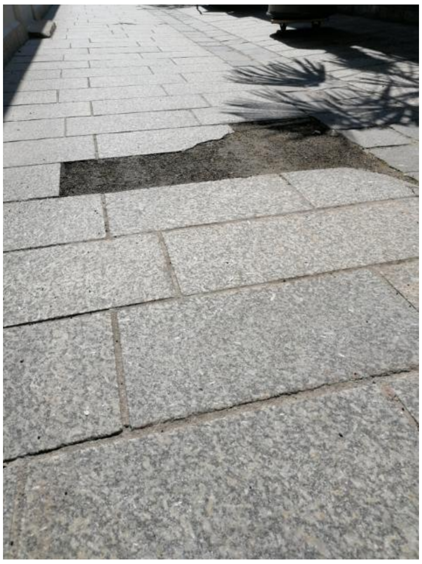

Figure 19. Asphalt-filled patches on a paved surface
Source: Hrapović, 2025

Figure 20. Asphalt-filled patches on a paved surface
Source: Hrapović, 2025

Figure 21. Asphalt-filled patches on a paved surface
Source: Hrapović, 2025

Figure 22. Open joints and tilting of cobblestone elements
Source: Hrapović, 2025

Figure 23. Open joints and tilting of cobblestone elements
Source: Hrapović, 2025

Figure 24. Open joints and tilting of cobblestone elements
Source: Hrapović, 2025

Figure 25. Rutting
Source: Hrapović, 2025

Figure 26. Rutting
Source: Hrapović, 2025

Figure 27. Open joints between slab elements
Source: Hrapović, 2025

Figure 28. Asphalt-filled patches at a pedestrian crossing made of marble and granite cobblestones
Source: Hrapović, 2025

Figure 29. Asphalt-filled patches at a pedestrian crossing made of marble and granite cobblestones
Source: Hrapović, 2025

Figure 30. Partially grouted joints filled with mortar
Source: Hrapović, 2025

Figure 31. Partially grouted joints filled with mortar
Source: Hrapović, 2025

Figure 32. Cracked granite slabs
Source: Hrapović, 2025

Figure 33. Irregular settlement of cobblestone and asphalt elements
Source: Hrapović, 2025

7. Strengthening, Rehabilitation, Improvement, and Reconstruction of Pavements Made of Cobblestones and Slabs

Pavement structures made of natural stone, concrete, clinker, and similar materials are often the first choice of designers and municipal authorities when considering the aesthetic appearance of town and city centres, due to the wide variety of designs and available paving options. Nevertheless, their application must be carefully considered, as these types of pavement structures are not suitable for all traffic situations and require meticulous planning as well as proper construction execution. If these aspects are neglected, various types of damage to cobblestone and slab pavements may easily occur, such as:

- loss of joint-filling material,
- “loosened” cobblestones (movement of stones under load),
- displacement of individual paving elements,
- formation of light-coloured deposits on the surface,
- breaking or chipping of element edges,
- open or widened joints between elements,
- loss of interlock within the paved surface (loss of mutual element connectivity).

Manufacturers of paving elements have responded to such types of damage by developing new products with specially enhanced interlocking features—either between individual elements or between the element and its bedding layer. However, this approach cannot prevent the occurrence of the damage listed above, since the true causes lie in insufficient structural design of the pavement system, as well as improper installation and joint filling. In the past, insufficient attention was paid to ensuring adequate permeability of these pavement structures and to guaranteeing the stability of the filter layers used in cobblestone and slab pavements. The deterioration process begins when surface water from rainfall cannot infiltrate quickly enough through the joints between paving elements and then percolate through the structural layers towards the drainage system. Traffic loading, especially heavy traffic, forces water trapped in the voids (pores) of the bedding layer sideways beneath the wheel paths. This movement displaces the bedding material and the joint-filling material. The appearance of light-grey deposits on the surface of cobblestones or slabs is a consequence of washing out fine particles (“pumping out”) from the bedding and jointing material after rainfall, especially when the used materials (sand or fine aggregates) do not possess sufficient resistance to grain fragmentation. To avoid such pavement damage, careful planning and structural design of the pavement are required, including a professional analysis of bus traffic loads, which is of particular importance on sections frequently used by public transport.

Furthermore, detailed knowledge of the materials used in the pavement structure and their suitability for the planned function of the roadway is essential. Adequate water permeability of the entire pavement system must be ensured—not only at the time of commissioning but throughout the entire service life of the roadway (Hrapović, 2025).

8. Conclusions

Pavement structures made of cobblestones and slabs in German-speaking countries are characterised by segmented surface elements, jointed construction and a pronounced dependence on construction quality, edge restraint effectiveness and drainage performance. Flexible, rigid and mixed construction methods provide adaptable solutions for a wide range of traffic and functional requirements; however, their long-term performance is governed less by the paving material itself than by joint configuration, bedding conditions and boundary detailing. Key design parameters include joint width, slab thickness and laying pattern, while the most frequent damage mechanisms are directly linked to settlement processes and joint-related deficiencies. Consequently, maintenance and rehabilitation strategies must primarily focus on preserving joint integrity, ensuring functional drainage and maintaining effective edge restraints rather than on surface replacement alone. The presented overview consolidates guideline-based knowledge and practical experience into a compact technical reference, supporting international comparison and informed decision-making in the design, construction and maintenance of cobblestone and slab pavements.

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