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Asphalt for underground and multi-storey car parks

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ABSTRACT

Underground car parks and multi-storey car parks are not ordinary buildings, but demanding engineering structures that require special knowledge of those involved in the construction in planning, execution and monitoring. Car parks and underground garages require a permanent seal or a functioning surface protection system to protect against damage from moisture, chloride-containing de-icing agents and dynamic loads. The mastic asphalts used meet all the requirements placed on the surfaces of underground car parks and multi-storey car parks, but the asphalt concrete layers used in special construction methods can also meet these requirements.

1. Introduction

1.1. Definition of car parking construction

The term "car parking construction" serves as a collective term for multi-storey car parks, underground garages and high-rise garages, which are subdivided into large, medium and small garages, as well as simple parking decks, each with parking spaces for parked passenger cars (*germ*. PKW = Personenkraftwagen).

The term "multi-storey car park" is used for a structure in which all ceilings are used exclusively for the parking of passenger cars [Lohmeyer & Ebeling 2020].

1.2. Division of car parking constructions

The car parking constructions are divided into open parking constructions, closed parking constructions, high-rise garages and underground garages. According to the size of the usable floor space, the garages are divided into:

- Up to 100 m^2 Small garages,
- Over 100 m^2 to 1000 m^2 medium garages,
- Over 1000 m^2 large garages [Beck-online 2021].

1.2.1 Open car parking constructions

Open car parking constructions are medium or large garages with permanently free cross-ventilation. High-rise garages are generally open car parking constructions (Fig.1). For cross-ventilation, open car parking constructions should have openings leading directly to the open air, which cannot be closed off, and the size of which is at least one third of the total area of the enclosing walls. These openings should be located in at least two opposing enclosure walls that are no more than 70 m apart. Above-ground car parking constructions mostly belong to the range of open car parking constructions [Lohmeyer & Ebeling 2020].

Figure 1. Large garage as an open parking structure
Source: Lohmeyer & Ebeling 2020

1.2.2 *Enclosed car parking constructions*

Medium or large garages are referred to as enclosed car parking constructions if they do not meet the requirements for open car parking constructions according to section 1.2.1. Underground garages are generally closed car parking constructions (Fig.2).

Figure 2. Large garage as a closed parking structure
Source: Lohmeyer & Ebeling 2020

Closed car parking constructions do not have natural cross-ventilation and require mechanical ventilation. Underground car parks are usually closed car parking constructions.

1.2.3 High-rise garages

Structures or parts of structures with above-ground parking spaces for cars are referred to as high-rise garages. According to the garage ordinances of the federal states, above-ground garages are generally garages whose floor in the lowest storey is on average no more than 1.50 m below the ground surface [Lohmeyer & Ebeling 2020].

1.2.4 Underground garages

Structures or parts of structures with parking spaces for cars that are located underground are referred to as underground garages. According to the garagerdinances of the federal states, underground garages are generally those garages whose floor on one storey is on average more than 1.50 m below the ground surface. Underground garages are often located underneath usual high-rise buildings (e.g. residential building, office building and shopping centres) or under squares, traffic areas or green spaces [Lohmeyer & Ebeling 2020].

1.2.5 Parking decks

Parking decks are the floor slabs in car parking constructions that are driven on and parked on. In general building construction, the floor slabs are referred to as "*ceiling*". In traffic route construction, a "*ceiling*" refers to the top layer as the uppermost part of the roadway structure. The term "*deck*" comes from English and is used internationally for the horizontal subdivision of ships. In the meantime, this term has also become common for car parking constructions. The term "*parking deck*" is used both for the intermediate parking decks (Zwischendeck ②) and for the roof parking deck (Freideck ③ or Topdeck) as the upper end of the building when vehicles can be parked there. It also applies to the low parking deck (ground deck ①) as the lower end of the building, if the ground slab of the parking building serves as a parking area. Traffic from the entrance to the parking decks is guided via ramps ④, likewise from one parking deck to another and also via the exit ramp back to the flowing traffic (Fig.3).

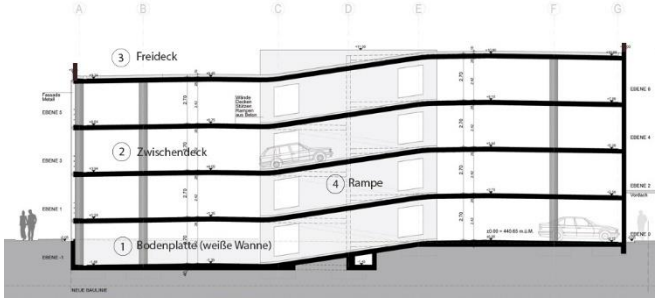

Figure 3. Main parts of car parking constructions
Source: Felsinger & Piringer 2016a

1.2.6 Ramps

The choice of ramp system is dependent on several influences, e.g.: Property dimensions, division of floor areas into lanes and parking spaces, number of parking spaces, type of use, traffic routing. Basically, four types of ramps can be distinguished, which are shown in Fig. 4: Full ramps, half ramps, spiral ramps, parking ramps [Lohmeyer & Ebeling 2020].

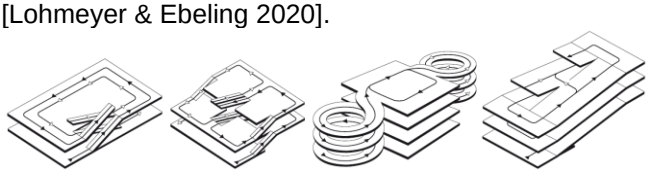

Figure 4. Ramp systems: a) Full ramps, b) Half ramps, c) Spiral ramps, d) Parking ramps
Source: FGSV 2005

The full ramps represent a connection with a straight run, usually inclination up to 10 % (Fig.5).

Figure 5. Full ramp in a large garage
Source: Lohmeyer & Ebeling 2020

The half-ramps are usually the connection of half-storeys, usually with a slope of up to 15 % (Fig. 6).

Figure 6. Example of a half ramp
Source: FGSV 2005

The spiral ramps represent storey changes via a spiral (half spiral, single and double full spiral); usually on the outside (Fig. 7).

Figure 7. An example of spiral ramp: Spiral driveway to a multi-storey car park in Braunschweig, Germany
Source: Wikipedia 2022

The parking ramps are part of the parking decks, designed for one-way or two-way traffic (Fig. 8).

Figure 8. Design of the driveway to level 1 as a parking ramp of an open large garage
Source: Bittermann GmbH 2022

1.3. Special requirements and stresses of car parking constructions

Parking decks and garages are actually traffic structures (i.e. sophisticated engineering structures) with very special requirements and stresses. Surfaces in freely weathered parking decks are exposed to different stresses than surfaces inside a parking garage (Fig.9):

- Thermal: humidity, wind, sun, freeze-thaw cycles.
- Mechanical: Tyre pressure, shear stress due to braking and starting, direct vibrations of the supporting structure or building.
- Chemical: Chloride - load from water brought in by cars, de-icing agents, oil and petrol.

The combination of waterproofing and asphalt wearing course (mastic asphalt or asphalt concrete) must permanently protect the structure - the supporting structure or the concrete - from these stresses [Felsinger & Piringer 2016b].

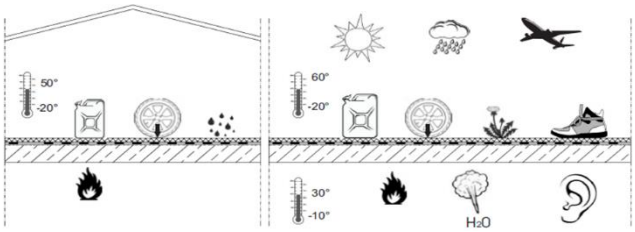

Figure 9. Areas within a multi-storey car park (a) are exposed differently than areas in openly weathered parking decks (b)
Source: Felsinger & Piringer 2016a

2. Planning

2.1. Planning principles

The following principles must therefore be observed in planning [Felsinger & Piringer 2016b]:

- Effective surface drainage: The water must be drained by the shortest route (connection to the canal, evaporation channels should be avoided);
- Sufficient slopes must be provided on the surface (at least 2% in covered areas, at least 2.5% in areas exposed to the weather);
- The stress must already be known in the planning phase; it can vary depending on the use and the resulting traffic load or frequency (e.g. commercially used parking deck in a shopping centre or residential garage);
- Expansion joints are to be placed at the high point;
- Proper design and construction of details: penetrations, paving elements, waterproofing elevations.

The asphalt surface layer is not a substitute for waterproofing. A waterproofing must be provided without fail!

2.2. Rules and regulations in Austria

There is a wealth of guidelines and regulations governing asphalt pavements in conjunction with waterproofing systems in garages and parking decks. The following regulations are given as examples:

- Guideline "Garages and parking decks" [ÖBV 2017]: Following Austrian Guidelines for Planning, Construction and Maintenance of Roads (RVS):
- RVS 03.07.31, RVS 03.07.32 and RVS 03.07.33 - Design principles of garages (inclinations, slope design, arrangement of drainage) [FSV 2018a, FSV 2018b, FSV 2018c]
- RVS 08.07.03 - Waterproofing and road surface on bridges and other concrete traffic areas [FSV 2015a].
- RVS 15.03.11 - Basics and definitions [FSV 2015b].
- RVS 11.06.81 - Quality assurance construction, testing, waterproofing and road surface on bridges and other traffic areas made of concrete, acceptance tests [FSV 2015c]
- RVS 15.03.12 - Bridges, construction, waterproofing and decking on bridges and other concrete traffic areas, waterproofing systems with polymer bitumen membranes [FSV 2015d]
- RVS 15.03.13 - Bridges, construction, waterproofing and roadway on bridges and other traffic surfaces made of concrete, waterproofing systems to be applied in liquid form [FSV 2015e]
- RVS 15.03.14 - Bridges, construction, waterproofing and roadway on bridges and other traffic areas made of concrete, levelling and repair mortar [FSV 2015f]
- RVS 15.03.15 - Bridges, construction, waterproofing and pavement on bridges and other concrete traffic areas, pavement structure [FSV 2015g].

2.3. Pavement structures in car parking constructions

For parking levels exposed to the weather, the total weight of the superstructure must be at least 150 kg/m², for non-exposed to the weather at least 100 kg/m². (150 kg/m² correspond to approx. 6.00 cm structure height, 100 kg/m² correspond to approx. 4.00 cm structure height) [Felsinger & Piringer 2016a]. Figure 10 shows the designation of the individual layers for two- and three-layer structures.

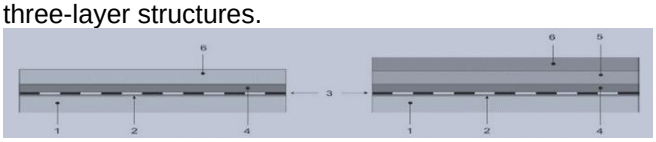

Figure 10. Pavement structure for parking decks: a) Structure with two layers, b) Structure with three layers
Source: FSV 2015g
Legend: 1. raw structure, 2. primer, 3. waterproofing, 4. protective layer, 5. intermediate layer, 6. top layer

2.3.1 Pavement structures for car parking constructions in non-directly weathered garage levels

Low and moderate traffic areas:

Single-layer asphalt structure:

- Bituminous sealing
- Protection and surface layer (3.0 cm - 3.5 cm mastic asphalt)

Total thickness of structure: min. 4.0 cm (100 kg/m²)
Single-layer structure for garages and parking decks with reduced chemical and mechanical stresses (e.g. in roofed residential garages) in areas not exposed to the weather (Fig.11) [Felsinger & Piringer 2016a].

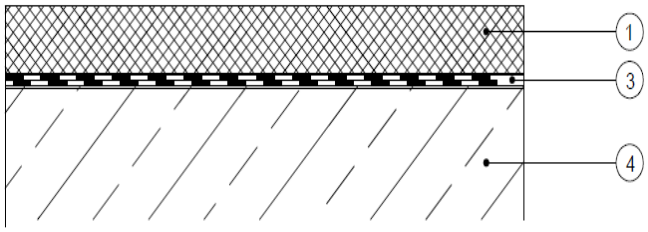

Figure 11. Single-layer structure for garages and parking decks with reduced chemical and mechanical loads
Source: Felsinger & Piringer 2016a
Legend: 1. top layer, 2. bituminous sealing, 3. concrete cover

Highly and very highly stressed traffic areas:

Two-layer asphalt structure:

- Bituminous sealing
- Protective layer (min. 2.0 cm mastic asphalt or asphalt concrete)
- Top layer (min. 3.0 cm mastic asphalt or asphalt concrete) Total thickness of structure: min. 6.0 cm (150 kg/m²).
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Roadway structures in directly weathered garden levels:

Two-layer asphalt structure:

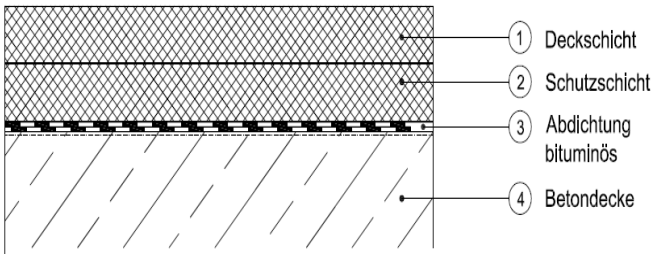

Figure 12. Two-layer structure for heavily used garages and parking decks (e.g. public car parks or garages in shopping centres)
Source: Felsinger & Piringer 2016a
Legend: 1. top layer, 2. protective layer, 3. bituminous sealing, 4. concrete cover

2.3.2 Pavement structures for car parking constructions in non-directly weathered garage levels

Structure - not freely weathered:
3.5 cm mastic asphalt layer in one layer on a 2 - layer bituminous waterproofing (Fig.13).

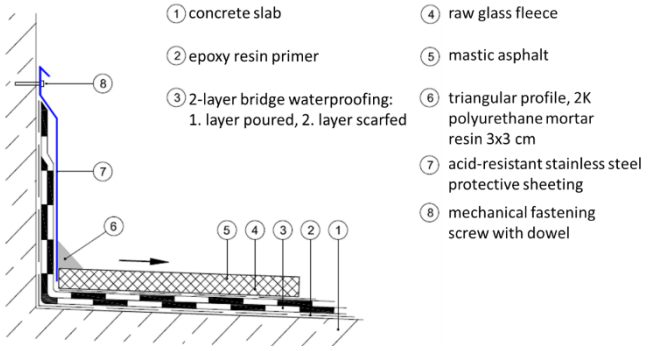

Figure 13. Pavement structure not exposed to weathering with 3.5 cm mastic asphalt layer in one layer on a 2-layer bituminous waterproofing layer
Source: Felsinger & Piringer 2016a

Structure - freely weathered:
3.5 cm mastic asphalt layer chipped on a 3 cm protective or intermediate layer on a 2 - layer bituminous waterproofing (Fig.14).

Figure 14. Pavement structure exposed to weathering with 3.5 cm mastic asphalt layer chipped on a 3 cm protective or intermediate layer
Source: Felsinger & Piringer 2016a

2.3.3 Pavement structures for car parking constructions with asphalt concrete surface layers

3 cm AC 8 deck on a 2 cm protection layer on a 2 - layer bituminous waterproofing (Fig.15).

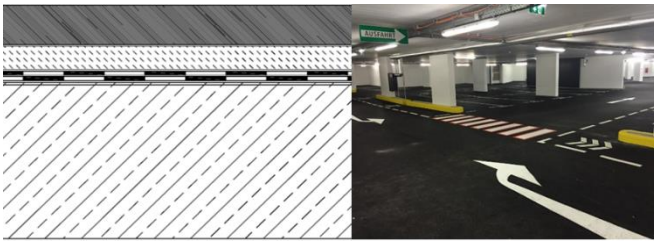

Figure 15. Pavement structures not exposed to weathering with asphalt concrete wearing course with 3 cm AC 8 deck on a 2 cm protection layer on a 2-layer bituminous waterproofing layer
Source: Felsinger & Piringer 2016a

Structure - freely weathered:

3.0 - 3.5 cm AC 8 deck on a 3 cm protection layer on a 2 - layer bituminous waterproofing (Fig.16).

Figure 16. Pavement structures exposed to weathering with asphalt concrete wearing course with 3 cm AC 8 deck on a 2 cm protection layer on a 2 - layer bituminous sealing
Source: Felsinger & Piringer 2016a

Pavement structure on ramps:

Indoor ramps:
Protective or levelling layer on waterproofing + 3.00 cm ribbed mastic asphalt (Fig.17).

Figure 17. Interior ramps with protective or levelling layer on waterproofing + 3.00 cm ribbed mastic asphalt
Source: Felsinger & Piringer 2016a

Outdoor ramps:
Protective or levelling layer on waterproofing + 3.50 cm mastic asphalt split off (for skid resistance) (Fig.18).

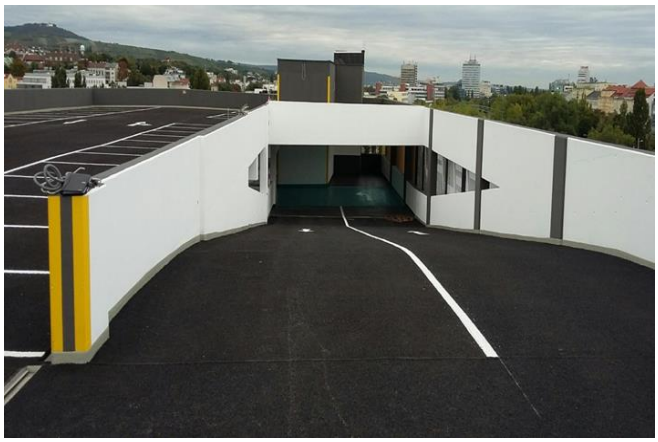

Figure 18. Ramps in the outdoor area with protective or levelling layer on waterproofing + 3.50 cm mastic asphalt split off (for skid resistance)
Source: Felsinger & Piringer 2016a

To increase the parking capacity, stackable parking bays with a pit were installed here (Fig.19). With these garage parking spaces, parking space offers are used more efficiently, which ultimately has a positive effect in terms of the already tight parking situation, especially in large cities. In this case, twice as many vehicles can thus be accommodated in the underground car park in the same space, which is an advantage for all concerned, especially in Cologne's densely populated *Friesenviertel*. In the pit under the parking spaces, too, the decision was made in favour of the economical construction method with mastic asphalt [BGA 2021].

Figure 19. Stacking car park with pit in a multi-storey car park
Source: BGA 2021

3. Conclusion

Depending on the stresses caused by traffic, temperature and water, a distinction is made between moderately, highly and very highly stressed waterproofing according to current codes of practice. The surfaces for underground garages, parking decks and ramps are highly or very highly stressed according to current regulations. The waterproofing must enclose or cover the component to be protected in the endangered area and prevent the penetration of water, especially water containing chloride.

The typical damage in parking structures is often caused by a completely missing or defective sealing of the traffic areas against chloride penetration, a missing or insufficient drainage concept, often combined with missing or insufficient maintenance. These effects can lead to reinforcement corrosion, initially in the area of the cracks, later also in the non-cracked area. Combined with mechanical impacts and frost effects, serious damage to the supporting structure can be the result.

Depending on whether the parking levels are freely weathered or not, asphalt pavements can be asphalt concrete or mastic asphalt or a multi-layer combination of both. The mastic asphalt used fulfils all the requirements placed on a parking deck. Mastic asphalt pavements with a special mix composition can be used on ramps with a gradient of up to 15 %.

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